Economic susceptibility of fire-prone landscapes in natural protected areas of the southern Andean Range

Abstract

Large fires are the most important disturbances at landscape-level due their ecological and socioeconomic impacts. This study aimed to develop an approach for the assessment of the socio-economic landscape susceptibility to fire. Our methodology focuses on the integration of economic components of landscape management based on contingent valuation method (CVM) and net-value change (NVC). This former component has been estimated using depreciation rates or changes on number of arrivals to different natural protected areas after large fire occurrence. Landscape susceptibility concept has been motivated by the need to assist fire prevention programs and environmental management.

There was a remarkable variation in annual economic value attributed to each protected area based on the CVM scenario, ranging from 40,189-46,887 $/year ("Tolhuaca National Park") to 241,000-341,953 $/year ("Conguillio National Park"). We added landscape susceptibility using depreciation rates or tourists arrivals decrease which varied from 2.04% (low fire intensity in "Tolhuaca National Park") to 76.67% (high fire intensity in "Conguillio National Park"). The integration of this approach and future studies about vegetation resilience should seek management strategies to increase economic efficiency in the fire prevention activities.

Keywords: environmental susceptibility, landscape management, contingent valuation, fire behavior, net-value change

1 Introduction

Forest fires are an active element in the configuration and shaping of wide variety of ecosystems (FAO, 2007). In this sense, fire has played a keystone role in the shaping of the heterogeneous Andean landscape (González et al., 2010) and its forest dynamics (Veblen et al., 1995; Donoso, 1998). Although humans have used fire since the Neolithic Era (Abrams, 1992), climate change and anthropic factors are transforming fire into a threat to the biodiversity and conservation (Chavardes and Daniels, 2016).

Catastrophic forest fires have ravaged parts of Chile, Portugal, Spain and United Sated this year. As a example, Chile was affected by severe forest fires between January and February 2017 with more than 470,000 ha under different fire intensity levels (Rivera-Careaga, 2017). Lead Emergency Management Authority (LEMA) catalogued this fire as a "firestorm", an unprecedented phenomenon in the history of humankind (European Civil Protection Agency, 2017). They highlighted the fact in a single night the fire consumed 8,000 ha per hour. Comparatively, France requested support for a fire that burned a total of 8,000 ha and Spain´s firefighting capacity collapsed with a fire that involved just 25,000 ha. The experts hypothesize that the type of fire that is being seen for the first time with Chile´s "firestorm" will occur in the future in several countries because it is partly due to phenomena such as climate change.

Forest fires constitute a worldwide problem, given their serious tangible assets, environmental service and landscape goods impacts (Rodríguez-Silva and González-Cabán, 2010). Therefore, an increase in economic losses from wildfires has been corroborated from different studies (Román et al., 2013; Chuvieco et al., 2014). In this sense, large wildfires could become a threat to social valuable landscapes because of climate change and fire regime change (Molina et al., 2017a). Landscape resource don´t usually take the form of monetary values in wildfire impacts valuation. Although indirect methods are challenging, forest management should involve intangible assets, mainly in natural protected areas. The high socio-economic value of protected areas should lead to preventive actions, in order to preserve its tourism activity, and as a consequence, its economic value. It is essential that landscape resource can be fully taken into account in planning and decision-making.

Although tangible assets and ecological losses have immediate short and medium-term importance, the disappearance or changes in landscape give rise to additional long-term impacts. However, in spite of some research approaches (Rodríguez y Silva et al., 2010; Castillo et al., 2013), there is lack of knowledge of the long-term economic impacts, mainly in natural protected areas. The conclusions of these former studies focuses on the need of a detailed study of the economic susceptibility of forest landscapes against wildfires. It is essential that the socioeconomic values of the environmental services and landscape goods be fully taken into account in planning and decision-making (Costanza et al., 2006; De Groot, 2006). Landscape can take the terms of monetary units though indirect methods such as travel cost, hedonic technique and contingent valuation (CVM). CVM is the main stated preference method over the last three decades (González and León, 2003; MacMillan et al., 2006; Grammatikopoulou and Olsen, 2013; Chen and Hua, 2015; Chatterjee et al., 2017). In spite of the CVM limitations (Schläpfer et al., 2004; Hynes et al., 2011), this methodology has been used in studies in order to facilitate the comparison of different management alternatives to mitigate forest fires (Molina et al., 2016).

Different studies have evaluated the economic damages caused by fire (Butry et al., 2000; Morton et al., 2003; Barrio et al., 2007), and even some of them (Rodríguez y Silva et al., 2010; Castillo et al., 2013) have been developed in Andean Range.

However, one of the most difficult things to do in valuing the economic impact of fire on natural resources is to determine the economic value lost (Rodríguez y Silva and González-Cabán 2010; Román et al. 2013). Potential damages can be quantified as the percentage net value change (CNV) depending on fire intensity and resources sensibility´ (Thompson et al., 2011). In this sense, taking potential fire behavior into account is fundamental to determine the economic efficiency of fire prevention and suppression activities (Duguy et al., 2007; Thompson et al., 2013). Fire behavior was included by fire intensity levels (FIL) which are closely related to the impact caused by the amount of heat emitted (Rodríguez y Silva et al., 2012; Castillo et al., 2017). The identification of CNV caused by wildfires was expressed as depreciation rates according to FIL based on the simplicity required by forest managers (Zamora et al., 2010; Molina et al., 2011). These depreciation ranges were identified based on the social perception using the stated social preferences. In the last part of the contingent valuation questionnaire, panoramic photographs were used to estimate depreciation rates or visits frequency depending on three outstanding FIL (Molina et al., 2017b).

Development of a multidiscipline forestry policy is not possible without considering landscape susceptibility, because of the importance of recreation activities for rural development and territorial planning (Molina et al., 2016). This paper aims to develop a social approach for the economic assessment of the landscape susceptibility to fire. The sense of this study is the identification of the landscape resource affectation and its economic valuation based on tourism and recreational impacts using three important natural protected areas in Chile. By extending landscape approach from the traditional point of contingent valuation studies, we have incorporated landscape susceptibility in order to identify effects of fire occurrence. Our approach proposes an economic framework for annual landscape susceptibility (Scott and Thompson, 2015) based on landscape value and net-value change (CNV). While landscape resource has been valued according to CVM, CNV has been estimated based on three potential fire intensity levels using estimated post-fire number of visitors. The landscape susceptibility model is more complete than the former studies, since it includes economic landscape value and potential fire impacts. The results could emphasize in the meaningful role of the recreation resource on natural protected areas, and as a consequence, the importance of fire prevention activities to landscape conservation. Landscape susceptibility approach would add to learning community knowledge the non-market fire impacts according to the higher probability of future large fires or "firestorm" in several countries.

2 Material and methods

2.1 Study area

The climate of the Andean Range has a Mediterranean influence reflected by a winter-maximum in precipitation and relatively dry summers. Annual precipitation varies between 1500 and 3000 mm, although at higher altitudes the precipitation can reach more than 4000 mm, the majority falling as snow. In this mountain range, most of the soils are derived from ash deposited by volcanic activity (Donoso, 1998). About 97% of the Araucaria forests are restricted to the upper elevations of the Andean mountain range from Region VIII to Region XIV. In this study, we used three natural protected areas of the IX Region of Chile ("Araucania Region") within the “Araucarias Biosphere Reserve” (Figure 1).

- "Conguillio National Park": this area occupies about 608 km^2, formed mainly by *Araucaria araucana* and *Nothofagus* spp. The shape of the Monkey Puzzle trees, lakes and Llaima volcano increases the scenic beauty of this park. In this sense, Conguillio was the most visited park in the IX Region (111,709 visitors in 2016). "China Muerta", which is an adjoining National Reserve with similar landscapes, was severely burned in 2015 fire.

- "Tolhuaca National Park": this park encompasses part of the forested foothills and part of the upper elevations of Andean mountain range covering about 6,500 ha. Their main attractions are mixed forest landscape, wildlife, Tolhuaca volcano, small lakes and thermal waters. The visitors' number was 11,270 in the last year. The Park and the adjoining "Malleco National Reserve" were affected by severe forest fires in 2002 and 2015.

- "Malalcahuello National Reserve": this northern area combines *Araucaria-Nothofagus* forests with a charcoal desert landscape of ash and sand (Lonquimay volcano and Navidad Crater). The reserve has a surface area of about 13,800 ha including the ash volcano landscape. In the border, "Nalcas National Reserve" is identified as the limit of *A.araucana* distribution. In 2016, the number of visitors reached 108,618 people of different nationalities.

2.2 Economic valuation of recreational resources in natural protected areas

In this study, landscape takes the form of monetary values through Contingent Valuation. The purpose of this method is to obtain respondent´s willingness to pay (WTP) for the conservation of protected areas. We estimate WTP using the maximum-likelihood method for interval-data model (Grammatikopoulou and Olsen, 2013). The implicit assumption is that one underlying WTP value drives the responses to both dichotomous-choice questions. If this is true, the following question provides a interval around the true WTP value and the maximum-likelihood optimization model is appropriate.

Contingent valuation information was obtained from 425 tourists in three protected areas in the IX Region of Chile. Random samples of tourists were interviewed at different park entrances (control points), hotels, thermal water centers and campsites along the protected areas. We must note that our sample suffered from over-representation of young adulthood tourists (aged between 20 and 40), and underrepresented elder tourists (aged upper to 60). For this reason, we considered two age ranges: < 40 years and > 40 years. The ratio of male and female respondents was very equitable (208 women and 206 men). A total of 414 interviews were completed out of 425, for a completion rate of 97%.

Firstly, the survey included a brief description of the project to prevent bias because of the insufficient detail of bad-informed people who think that they will pay more money in the future if they select this question option. The first part of the questionnaire incorporated respondent´s personal information (gender, age, job, place of origin and travel motivation). The following question "Do you agree with the payment of an amount of money to protected areas conservation due to the increase of the forest fire risk due to the climate and socio-economic changes and its ecological value?" attempted to minimize the rejection responses. The second part, using a discrete change in entrance fees, was aimed at tourists and an estimation of WTP. Similar to other studies (Vaux et al., 1984; Christie et al., 2006), respondents are asked whether or not they would pay some specific sum or "bid". In the last part of the questionnaire, each tourist was asked about its future visit or the change to other natural protected area on holidays based on a fire occurrence.

WTP must be statistically analyzed to obtain an estimate of the mean WTP. However, when respondents disagreed to pay any bid at all, different interpretations can be found: enough taxes, lack of worth. Excluding these bids from the mean WTP calculation would lead to biased estimates of population assessment (Hynes et al., 2011). In this sense, we used two approaches (Molina et al., 2016): either taking all respondents into consideration, valuing those who refuse to pay an entrance fee as zero WTP (known as ‘‘all respondents’’), or taking only affirmative answers into consideration (known as ‘‘only affirmative respondents’’). Mean WTP of each study area is multiplied by the number of visitors annually to estimate its annual use value. This former data was obtained from official statistics in 2016 of the Forestry Corporation (http://www.conaf.cl/parques-nacionales/visitanos/estadisticas-de-visitacion/, August 2017).

2.3 Landscape susceptibility in natural protected areas

Fire behavior is not homogeneous in forest fires depending on meteorological, physiographic and fuel model conditions (Finney, 1998). The level of damage could be determined by the fire intensity levels (FIL) (Zamora et al., 2010; Rodríguez y Silva et al., 2012; Castillo et al., 2017). In our study, Fire Intensity Levels (FIL) were identified based on photographs with different fire behavior in study area fires:

- FIL I: surface and passive fire behavior

- FIL II: active fire with unburned islands and attractive elements

- FIL III: active fire without unburned areas

Depreciation rates were estimated based on the contingent valuation questionnaire where three panoramic photographs were affected by these different FIL (Appendix I). On this FIL ladder, each photograph represented progressive higher fire impacts. Although low-intensity fires could have positive effects on fire-prone ecosystems (Smucker et al., 2005), in this study fire impacts on a landscape level were viewed as a negative decrease in visitors number in a short-term perspective. The depreciation rate (%) was identified as the difference in the number of arrivals according to each FIL. Respondents were asked about trip changes based on a fire occurrence. These recreational changes or deterioration rates (DR) provide a versatile assessment tool (Equation 1) for landscape susceptibility assessment based on fire intensity (Molina et al., 2017b):

$$LS = L * DR \quad (1)$$

where "LS" is the annual landscape susceptibility of each protected area (€), “L” is the estimated annual landscape value (€) and "DR" is the depreciation rate in visitors (%) based on fire intensity.

2.4 Statistical analysis

Firstly, a logit regression model was employed to test the sensitivity of our respondents in relation to their socio-economic characteristics on the probability of giving protest responses or non-protest responses. In general, logit analysis would be preferable in situations where the normality assumption (of the sample) are violated and many of the independent variables are qualitative (Chen and Hua, 2015). It is appropriate for the present study in which subgroups have been clearly defined in terms of protest and non-protest responses. The dependent variable takes the value 1 if the respondent states a zero bid and 0 if the respondents states a positive WTP amount. In a sensitivity analysis, we compared WTP for those people expressing the highest level of confidence with all others. Previous studies have found that estimated WTP is more consistent with theory for respondents who reported greater confidence in their answers (Grammatikopoulou and Olsen, 2013; Chen and Hua, 2015).

One-way analysis of variance (ANOVA) was used to determinate if significant differences ($p<0.05$) existed in gender (female and male), age (< 40 years and > 40 years), job or economic condition (students and unemployed respondents, conventional workers and high level workers) and place of origin (Araucania Region, Bio-Bio Region, Metropolitana Region, Other Regions and Foreign visitors) for each natural protected area and CVM scenario. If significant differences were detected, a Tukey HSD test was performed to determine which specific study area and CVM scenario was different from another.

The significant differences among the mean deterioration rates according to each FIL were calculated using the non-parametric analysis. In this case, Wilcoxon test was used to identify if significant differences ($p<0.05$) existed in depreciation rate for each Fire Intensity Level and different respondent characteristics. CVM scenario, gender, age, job and place of origin were tested using non-parametric test. SPSS(C) was used in all analysis.

3 Results

3.1 Economic valuation of recreational resources in natural protected areas

Three subgroups can be categorized In this sense, based on respondents´ answer: legitimate zero respondents ("respondents cannot afford due to my budget constrains"), protest respondents induced by "distrust of government" and positive WTP responses. We considered two logit models based on all zero respondents and only protest zero respondents. For the reduced model, we use the same variables as in the previous logit model. There explanatory variables showed a statistically significant bearing on WTP: education, income and place of origin (Table 1). Respondents with relative high levels of education stated a significant higher WTP since education is often found to have a positive impact on WTP. Higher education was found to have significantly lower probability of protesting. In the case of positive WTP and protest zero respondents, the level of income was significant, as economic theory would prescribe, WTP increases with increasing income. The increased personal experience with the area (IX Region of Chile), induced more lexicographical preferences that could translate into an increase in protest zero respondents. The signs of other coefficients estimates were as expected, though not statistically significant at conventional levels.

WTP was obtained from a conservation free payment that ranged from 0 to 45.94 US dollar ($). The percentage of respondents that proposed to abstain from paying for the conservation areas was 22.52%. Most of these disagreed respondents (75.01%) were related to the enough taxes paid to the government. In this sense, differences were performed between the least favorable contingent valuation scenario ("all respondents") and the most favorable scenario ("affirmative respondents") (Table 2). There was a notable increase between 14.28% ("Tolhuaca National Park") and 29.03% ("Conguillio

National Park") depending on the CVM scenario. In a similar CVM scenario, WTP identified two significant groups: "Conguillio National Park" and "Malalcahuello National Reserve" and "Tolhuaca National Park" (Table 2). The maximum WTP was attributed to this former national park in both CVM scenarios.

On the other hand, WTP was significant higher in female respondents of "Tolhuaca National Park" when compared to the other two study areas (Table 3). In "Conguillio National Park" and "Malalcahuello National Reserve", it could be observed a higher male WTP than female WTP. According to the age, < 40 years respondents of "Tolhuaca National Park" presented significant differences with the others (Table 4). While in selected respondents of "Tolhuaca National Park" and "Malalcahuello National Reserve", < 40 years increased the economic value, in selected respondents of "Conguillio National Park", > 40 years showed a higher WTP.

Significant differences were shown between "Tolhuaca National Park" and the other study areas based on students and unemployed respondents and high level workers (Table 5). In all areas, the highest WTP was found in high level workers according to its quality life. Therefore, significant differences were performed based on the place of origin. Bio-Bio, Metropolitano, others Chilean regions and foreign respondents identified significant groups among the study areas (Table 6). Selected foreign WTP in "Malalcahuello National Reserve" and selected Metropolitano WTP in "Tolhuaca National Park" surpassed the rest of monetary values.

In 2016, the number of visitors reached more than 100,000 people from different nationalities in two selected areas. There was a notable variation in the annual value attributed to each natural protected area depending on the CVM scenario: ‘‘all respondents" and "affirmative respondents’’ (Table 7). The maximum economic impact

(341,953 $/year) was obtained in "Conguillio National Park" according to the most favorable CVM scenario. However, "Malalcahuello National Reserve" reached the higher valuation (251,036 $/year) based on the least favorable CVM scenario.

3.2 Landscape susceptibility in natural protected areas

Wilcoxon test showed the presence of significant differences ($p < 0.05$) among FIL. In this sense, depreciation rate (%) was proportional to Fire Intensity Level (FIL) providing the maximum landscape impact to FIL III. In terms of visit frequency, the presence of tourists could decline annually from 2.04% to 76.67% according to FIL and protected area (Figure 2). Non-parametric test identified two significant area groups due to the similar behavior for depreciation rates. In FIL II and FIL III, we could observe a group of respondents who would visit the area depending on the entrance fee and the price of recreational activities.

There are many respondent characteristics that are likely to be related to the propensity to respondent. We found significant differences in rate of depreciation focusing on CVM scenario and economic condition of the respondents (Table 8). Under this former respondent characteristic, two groups (student and unemployed and conventional and high level workers) were performed. Therefore, depreciation rate according to place of origin was very heterogeneous based on each protected area. Finally, there are not significant differences based on gender and age classification (Table 8).

We provided the landscape susceptibility using the annual economic value that was generated from each WTP scenario (Table 7) and the mean depreciation rate for each FIL and protected area (Figure 2). Furthermore, differences of depreciation rates could be observed using or not using the conditional respondents who would visit the affected area depending on the entrance fee and the price of recreational activities. Remarkable differences were observed in annual landscape susceptibility according to each protected area and FIL (Table 9). In this sense, "Conguillio National Park" annual susceptibility varied considerably, ranging from $9,182-13,028 to $184,778-262,175 (Table 9). While in "Tolhuaca National Park" landscape susceptibility ranged from $820-956 to $28,707-34,448, in "Malalcahuello National Reserve" varied from $23,120-27,390 to $ 133,877-166,422.

4 Discussion

Forest fires constitute a worldwide problem according to its associated socio-economic and ecological impacts (Román et al., 2013; Chuvieco et al., 2014). The current large fire frequency and fire intensity are increasingly becoming a growing global concern for woodlands. Fire regime change has homogenized forests affecting its landscape value and bio-diversity (Chavardes and Daniels, 2016; Molina et al., 2017a). In this sense, our study area has been globally designated as a main conservation eco-region, "hotspot" of biodiversity (Myers et al., 2000). This approach shows the potential fire impacts associated to recreational resources in three "hotspot" or natural protected areas.

Annual landscape susceptibility varied considerably in the Chilean protected areas ranging from $34,448 to $262,175 (maximum recreational impact). However, contingent valuation method (CVM) is a stated preference methodology that provides respondents the possibility to refuse a payment for protected area conservation. When respondents disagreed to paying any entrance fee (22.52% of the respondents) are excluding of the statistical analysis, a selection bias problem could be generated (Schläpfer et al., 2004; Hynes et al., 2011). For this reason, this approach allows us to compare two scenarios (all respondents and affirmative respondents) of WTP and annual value showing significant differences between them. The annual recreation value increased from 14.38% ("Tolhuaca National Park") to 29.16% ("Conguillio National Park") using only affirmative respondents. Differences were performed based on the economic condition and place of origin for all selected areas. The economic condition is associated to the amount of money that can be paid for annual conservation. The place of origin could be related to the economic ranking of each Chilean Region and foreign countries.

Landscape goods are rarely incorporated into territorial planning, even though this resource could constitute a large proportion of the ecosystem value, mainly in protected areas (Costanza et al., 2006; De Groot, 2006; Román et al., 2013). An adequate preventive management of Mediterranean landscape requires the knowledge of landscape susceptibility (Scott and Thompson, 2015). This research has proposed an integrated landscape susceptibility framework from landscape valuation and net-value change (NVC) using fire intensity (Molina et al., 2017b). Fire intensity can be represented by intensity scales similar to other European approaches (Rodríguez y Silva et al., 2012) and Chilean studies (Castillo et al., 2017). The use of three FIL or fire types belongs to the simplicity required by respondents to identify differences in the impact caused by each fire type. These FIL can directly support the estimation of the NVC of the natural resources (Zamora et al., 2010). In this paper, the NCV was expressed in term of a reduction on protected area visits using social stated preferences. As an example, tourists number could decrease in "Conguillio National Park" from 3.81% (FIL I) to 76.67% (FIL III). Respondents, who would return to the burned area depending on the entrance fee and the price of recreational activities, were higher in FIL

II compared to the rest. There is an increase of the number of post-fire visits in FIL III according to the furthest respondents (Other Regions and Foreign tourists).

The depreciation rate varied significantly according to fire intensity similar to other studies (Zamora et al., 2010; Rodríguez y Silva et al., 2012). While FIL II would decrease number of tourists from 10.09% ("Malalcahuello National Park") to 32.66% ("Tolhuaca National Park") in relation to surface fire or FIL I, FIL III would reduce the number of visitors from 46.75% ("Malalcahuello National Park") to 72.86% ("Conguillio National Park"). "Conguillio National Park" and "Tolhuaca National Park" have shown the highest depreciation rates. This fact could be related to the recent occurrence of large fires in these protected areas or their surrounding areas, where fire impacts are still observed.

Although there was an increase of 20.77% of the number of tourists in protected areas in IX Region of Chile (2015), Forestry Corporation statistics (http://www.conaf.cl/parques-nacionales/visitanos/estadisticas-de-visitacion/, August 2017) showed a reduction of 6.33% tourists after "Tolhuaca fire". If we added both values, (tourists increase in the Region and visitors decrease) we would reach 27.09% of depreciation rate that is very similar to the one observed in social analysis from FIL II (Figure 2). In the case of "Malleco National Reserve", after fire occurrence (2015), there was a decrease of 26.46% of visitors. If regional tourists increase is considered, the reduction would increase at 47.23%. These fire impacts differences could be associated to the burned area and fire intensity in both Chilean protected areas (differences in FIL). In spite of the differences, highest fire intensities (FIL II and FIL III) would play a keystone role in the economic rural development of these Chilean wilderness areas.

In European natural parks, large fires on some protected areas caused a dramatic reduction in number of arrivals. The number of arrivals decreased between 23.65% and 91.01% (Molina et al., 2017b). According to the Association of Rural Hotels, ‘‘fires stopped the arrival of thousands of tourists. Despite the number of confirmed reservations, eco-tourism decreased 40% since fire occurrence. This decrease in the annual number of visitors had a significant impact on new enterprises projects, which focused on the development of rural economy’’ (Molina et al., 2017b).

Landscape susceptibility is a meaningful component of forest fire management (Castillo et al., 2013; Chuvieco et al., 2014). We used two scenarios ("all respondents" and "affirmative respondents") based on uncertainty associated with the sampling bias and CVM method similar to other approaches (Molina et al., 2016). There was an outstanding difference in annual landscape susceptibility per unit area depending on the natural protected area (Figure 3). The snow centre and thermal water resorts make Malalcahuello area attractive to respondents as a travel destination, and as a consequence, one of the most visited protected areas in Chile despite of its limited size. According to the highest fire intensity, while "Malalcahuello National Reserve" annual susceptibility ranged from 10.47 $/ha*year to 13.01$ /ha*year, "Conguillio National Park" (3.04-4.31 $/ha*year) and "Tolhuaca National Park" (4.43-5.32 $/ha*year) reached values closer than European natural parks (Molina et al., 2017b). One Virginia study (Morton et al., 2003) showed a middle annual value per unit area (7 $/ha) in relation to "Conguillio National Park" and "Tolhuaca National Park" and "Malalcahuello National Reserve".

There are other studies which obtain the total recreational losses based on the integration of landscape value and vegetation resilience or the time needed by a landscape to recuperate its original scenic beauty and recreational value because of fire

(Butry et al., 2000; Barrio et al., 2007). When comparing our results with these former studies, we observed an infra-valuation of the monetary values. Knowing the annual landscape value, fire behavior and vegetation resilience, landscape vulnerability could be represented by updating the economic value over the years necessary for restoring the original landscape quality (Molina et al., 2017b). Future studies should contemplate the vegetation resilience of the different landscapes on the study areas. As an example, if we consider vegetation resilience between 13 to 44 years for *Nothofagus* forests (Molina et al., 2017a), we would estimate a similar value per hectare than those studies (Butry et al., 2000; Barrio et al., 2007).

Despite the limitations of CVM and social preferences method (González and León, 2003; MacMillan et al., 2006; Grammatikopoulou and Olsen, 2013; Chen and Hua, 2015; Chatterjee et al., 2017), they have become important tools to economic valuation of environmental services and landscape goods. Bias resulting from the insufficient detail of bad-informed people could be resolved by the study design and implementation. Former CVM studies have typically found that WTP is less sensitive to the stated magnitude of fire risk than standard economic theory would predicted. A plausible explanation for this inadequate sensitivity is that respondents may not understand the magnitude of the described fire risk (Molina et al., 2017b). Therefore, important differences in the effect of alternative visual aids could be found based on the photographs used. For a subsample of respondents that received no visual aids or other photographs, it could not be performed statistically significant difference. Replication of these results in a context other than fire-prone landscapes is needed before these results can be generalized. Consequently, the effect of visual aids on sensitivity to magnitude of fire risk may be quite different than considered in Chile and Spain studies.

Forest managers require information on the socioeconomic consequences of landscape alteration. Considering this, landscape susceptibility provides a tool to improve fuel treatment optimization and budget allocation in order to ensure the cost-efficient of management activities. Landscape susceptibility approach would help pointing out the situations where fuel management may be useful in reducing fire impacts. The landscape model provided here permits the extrapolation of this landscape susceptibility approach to any territory and scale using social questionnaires in the natural protected areas. Further studies are required to identify a proportional allocation of the economic annual value according to landscape quality and the location of recreational activities based on contingent rating. Experiences of large wildfires (2017) and potential fire impacts associated with Chilean protected areas should lead to fire management decisions by prioritizing more valuable and susceptible areas.

Conclusions

Landscape goods could reactive the economy of rural wilderness areas, mainly in natural protected areas. In this sense, results reflect the relevance of landscape and leisure activities provided by Chilean protected areas. For decision-making, the economic valuation of landscape and recreation resources is useful and important, because it provides managers information necessary to evaluate potential tradeoffs when proposing fire reduction programs for protected areas conservation. The economy relevance of landscape goods would justify greater investments in fire prevention programs.

A model of evaluating the landscape susceptibility using social stated preferences and potential fire impacts is of great importance for the comprehensive management of the territory. The proposed methodology can be extrapolated to other regions and countries, although contingent valuation is required for the inclusion of landscape value in the economic assessment. Expressing the landscape susceptibility in terms of the deterioration rate or visit frequency decrease responds to a needed simplicity required by the questionnaire respondents. The potential impacts associated with fire occurrence in natural protected areas should lead to fire prevention treatments such as fuel reduction and prescribed fire programs to mitigate potential fire impacts. The reduction of fire vulnerability under different management alternatives is a keystone to sustainable landscape and forest planning.

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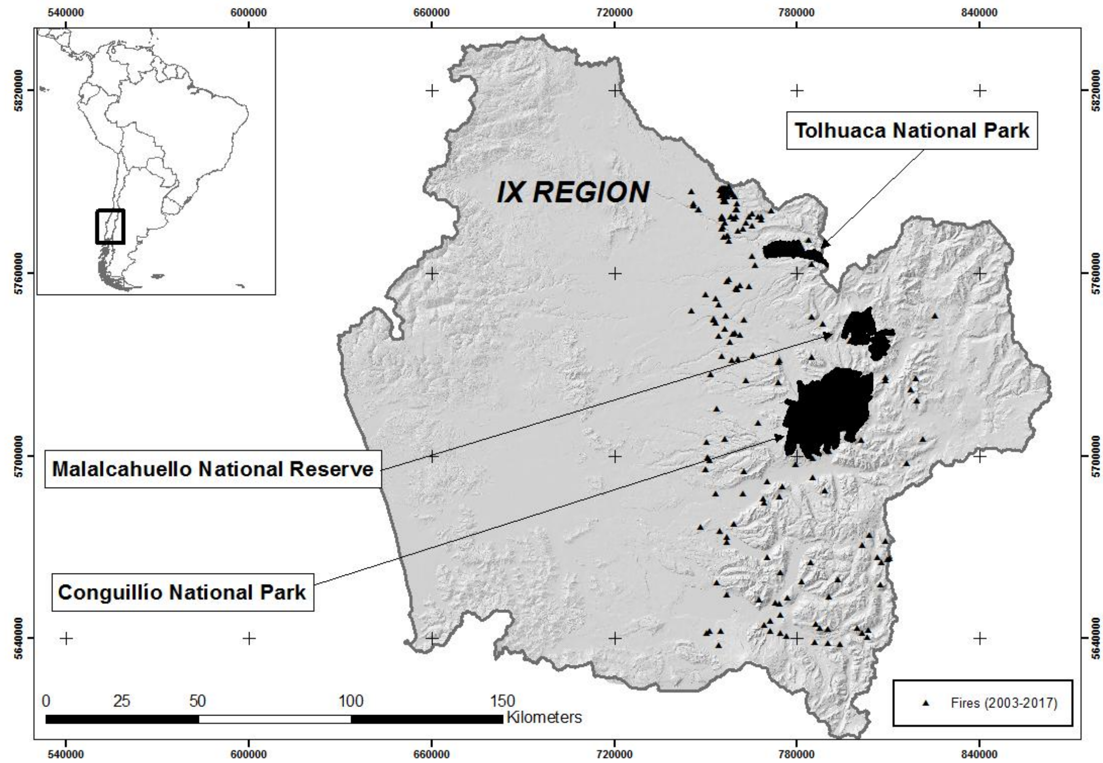
Figure captions

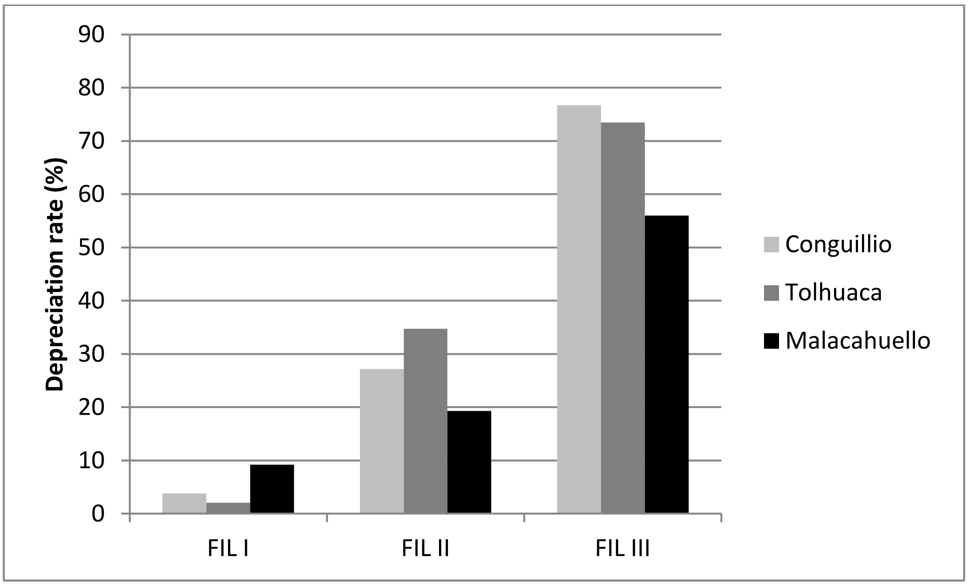
Figure 1. Study area location

Figure 2. Depreciation rate in the number of arrivals according to each protected area and fire intensity (FIL)

Figure 3. Annual landscape susceptibility ($/ha) according to each protected area and fire intensity (FIL)



540000
600000
660000
720000
780000
840000
5820000
5760000
5700000
5640000
IX REGION
Tolhuaca National Park
Malalcahuello National Reserve
Conguillio National Park
0
25
50
100
150
Kilometers
Fires (2003-2017)



Depreciation rate (%)
90
80
70
60
50
40
30
20
10
0
FIL I
FIL II
FIL III
Conguillio
Tolhuaca
Malacahuello

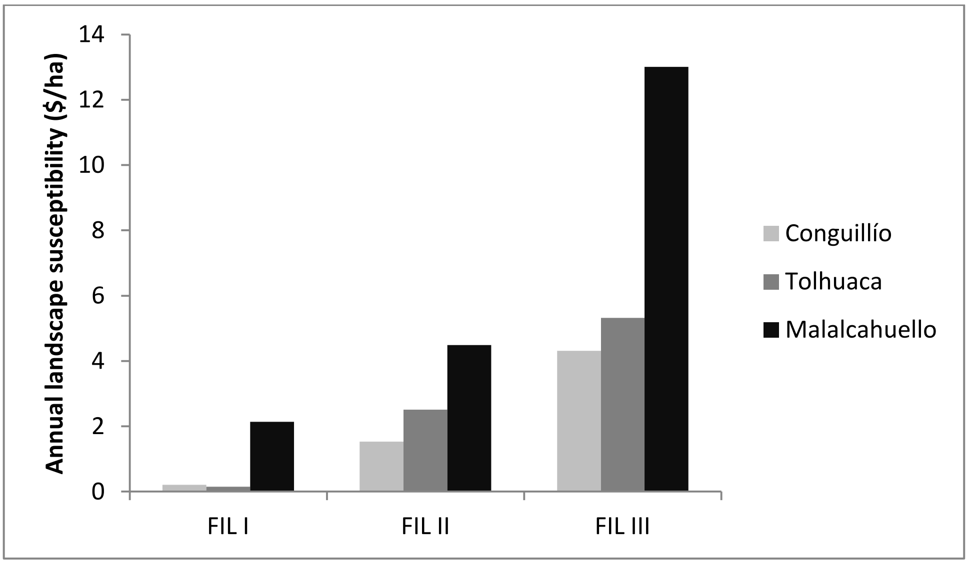

Annual landscape susceptibility ($/ha)
14
12
10
8
6
4
2
0
FIL I
FIL II
FIL III
Conguillío
Tolhuaca
Malalcahuello

Table 1. Logit model results for all respondents (positive WTP, legitimate zero and protest respondents) and selected model (positive WTP and protest zero respondents)

	All respondents		Positive WTP and protest zero respondents	
	Coef.	Std. error	Coef.	Std. error
Constant	1.88	0.34	17.84	1.14
Income	-0.43	0.39	-21.07[a]	0.01
Education	0.43[b]	0.24	1.08	1.06
Age	-0.11	0.31	0.40	0.59
Gender	0.09	0.22	-0.84	1.06
Place	0.35[b]	0.24	0.89[b]	0.48
Chi-square	15.89		36.16	
Pseudo-R2	0.09		0.34	

Income: 1 = less than $1,000, 0 = otherwise

Education: 1 = university degree o higher, 0 = otherwise

Age: 1 = age is less than 40 years, 0 = ages is more than 40 years

Gender: 1 = female, 0= male

Place: 1 = IX region of Chile, 0 = otherwise

a 5% significance level

b 10% significance level

Table 2. WTP differences ($) between the least and the most favorable CVM scenarios

Area	WTP "all respondents"	WTP "affirmative respondents"
Conguillio	2.2(±3)[a]	3.1(±3.2)[a]
Tolhuaca	3.6(±5)[b]	4.2(±5.4)[b]
Malacahuello	2.3(±2.7)[a]	2.7(±2.2)[a]

Mean values in a column followed by the same letters are not significant different ($p < 0.05$, ANOVA Tukey HSD)

Table 3. WTP differences ($) based on gender distinction and protected area

Gender distinction			
Scenario*	Conguillio	Tolhuaca	Malalcahuello
WTP F1	2(±2.1)[a]	4.8(±9.5)[b]	2.1(±1.9)[a]
WTP F2	2.8(±2.1)[a]	5.9(±10.3)[b]	2.5(±1.9)[a]
WTP M1	2.3(±3.8)[a]	2.6(±2)[a]	2.5(±2.6)[a]
WTP M2	3.4(±4.2)[a]	2.9(±1.8)[a]	3(±2.6)[a]

Mean values in a raw followed by the same letters are not significant different ($p < 0.05$, ANOVA Tukey HSD)

*WTP F1: Willingness to Pay of all female respondents; WTP F2: Willingness to Pay of affirmative female respondents; WTP M1: Willingness to Pay of all male respondents; WTP M2: Willingness to Pay of affirmative male respondents

Table 4. WTP differences ($) based on age and protected area

	Age (years)		
Scenario*	Conguillio	Tolhuaca	Malalcahuello
< 40 all	2.1(±2.5)[a]	4.3(±8.7)[b]	2.4(±2.3)[a]
< 40 selected	2.8(±2.5)[a]	4.8(±9.1)[b]	2.8(±2.3)[a]
> 40 all	2.3(±3.7)[a]	2.6(±2.5)[a]	2.3(±2.5)[a]
> 40 selected	3.3(±4.1)[a]	3.1(±2.4)[a]	2.7(±2.5)[a]

Mean values in a raw followed by the same letters are not significant different ($p < 0.05$, ANOVA Tukey HSD)

*All: Willingness to Pay of all respondents; Selected: Willingness to Pay of affirmative respondents

Table 5. WTP differences ($) based on job or economic condition and protected area

Job (economic condition)			
Scenario*	Conguillio	Tolhuaca	Malalcahuello
S and U all	1.9(±2.3)[a]	3.8(±2.8)[b]	2(±1.9)[a]
S and U selection	2.6(±2.3)[a]	4.5(±2.5)[b]	2.4(±1.9)[a]
W all	2.1(±3.4)[a]	2.3(±2)[a]	2.3(±2.7)[a]
W selection	3.1(±3.8)[a]	2.9(±1.7)[a]	2.7(±2.7)[a]
HLW all	2.5(±2.8)[a]	5.2(±10.7)[b]	2.4(±2.1)[a]
HLW selection	3.3(±2.8)[a]	5.6(±11)[b]	2.9(±2)[a]

Mean values in a raw followed by the same letters are not significant different ($p < 0.05$, ANOVA Tukey HSD)

*S and U all: Willingness to Pay of all student and unemployed respondents; S and U selection: Willingness to Pay of affirmative student and unemployed respondents; W all: Willingness to Pay of all conventional workers; W selection: Willingness to Pay of affirmative conventional workers; HLW all: Willingness to Pay of all high level respondents based on its medium salary (engineer, doctor, pilot, architect, banker, politician, manager, vet, lawyer and broker); HLW selection: Willingness to Pay of affirmative high level respondents

Table 6. WTP differences ($) based on place of origin and protected area

	Place of origin		
Scenario*	Conguillio	Tolhuaca	Malalcahuello
Araucania all	1.8(±2.2)[a]	2.2(±2.3)[a]	2.4(±2.8)[a]
Araucania selection	2.6(±2.2)[a]	2.9(±2.2)[a]	2.6(±2.8)[a]
Bio-Bio all	3.1(±4.9)[a]	1.9(±1)[b]	2.2(±2.2)[b]
Bio-Bio selection	3.8(±5.2)[a]	2.3(±0.8)[b]	2.6(±2.2)[b]
Metropolitano all	2.5(±2.9)[a]	5.3(±9.9)[b]	2.4(±1.8)[a]
Metropolitano selection	3.5(±2.8)[a]	5.9(±10.3)[b]	2.8(±1.6)[a]
Others all	1(±2)[a]	2.3(±0.5)[b]	2.8(±3)[b]
Others selection	1.1(±0.6)[a]	3.1(±0.8)[b]	3.6(±3)[b]
Foreign all	1.8(±1)[a]	3.1(±0.9)[a]	4.1(±3.6)[b]
Foreign selection	2.1(±0.7)[a]	3.1(±0.9)[a]	6.1(±1.1)[b]

Mean values in a raw followed by the same letters are not significant different ($p < 0.05$, ANOVA Tukey HSD)

*Araucaria all: Willingness to Pay of all Araucaria Region respondents; Araucaria selection: Willingness to Pay of affirmative Araucaria Region respondents; Bio-Bio all: Willingness to Pay of all Bio-Bio Region respondents; Bio-Bio selection: Willingness to Pay of affirmative Bio-Bio Region respondents; Metropolitano all: Willingness to Pay of all Metropolitano Region respondents; Metropolitano selection: Willingness to Pay of affirmative Metropolitano Region respondents; Others all: Willingness to Pay of all other Regions respondents; Others selection: Willingness to Pay of affirmative other Regions respondents; Foreign all: Willingness to Pay of all foreign respondents; Foreign selection: Willingness to Pay of affirmative foreign respondents

Table 7. Annual valuation of recreational resources in the protected areas based on the CVM scenario

Area	WTP ($/visitor*year)*	Visitors	Annual economic value ($)*
Conguillio	2.2-3.1	111,709	241,004-341,953
Tolhuaca	3.6-4.2	11,270	40,189-46,887
Malacahuello	2.3-2.7	108,618	251,036-297,394

* The first value is in relation to "all respondents" scenario and the second value is based on "affirmative respondents" scenario

Table 8. Depreciation rate (%) according to respondent characteristics

Respondents	FIL I	FIL II	FIL III
CVM scenario			
All respondents	9.78/9.78[a]	28.26/35.87[a]	70.65/70.65[a]
Affirmative respondents	4.37/4.37[b]	19.06/25[b]	75.94/77.19[b]
Gender distinction			
Female	5.34/5.34[a]	23.3/27.67[a]	78.15/79.6[a]
Male	5.85/5.85[a]	19.02/27.31[a]	71.22/71.71[a]
Age (years)			
< 40 years	5.49/5.49[a]	19.61/25.1[a]	72.55/74.12[a]
> 40 years	5.77/5.77[a]	23.72/31.41[a]	78.2/78.2[a]
Job (economic condition)			
Student and unemployed	4.94/4.94[a]	16.05/22.22[a]	65.43/67.9[a]
Conventional workers	5.58/5.58[b]	21.23/29.05[b]	78.21/79.33[b]
High level workers	6/6[b]	24/28.67[b]	75.33/75.33[b]
Place of origin			
Araucania	4.9/4.9[a]	21.57/27.45[a]	77.45/77.45[a]
Bio-Bio	7.75/7.75[b]	20.15/28.68[a]	80.62/82.17[a]
Metropolitana	2.58/2.58[c]	24.14/29.31[b]	71.55/73.27[a]
Others Regions	7.14/7.14[b]	19.05/19.05[c]	64.28/64.28[b]
Foreign	9.52/9.52[d]	14.28/28.56[d]	61.91/61.91[b]

Mean values for each respondent characteristic in a column followed by the same letters are not significant different ($p < 0.05$, Wilcoxon test)

Table 9. Annual landscape susceptibility according to protected area and FIL

Area	FIL I ($)	FIL II ($)	FIL III ($)
Conguillio	9,182-13,028	44,754-92,806	184,778-262,175
Tolhuaca	820-956	10,590-16,270	28,707-34,448
Malacahuello	23,120-27,390	41,848-57,397	133,877-166,422

Appendix I (Questionnaire photographs)