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VALUATION OF CLIMATE-CHANGE EFFECTS ON MEDITERRANEAN SHRUBLANDS

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Abstract. In general, the socioeconomic analysis of natural systems does not enter into the realms of natural science. This paper, however, estimates the human-welfare effects of possible physicochemical and biological impacts of climate change on Mediterranean shrublands over the coming 50 years. The contingent choice method was applied to elicit the trade-offs in perceived values for three climate-sensitive attributes of shrubland (plant cover, fire risk, and soil erosion) and for the costs of programs designed to mitigate changes. Soil erosion was found to be the attribute of shrubland that most concerned the population, followed by fire risk and then plant cover. An increase of 1% in the shrubland area affected by erosion was estimated to cost each person on average 2.9 euros per year in terms of lost welfare, a figure that is equivalent in terms of perceptions of social welfare to an increase of 0.24% in the shrub area burned annually and a decrease of 3.19% in the area of plant cover. These trade-off values may help ecologists, policy makers, and land managers to take social preferences into account.

Key words: Catalonia; climate change; contingent choice method; human welfare effects of climate change; land management policy; Mediterranean shrubs; plant-cover loss–fire risk–erosion trade-offs; shrublands; social valuation of environmental-impact choices; valuation.

Introduction

Mediterranean shrublands occupy extensive areas of the Mediterranean region (Fig. 1a) and have significant functions as ecosystems and provide several provisioning, regulatory, and cultural services (Millennium Ecosystem Assessment 2005). On the Iberian Peninsula shrublands cover greater areas than in any European country (Fig. 1a) and, as in many other areas of Europe, have been spreading over the last few decades (Tarrega et al. 2001). This spread is the result of secondary succession in abandoned pastures and croplands and of more frequent disturbances in Mediterranean forests such as increasing fire recurrence (Thanos and Marcou 1991, Tarrega et al. 2001, Diaz-Delgado et al. 2002).

The availability of water in Mediterranean shrublands is a key factor determining vegetation composition and the patterns of plant distribution. Progressive aridification has taken place over the last few decades as a result of increased evapotranspiration (caused by 1°C average warming) without any parallel increase in rainfall (Piñol et al. 1998, Peñuelas et al. 2002, Peñuelas and Boada 2003). Further warming and aridification are forecast over the coming decades (IPCC 2001, Peñuelas et al. 2004*b*), and current and future warming and aridification processes will surely have important consequences for the physiology, phenology and distribution of living organisms found in shrublands and, therefore, ultimately for the structure and functioning of these ecosystems (Peñuelas and Filella 2001, Peñuelas et al. 2002, 2004*a*, Peñuelas and Boada 2003).

Field studies show that warming and drought both decrease growth and reproduction in some plant species, while others are less affected (Peñuelas et al. 2004*a*). Decreases in seedling and plant diversity have been reported from experimental studies in Catalonia (northeastern Spain), indicating that both warming and drought may reduce biodiversity and shift the composition of plant communities (see Plate 1; Lloret et al. 2004, Peñuelas et al. 2004*b*). Even more visually obvious than this decrease is the fact that lower plant cover is a typical response to drought (Filella et al. 2004).

The more arid conditions produced by warming and drought can also increase the threat of forest fires. The frequency of forest fires has increased over the last few decades as a result of climate change and changes in human socioeconomic activities and land use (Piñol et al. 1998). The effects of fire are complex because the response of plants varies greatly with the type and timing of the fire, the intrinsic regeneration capacities of different species (from obligate resprouters to obligate seeders) and the pre-fire status of the vegetation. The response of resprouter species to fire is regulated by a positive-feedback mechanism of vegetative regeneration that allows for quick space occupation, often before seeding species have germinated. In fact, in all Mediter-

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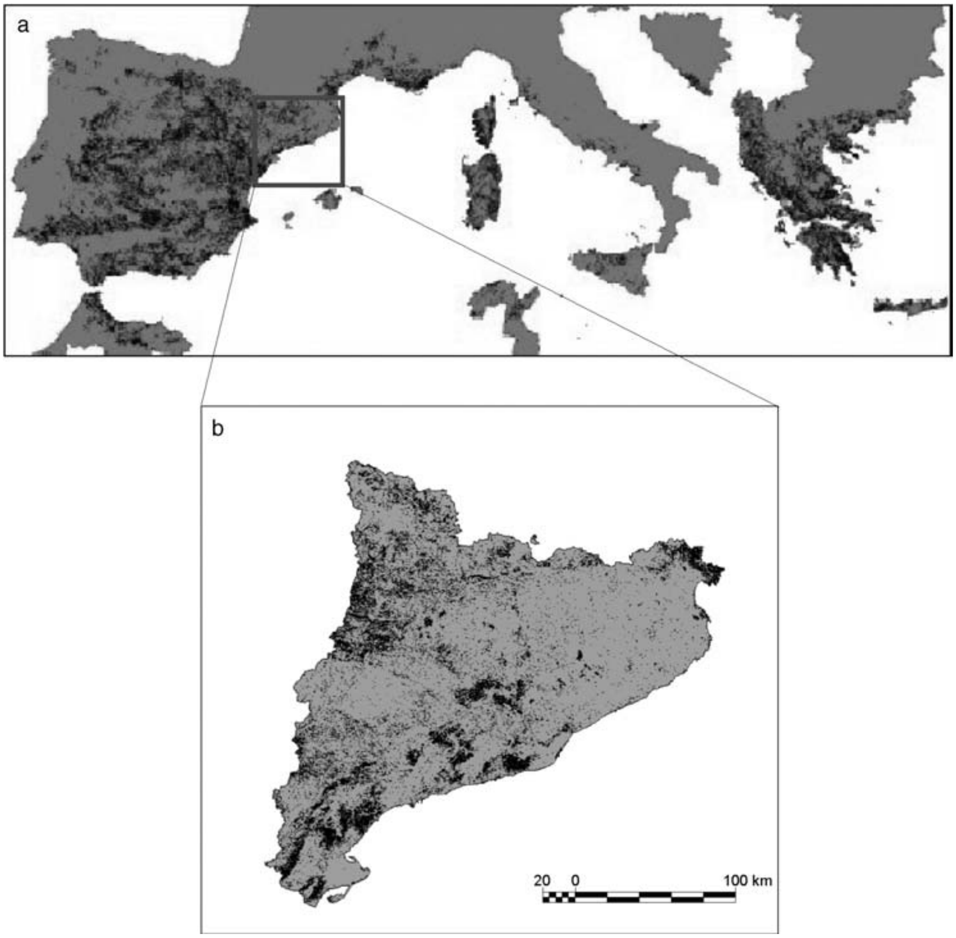

FIG. 1. Schlerophyllous shrublands (a) in the Mediterranean region (source: European Environment Agency/CORINE land cover CLC90) and (b) in Catalonia (source: Land cover of Catalonia (2000-2003) ⟨http://www.creaf.uab.es/mcsc⟩). The dark areas are shrublands.

ranean regions of the world fire has long been considered a dominant ecological and evolutionary factor.

However, Mediterranean vegetation may not be adapted to an even-more-frequent fire regime and negative consequences may occur as a result (Diaz-Delgado et al. 2002). More-frequent fires may contribute to a further reduction in the productivity of the vegetation and the organic content of the soil. Reductions in soil organic matter diminish soil aggregate size and stability and this, together with a decrease in vegetation cover, reduces the infiltration of water into the soil and increases surface flow. All this leads to soil erosion and the further deterioration of the hydrological characteristics of the soil (Albaladejo et al. 1994, Garcia et al. 2002, 2005).

These impacts—reduction of plant cover and increased fire and erosion risk—are three of the most pronounced and socially worrisome effects of climatic change in Mediterranean shrublands.

Based on results from the above-mentioned field studies in shrublands in Catalonia (northeastern Iberian peninsula; Fig. 1b) (Peñuelas and Boada 2003, Llorens et al. 2003, 2004, Estiarte et al. 2004, Filella et al. 2004, Peñuelas et al. 2004*a*, *b*) and on current knowledge of the plant cover (Llorens et al. 2004 and Fig. 1b), frequency and impact of fires (Terradas 1996, Piñol et al. 1998, Espelta 2004) and erosion rates (TRAGSA 2003) in this Mediterranean area, we hypothesised a possible temperature-change scenario for the middle of the twenty-first century, which we will refer to as the "do nothing" or "business-as-usual" (BAU) scenario. For the three variables considered—plant cover, fire risk and soil erosion—the changes from current average values to new values 50 years hence were estimated on the basis of a temperature increase of 2°C—a figure in the low–medium range of temperature increases predicted for this region by multiple global circulation models (IPCC 2001)—and a decrease in water availability of 15–20%,

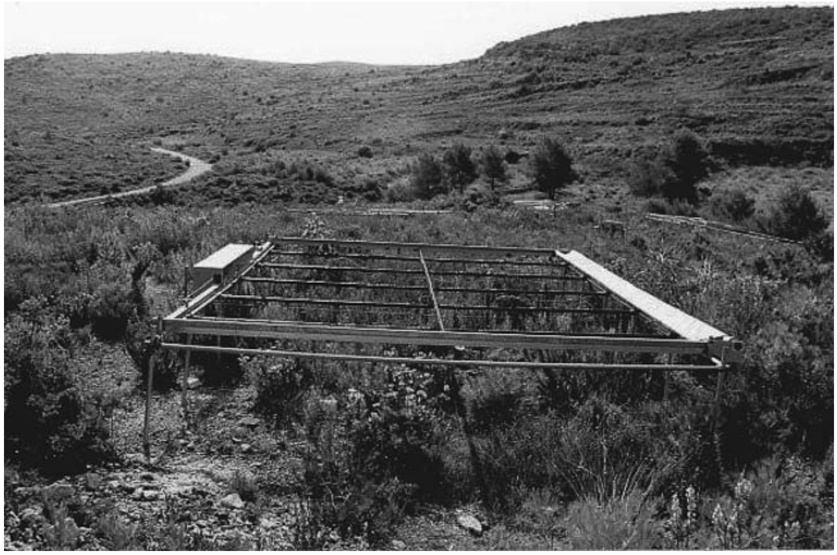

PLATE 1. Field experimental facilities to study climate change effects on Mediterranean shrublands located at Parc Natural del Garraf, in Catalonia, Spain. Scaffolding supports a folded roof (at the right) and a motor box (at the left). When activated, the motor unfolds the roof to cover the vegetation. Climate warming is simulated at night by unfolding a roof made of an infrared reflecting material that keeps the ecosystem 1°C warmer than the annual average. Drought is simulated covering the vegetation with an impermeable roof during rain events for some pre-established periods (see Peñuelas et al. [2004*a*] for more details). Photo credit: Paula Bruna.

as predicted by ecophysiological models such as GOTILWA (Sabaté et al. 2002).

The predicted BAU scenario hypothesized the following value changes: plant cover percentage, currently averaging ~80% in Catalan shrublands, will drop to ~40% (Filella et al. 2004, Llorens et al. 2004, Peñuelas et al. 2004*a*, *b*); forest fires, currently affecting on average 1% of the shrubland surface area every year, will increase to 5% (Piñol et al. 1998, Terradas 1996, Espelta 2004); and, finally, the percentage of shrubland soil classified as affected by erosion in Catalonia—currently estimated at around 8% (TRAGSA 2003)—will increase four-fold to as much as 32% (TRAGSA 2003). These possible changes are based on moderate interpretations of the results reported in the above-mentioned literature.

However, the importance of these ecological changes to Catalan people is unknown. Learning about the social preferences could be useful in different ways. For instance, If society could intervene to partially mitigate the effects of climate change, which interventions should receive priority? Furthermore, What is the maximum amount we are prepared to spend on a given mitigation program? These are questions that economic-valuation methods are able to answer. Economic valuation is regularly applied to ecological changes (see Carson et al. [1993] for an early review), but has never been used to value changes in shrubland provoked by global warming (the nearest such studies are by Layton and Brown [2000] for forests and climate change and Scott et al. [1998] for shrubs and alternative land uses). Other related studies dealing with climate change valuation are by Pendleton and Mendelsohn [1998], Ahn et al. [2000], and Mendelsohn and Neumann [1999], among others.

Our main aim was to estimate the trade-offs, as perceived by Catalan citizens, for changes in plant cover, fire risk, and soil erosion, and the willingness to pay for management programs and/or new policies that would mitigate the intensity of such changes. Although no explicit management alternatives will be considered in our valuation study because this study was focused only on quantifying which impacts Catalans are most concerned and how much they would be willing to pay to mitigate such impacts, there are several management possibilities, including measures for erosion prevention (terraces, seedling planting, or soil coverage with straw) and fire risk reduction (for example forest corridors), which are both widely dealt with in environmental-management studies and fire ecology. We used the contingent choice method as a valuation methodology consistent with welfare economic theory (Unsworth and Bishop 1994, Jones and Pease 1997, Louviere et al. 2000, Bennett and Blamey 2001). With this method the trade-offs can be expressed in monetary units or in any of the units of the attributes included in this study.

METHODOLOGY

Stated-preference methods

People are constantly faced with decisions involving trade-offs. For example, Should one buy this article at this price or that one at that price? The label "contingent choice" refers to a survey-based valuation method that simulates this familiar behavior (Louviere 1988, Hane-

TABLE 1. The three ecological attributes and levels used in the contingent choice exercise.

Attribute	Description	Levels
Plant cover	The average percentage of shrubland plant cover in 50 years time	80% (current level) 70% 60% 40% (business-as-usual)
Fire risk	The annual average percentage of shrubland surface affected by fire in 50 years time	1% (current level) 3% 4% 5% (business-as-usual)
Soil erosion	The average percentage of shrubland soil affected by erosion in 50 years time	8% (current level) 16% 24% 32% (business-as-usual)
Payment	The required payment per person per year for shrubland management programs	30 euros 15 euros 5 euros 0 euros (business-as-usual)

mann and Kanninen 1999, Bennett and Blamey 2001). The options to choose from are described in a questionnaire that details the goods or variables to be considered, the changes in quantity or quality levels that may occur, and a proposed payment. This payment can be seen as a contribution towards obtaining a desired change or avoiding an undesirable one. In this way, more than one variable or characteristic of a variable is taken into account at the same time.

Using stated-preference methods to put a value on environmental impacts is somewhat controversial and some authors stress the problems that occur with factors such as strategic behavior, protest answers, response bias, and respondents ignoring income constraints, especially in light of the way in which contingent valuations have been conducted in the past. A problem more specifically related to the environment is the embedding effect, whereby respondents express a general preference for environmental spending instead of taking only the specific impacts described in the questionnaire into account (for a general discussion see Diamond and Hausman [1994], Hanemann [1994], and Portney [1994]). Some of the contingent valuation problems are solved with the use of contingent choice, although others still remain. The NOAA report (Arrow et al. 1993) and other more recent texts (Bateman et al. 2002, Hensher et al. 2005) provide a good guide on how to mitigate possible shortcomings. In this application to Catalan shrublands we have followed current state-of-the-art practice.

Choice sets

The different goods or characteristics are usually called *attributes*. In our contingent choice exercise there were four attributes, namely: (1) percentage of plant cover, (2) percentage of shrubland surface burned in a given year, (3) percentage of soil erosion, and (4) a payment amount to finance a policy that might simultaneously mitigate these problems.

Each attribute had four *levels*, as shown in Table 1. The levels for plant cover, erosion, and fires were spread equally between current values and the ones given by the BAU (business-as-usual) scenario. Payment levels were determined after a pilot study in which respondents stated the maximum they were willing to pay for various different scenarios; the extra cost for doing nothing as with the BAU option was zero. The BAU or "do-nothing" situation was taken to be the estimated situation in 50 years time if no management was undertaken, while the rest of the levels corresponded to management corrections.

Each combination of attribute levels is known as an *alternative*. BAU is thus an alternative. There were 81 (3^4) possible combinations or different alternatives, excluding the BAU levels. These were randomly grouped into 3 + 1 (BAU) to make four alternatives for each person. Although some choice sets could contain nonrealistic alternatives, they were kept in the survey for purposes of valuation only. Each block of four alternatives corresponds to a *choice set*. A different choice set was presented to each different individual and, as per the contingent choice method, surveyed individuals were asked to pick the alternative they preferred within a choice set. Fig. 2 reproduces a typical choice set, with the three ecological attributes and the monetary attribute; the original survey was in color.

Contingent choice

Contingent choice is a method based on random utility maximization (RUM) models (Thurstone 1927, McFadden 1973). Under the RUM framework, the indirect utility (i.e., welfare) function for each respondent can be expressed as $U_{ij} = V_{ij} + \varepsilon_{ij}$, where U_{ij} is person i's utility from choosing alternative j, V_{ij} is the deterministic component of utility, and ε_{ij} is a stochastic element that represents influences on individual choices that are unobservable to the researcher but are known to the individual.

The probability P that any particular respondent prefers option j in the choice set to any alternative option k can be expressed as the probability that the

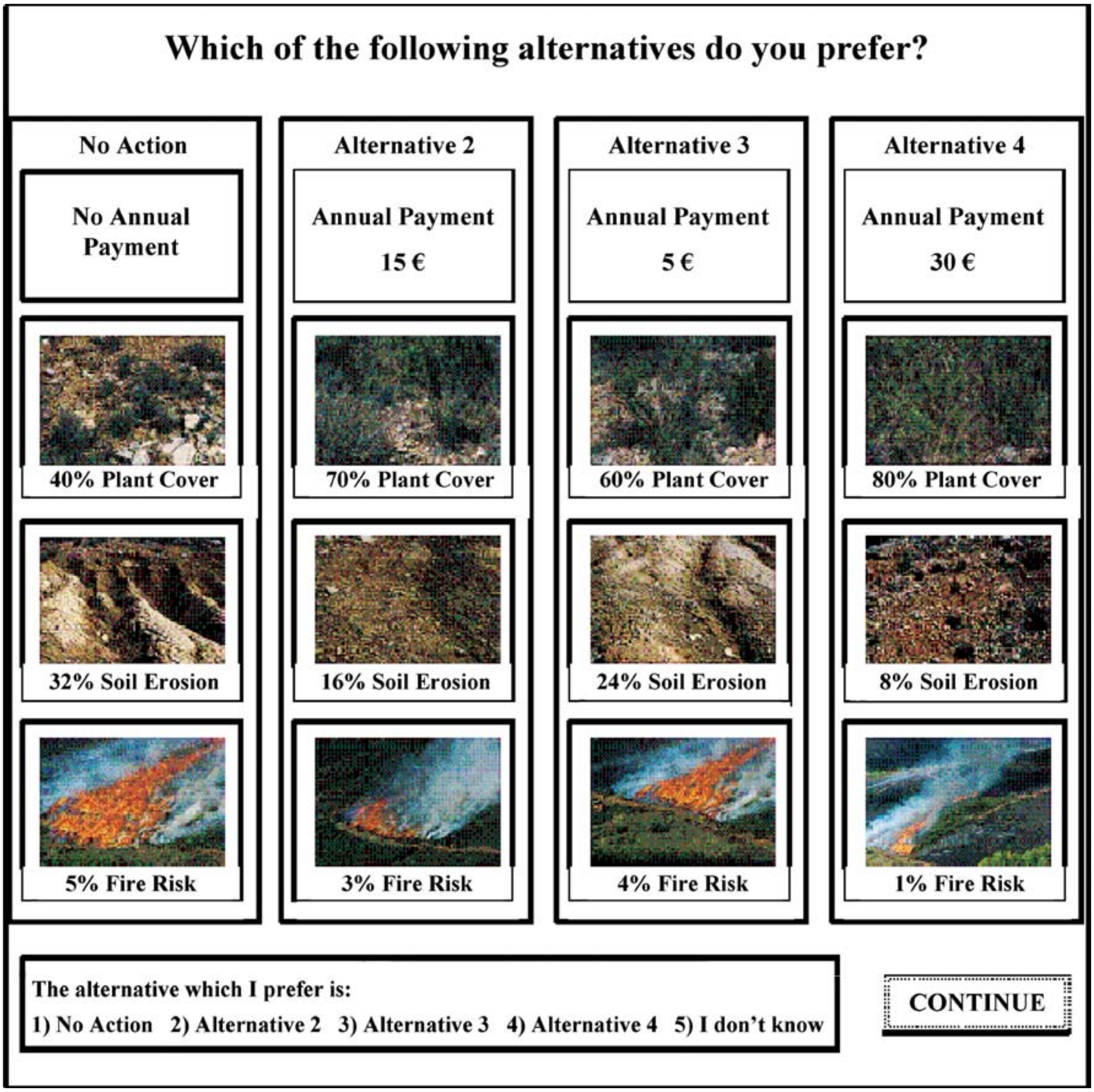

FIG. 2. Example of a choice set presented to respondents in the contingent choice survey.

utility associated with option j exceeds that associated with any other option. Formally,

$$P_{ij} = P\{V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}; \forall\ k \neq j \in C\}$$

where C is the set of all possible alternatives. The choice probability can also be expressed as

$$P_{ij} = P\{(V_{ij} + \varepsilon_{ij}) - (V_{ik} + \varepsilon_{ik}) > 0; \forall\ k \neq j \in C\}$$

Possible interactions among attributes can be modeled in the V function. Most often, choice probabilities of this type are estimated using the conditional logit model (McFadden 1973). The regression model is then estimated using a maximum-likelihood approximation (Hensher and Johnson 1981).

Application, questionnaire, and interviews

An estimation of social-welfare change due to the effects of climate warming on Catalan shrublands was undertaken in spring 2004. A computerized questionnaire was designed in Visual Basic and shown on laptop computers to a representative sample of 354 Catalan citizens in their homes. Catalonia has a population of seven million people and the sample included residents in towns of over 10 000 people drawn randomly (after weighting towns according to their population size) and interviewed in blocks of 12. The selection of the individuals within a block followed a random-route procedure to select a household, and then age and gender quotas to select the particular individual in the household. About 90% of the individuals approached

TABLE 2. Results of the conditional logit regression analysis between the alternative chosen and explanatory variables (data analyzed were from interviews of 354 Catalan citizens in spring 2004).

Source of variation‡	Coefficient (mean ± SE)	*t* ratio
Constant	−0.93 ± 0.43	−2.151*
Plant cover	0.02 ± 0.01	2.469*
Fire risk	−0.33 ± 0.06	−5.237**
Soil erosion	−0.07 ± 0.01	−5.774**
Payment	−0.02 ± 0.01	−2.192*
Income B2	0.25 ± 0.44	0.574
Income B3	1.18 ± 0.43	2.720**
Income B4	0.96 ± 0.41	2.316*
Income C2	0.97 ± 0.52	1.850†
Income C3	1.26 ± 0.55	2.284*
Income C4	0.42 ± 0.56	0.750
Age2	−0.04 ± 0.01	−4.917**
Age3	−0.06 ± 0.01	−7.145**
Age4	−0.03 ± 0.01	−3.406**

Notes: Log likelihood = −337.79; pseudo-R^2 = 0.16.
$*P < 0.05$; $**P < 0.01$; $†P < 0.10$.
‡ Variables: plant cover = average percentage of shrubland soil area covered by vegetation; fire risk = average percentage of shrubland area burned per year; soil erosion = average percentage of shrubland area with eroded soil; payment = individual yearly contribution in euros; income = dummy variables of monthly income of the respondent, with value 1 when 300 euro < income B ≤ 1200 euro, and income C > 1200 euro, with 2, 3, and 4 denoting the specific alternatives (i.e., the business-as-usual situation or alternative 1 was left out); age = continuous variable reflecting the age in years of the individual, with 2, 3, and 4, denoting the specific alternative (see e.g., McFadden 1973).

agreed to be interviewed. The first part of the questionnaire was devoted to the presentation of the attributes to be valued, as well as the means of payment and its consequences. The core of the interview contained the choice exercise and a number of debriefing questions. The third and final part of the questionnaire was designed to collect socioeconomic data and further information regarding the surveyed individuals (for a questionnaire example, see the Appendix). The questionnaire described the current average level of each attribute in Catalonia (plant cover, fire, and erosion) and the most reliable prediction of the average levels of each attribute in 50 years time (using the working hypothesis of an increase in temperature of 2°C). Therefore, the questionnaire first presented the expected change in the three attributes in the case of no action being taken; the BAU or "do-nothing" scenario was thus characterized as the levels expected for each attribute in 50 years time. Next, the questionnaire explained that, depending on the investment devoted to mitigating the impacts of increased temperatures on shrublands, the BAU situation could be modified. Three alternative levels, apart from the BAU option, were offered for each physical attribute (Table 1). In order to further familiarize individuals with possible levels of change, participants were then asked at this point to pick individually for each attribute which of the four levels they preferred, regardless of the cost. In this way, we could detect whether an attribute was considered to have a positive or negative value and if the choices made later were in fact consistent.

After the presentation of the physical attributes, the monetary trade-off was introduced (Table 1). It was stated that the regional government was considering implementing a program aimed at mitigating the expected effects of climate change on shrublands in Catalonia and that this program would accomplish more or less depending on the amount of resources devoted to it. Participants were then told that the amount of resources would depend on their answers to this questionnaire: if the average results indicated that people would be happy to pay something for the program, then payments would be collected annually and indefinitely from citizens and the money given to a foundation to be created to this end.

The central part of the questionnaire presented the choice sets, with the BAU situation and three other alternatives. Individuals were then asked to pick the alternative they preferred. This central part of the questionnaire also contained some debriefing questions.

The final part of the questionnaire inquired into socio-demographical characteristics such as age, gender, income, and educational level of respondents. Interviewers were equipped with a laptop computer and offered individuals the opportunity to complete the questionnaire on the laptop for themselves; alternatively, the individual was allowed to dictate the answers to the interviewer. A recorded voice read out the text of the questionnaire to the individuals, thus easing pressure on the respondents and avoiding possible differences between one interviewer and another. All of the answers were automatically registered in a Microsoft Access file. The average time of the interviews was 15 minutes and no signs of fatigue were detected at the end of any of them.

Data treatment

The regression analysis and the rest of the data processing were undertaken using version 7 of LIMDEP statistical package (Econometric Software, Castle Hill, New South Wales, Australia).

RESULTS

The results from the regression analysis are given in Table 2. The signs of the coefficients were as expected and most of the variables were statistically significant (i.e., different from zero) at the 95% confidence level. The positive sign in the coefficient of the plant cover indicates that Catalan citizens tend to prefer current plant-cover rates in shrublands to lower levels of cover. This implies that the greater the plant cover present, the more likely that alternative was to be chosen as the most preferred option. This variable may be interpreted, at least partially, as value for the aesthetic appreciation of the landscape. The fire, erosion and payment coefficients were negative, indicating that higher percentages of

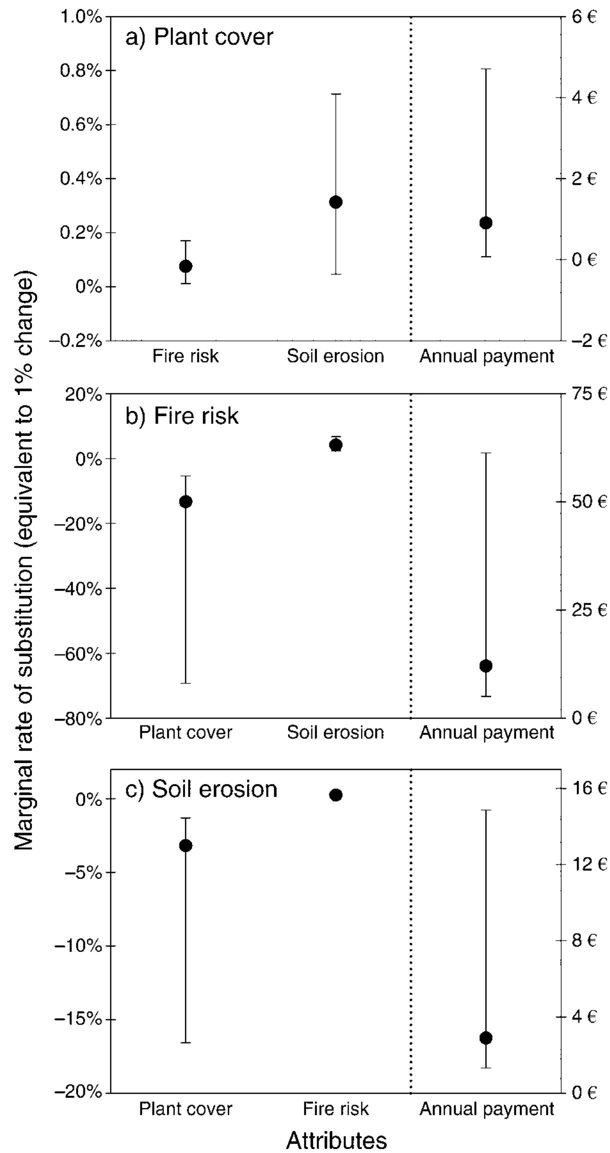

FIG. 3. Values in relative units of attributes, with 95% CI for (a) an increase of 1% in plant cover, (b) a decrease of 1% in fire risk, and (c) a decrease of 1% in soil erosion. Physical attributes are expressed as a percentage on the left-hand vertical axis, while the monetary attribute is expressed in euros (2004 value) on the right-hand vertical axis. (a) An increase in shrubland plant cover of one additional absolute percentage point (e.g., from 40% to 41%) offsets (1) an increase in fire risk of an additional 0.07 (0.01, 0.17) percentage points, the figures in parentheses denoting the limits of the 95% CI; (2) an increase in soil erosion of an additional 0.31 (0.05, 0.71) percentage points; and (3) the individual welfare equivalent of a yearly expenditure of 0.91 (0.07, 4.71) euros. (b) A decrease in shrubland fire risk of one additional absolute percentage point (e.g., from 5% to 4%) offsets (1) a decrease in plant cover of 13.32 (5.35, 69.26) percentage points, (2) an increase in soil erosion of an additional 4.17 (2.45, 6.78) percentage points, and (3) the individual welfare equivalent of yearly expenditure of 12.06 (5.05, 61.338) euros. (c) A decrease in shrubland soil erosion of one additional absolute percentage point (e.g., from 32% to 31%) offsets (1) a decrease in plant cover of 3.19 (1.3, 16.58) percentage points, (2) an increase in fire risk of an additional 0.24 (0.1478, 0.41) percentage points, and (3) the individual welfare equivalent of a yearly expenditure of 2.9 (1.33, 14.86) euros.

these coefficients decrease the welfare of the population. The negative sign in the age dummy variables denotes that the probability of choosing an alternative other than the BAU (business-as-usual [i.e., do-nothing]) option decreases with age. On the other hand, respondents with higher incomes are less likely to choose the BAU option, that is, they are more likely to be prepared to pay for climate-change mitigation programs in Catalan shrublands.

The estimated values for a marginal change in each attribute are represented in Fig. 3. All values reflect the mean of the population with a 95% confidence interval, expressed in the units of the respective variable as they entered the regression (percentage points or euros at 2004 prices). The marginal values for each attribute can be inferred by calculating the ratio $-\beta_i/\beta_j$, where β_i is the regression coefficient of the attribute to be valued and β_j represents the coefficient of the attribute in the units in which the value will be expressed. To get an additional percentage point increase in the level of plant cover, a citizen would, on average, be willing to consent (at most) to a 0.08% increase in the level of fire risk, a 0.31% increase in soil erosion, and to pay (at most) 0.91 euros annually and indefinitely. The confidence intervals for the marginal value of each attribute were calculated using the Krinsky and Robb (1986) procedure with 2000 repetitions.

These estimations may also refer to the social value of the expected changes if no or only partial mitigation action was taken to diminish the effects of climate change in Catalan shrublands. Assuming a unitary price elasticity of demand, the amount of change in each attribute expressed in percentage points could be multiplied by its unitary value. For instance, according

TABLE 3. Percentage of respondents saying that they took this variable into account more than any other when making the contingent choice

Variable	Respondent consideration (%)
Plant cover	51.4
Fire risk	48.6
Soil erosion	71.2
Payment	45.9
Years†	11.3

Note: Percentages do not add to 100% because respondents could select more than one answer.
† The time horizon (50 years) for the climate change.

to respondents' perception, the increased welfare they would experience on average as a result of an increase from 40% to 50% in plant cover is equivalent to the welfare drop they would experience after an increase from 2% to 2.8% in shrubland area burned per year.

Likewise, different working scenarios for the 2°C increase may be considered, and the valuation of each attribute can be inferred from Table 2. In the same way, we can calculate the value of the effects from an increase in temperature of only 1°C over the next 50 years. There are, however, some limitations. The values were estimated using a given range of levels of change for each attribute (Table 1) and there is no guarantee that, for levels outside this range, respondent's perception would not vary. For instance, some people might prefer more plant cover to less plant cover, but not up to a 100% cover.

DISCUSSION

A distinctive feature of our study is that it provides results not only in monetary terms, but also in units of the other attributes considered (Fig. 3). This may be of particular use for policy makers, planners, and land managers. For instance, if faced with a fixed budget to be devoted to the mitigation of the impact of climate change on shrublands, land managers may want to design a program in which the balance between soil erosion, fire prevention, and plant cover mirrors the trade-offs expressed by citizens. Likewise, for a given program the administration may be interested in assessing whether costs are higher than the benefits (expressed in monetary terms) it would provide citizens.

Our study of the willingness to pay found that erosion was the attribute that most concerned the population given the likely percentage effects of 2°C warming on plant cover (from 80% to 40%), fire risk (from 1% to 5%), and soil erosion (from 8% to 32%). This economic result is consistent with the answers to an explicit question on the relative importance of the attributes. As reflected in Table 3, when we asked respondents to state which attribute(s) they had in mind when deciding on contingent choices, the most cited attribute (almost three quarters of all individuals) was soil erosion, which denotes a certain consistency with the valuation results. Although there was no explicit question that investigated the reason for this preference, erosion problems in the southeast of the Iberian Peninsula and in the Mediterranean basin in general are often discussed by the media in Spain and are seen as being connected to desertification and poverty. This result is also in line with the findings of Scott et al. (1998), a study that dealt with the valuation of shrub-steppe dryland habitat functions in the United States. Scott et al. used different methods to value different attributes (erosion, recreation, and alternative land-uses). An attribute that their paper and ours has in common is soil erosion, which Scott et al. (1998) valued using five different approaches. Next to the value of land for urban use, preventing soil erosion was found to be the most valuable attribute.

The sign and statistical significance of the results obtained are consistent with welfare economic theory and expectations. For instance, the estimated willingness to pay increases with income and decreases with age, a result also reported in several other studies (see for instance Willis and Garrod [1998] or Farreras et al. [2005]). The debriefing questions revealed no worrying inconsistencies from the respondents and we found in the first part of the questionnaire that only very exceptionally, did plant cover, which incorporates an aesthetic component, have a negative value and fire and erosion a positive value within the levels considered. These answers were consistent with those given in the valuation section.

There is some uncertainty associated with the effects of climate change and when and to what extent they will occur. The answers obtained in the survey ought to be seen as contingent on the information given and to the uncertainty perceived by each respondent. Regarding time, we asked people whether their choices were influenced by the 50-year time horizon (as opposed to 25 or 100 years). While the majority of people said they did bear in mind that the time horizon was 50 years, only 10% of respondents stated that their choices might have changed if these other time horizons had been used. A similar conclusion has been reached by Kinnell et al. (2002), who tested hunters' willingness to pay for reducing the effects of climate change on the duck population of the Prairie Pothole Region at 40 and 100-year time horizons. Layton and Brown (2000) also reached a similar conclusion. Using the contingent choice method, they looked at the value of preventing forest losses induced by climate change along the Colorado Front Range of the Rocky Mountains. They used a 60- and 150-year time scale and found that this made no significant difference to respondents' answers, concluding that people probably do not care very much if something occurs in the long run or in the very long run.

There is also some uncertainty reflected in the large error bars associated with trade-offs between fire risk and other attributes. This seems to reflect a heterogeneous preference composition of the surveyed population. Whereas some people were markedly fire averse, other respondents cared much less. Thus, the result was a relatively modest average trade-off.

Precautions were taken to assure a state-of-the-art application of contingent choice, following the recommendations in Arrow et al. 1993, Carson 2000, Bateman et al. 2002, and Hensher et al. 2005. For instance, focus groups were targeted in the questionnaire design process, and some payment methods and market-institution alternatives were tested. It was found that a compulsory contribution to a foundation whose task would be to manage Catalan shrublands had no credibility problems and was the best solution. None of the participants considered it unreasonable to have to pay an annual amount henceforth for a working management plan whose objective is to mitigate the likely effects of climate change over the next 50 years. Likewise, the random combination of attribute levels to form the choice sets posed no problems for participants. The process was completed with a pilot exercise, where the valuation adequacy of the choices from the focus groups was confirmed.

In summary, this study shows that the welfare of individual Catalans is expected to drop in line with the changes in Catalan shrublands that are predicted to occur as a result of global warming. The issue of most concern is soil erosion, followed by fire and plant cover. This information may be of particular use for ecologists, policy makers, and environmental managers in the design of their programs and activities.

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APPENDIX

The valuation-study questionnaire used to survey Catalan citizens for their trade-off preferences among changes in plant cover, fire risk, and soil erosion, and their willingness to pay for management practices and/or new policies that would mitigate the intensity of such changes (*Ecological Archives* A017-005-A1).