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Analysis

Determining the insurance value of ecosystems: A discrete choice study on natural hazard protection by forests

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ABSTRACT

Forest ecosystems provide multiple services. In mountainous regions, protection against gravitational hazards is of particular importance. By preventing soil erosion and functioning as natural barriers and buffers, forests protect the population and infrastructure against avalanches and rock falls. The higher the forests' capacity to regulate and withstand external disturbances and adverse effects the higher the insurance value they provide. To operationalize the insurance value approach and to integrate it into climate change adaptation and disaster risk management, information about supply and demand of this ecosystem service is required. While assessing the capacity of forests to provide protection services has been a longstanding research focus, knowledge about the population's demand for insurance services provided by forests is still lacking. Our study analyzes the preferences of beneficiaries of such services. We conducted a choice experiment in several Swiss municipalities exposed to avalanches and rock falls, accounting for different spatial and institutional contexts. We found that households are willing to pay a significant amount for forest management that enhances forests' insurance services and reduces natural hazard risks. The results help to inform decision making in natural hazard management, and represent a further step towards operationalizing the insurance value of ecosystems.

1. Introduction

Climate change is a global phenomenon; its impacts, however, are largely felt at the regional to local scale (Duffy et al., 2019; Hsiang et al., 2017). Studies from natural and social sciences analyzing the past and future nexus of climate change and socioeconomic development frequently highlight the uncertainties that originate from regional climatic conditions and socioeconomic trends (Aerts et al., 2018; Roe et al., 2015; Schroeer and Tye, 2019). These uncertainties propagate when it comes to identifying effective climate change adaptation and disaster risk management strategies.

Effective adaptation and disaster risk management strategies need to consider the regional and local context. Set up as integrated risk reduction approaches they should allow for adaptive responses and warrant protection from the impacts of gradual climate change and extreme weather events (Aerts et al., 2018). This can be achieved by combining structural protection measures, like avalanche barriers or flood walls, with nature-based solutions, early-warning systems and risk-financing instruments (Hudson et al., 2019; Unterberger et al., 2019). While the appropriate composition of measures is location-dependent and subject to the particular hazard risk faced, the general aim is to increase society's resilience (Jongman, 2018), i.e., its capacity or ability to withstand, absorb or recover from the effects of hazardous events (Ciullo et al., 2017; Grafton et al., 2019).

Ciullo et al. (2017) have shown that the mere focus on structural protection measures does not necessarily lead to higher resilience. Using a socio-hydrological model they show that, while structural protection measures always lead to lower hazard risk, they also create a feeling of safety, which incentivizes more and more people and assets to be moved towards actually vulnerable areas, the so called “levee effect”. This causes a high dependence on functional structural protection with potentially catastrophic outcomes in case these measures fail. Over time, this dependence can lead to a reinforcing cycle of rising protection levels and increasing socioeconomic development in hazard-prone areas (Mård et al., 2018). Thus, sole reliance on structural protection measures can have adverse effects on society's resilience.

To sustainably increase the level of resilience, a more holistic approach is needed, which integrates regionally prevalent environmental, social and economic conditions (Jones et al., 2012). Nature-based solutions harness ecosystems and the services they provide to mitigate and to adapt to the effects of climate change and natural hazards (Locatelli et al., 2015; Nesshöver et al., 2017). While there is still no universal agreement, nature in general, and forests in particular, are commonly assumed to be important factors in tackling climate change adaptation and managing disaster risks (Calliari et al., 2019). Also, nature-based solutions are considered as multifunctional, indicating that the society, environment and economy can benefit from their

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implementation. The European Commission particularly emphasizes the benefits for the economy, describing nature-based solutions as facilitators in the transition to a more resource-efficient economy and towards sustainable economic growth (European Commission, 2015).

Ecosystems, such as forests, wetlands and coastal regions, provide regulating services (Griscom et al., 2017). They prevent the erosion of soil, maintain its fertility, and function as natural barriers and buffers. In doing so, they mitigate the impacts of climate change and natural hazards (Cohen-Shachman et al., 2016). Beck et al. (2018) have shown that coral reefs provide highly valuable protection against storms and floods. Without coral reefs, the globally expected annual damage of flooding would more than double and the costs of frequent storms would triple. Focusing on food production, greenhouse gas mitigation and climate regulation, Strand et al. (2018) have estimated the value of four main ecosystem services provided by the Brazilian Amazon forest. They identified ecosystem service hotspots, in which the composite value of the provided ecosystem services lies between about USD 60 and USD 740 per hectare and year.

These regulating ecosystem services have a positive impact on society's resilience. Baumgärtner and Strunz (2014) showed theoretically that the higher an ecosystem's capacity to regulate and withstand adverse effects, such as climate change, natural hazards and other external disturbances, the higher its insurance value. The notion of the insurance value of ecosystems has also been picked up by the European Commission. In its Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities, it highlights the need to "assess the insurance value of nature" and "integrate it into the disaster risk management agenda" (European Commission, 2015).

To operationalize the insurance value of nature and to integrate it into climate change adaptation and disaster risk management, information about the supply and demand for regulating ecosystem services is required. As shown above, research on determining the supply of regulating ecosystem services has already well advanced and the provided estimates give a comprehensive picture of the insurance service provided by ecosystems (see e.g., Griscom et al. (2017), Beck et al. (2018) and Strand et al. (2018)). In contrast, knowledge about the demand for such insurance services is still lacking (Wolff et al., 2015).

Existing studies usually approximate the demand for regulating ecosystem services by looking at the derived benefits (Wolff et al., 2015). For coastal protection and flood risk regulation these benefits reflect the reduced risks of flooding and extreme hydrodynamic conditions due to the water storage capacity of land cover and its importance as protective buffer zone (Liquete et al., 2013; Stürck et al., 2014). While this clearly reveals the overall societal need for and dependence on regulating ecosystem services, it implicitly assumes that their supply equals the respective demand. This demand, however, may exceed or fall below the currently supplied amounts, particularly if they emerge spatially separated from each other (Wolff et al., 2015). The preferences of the service beneficiaries are important and should be considered when making decisions. This applies all the more to (i) deliberations on how to include the insurance value of ecosystems in conventional insurance contracts and (ii) the development of payment for ecosystem service schemes.

Our study analyzes the insurance value of forests from the demand perspective. We conducted a choice experiment (CE) in seven Swiss municipalities to elicit households' preferences for forest management that reduces avalanche and rock fall risks. Based on these preferences we determined the households' willingness to pay for funding improved forest management that goes beyond current legal requirements. Our results show that the respondents indeed assign an insurance value to the forest. Based on the presented scenario, the majority has a clear preference to reduce hazard risks for their households as well as to extend protection to traffic infrastructure by an annually levied payment.

The following section provides an overview on how the insurance value of ecosystems is currently applied in the economic literature and discusses issues relevant for its provision. In section three we explain the methods used as well as the underlying data. The results are presented in section four and afterwards discussed in section five. Section six draws some conclusions of our analysis.

2. The insurance value of ecosystems

Ecosystem services, such as climate regulation, natural hazard regulation, water purification, waste-management, pollination and pest control (i.e., regulating ecosystem services), significantly contribute to ecosystems' resilience and stability. Thus, they reduce variations in production and income levels of ecosystem managers (e.g., forest owners) as well as of other ecosystem service users (e.g., residents living close to a forest). In doing so they provide an "insurance value" (Augeraud-Véron et al., 2019). This term builds on the classical definition of insurance as an action or institution to alleviate the effects of uncertainty on a person's well-being (Baumgärtner and Strunz, 2014).

Baumgärtner and Strunz (2014) analyzed the insurance value of natural capital by focusing on ecosystem resilience. They refer to three crucial insurance elements: (i) the objective state of risk of a specific ecosystem, (ii) the subjective risk perceived by individuals, and (iii) a possible (market) mechanism to reduce the objective risk, while taking individual risk preferences into account. Using a static ecological-economic model they show that high levels of resilience reduce ecosystem users' income risk: the higher the level of ecosystem resilience, the lower the income risk. Thus, high levels of ecosystem resilience implicate natural insurance against fluctuations in income and well-being.

To illustrate the insurance value of an ecosystem, Fig. 1 shows the utility function $u(y)$ of a risk-averse user of ecosystem services. The expected level of income depends on ecosystem resilience R. R combines different regulating ecosystem services, and is a function of the probability p of an ecosystem flip from a high ecosystem service provisioning state to a low provisioning state. y_L refers to the user's income in the low and y_H in the high state. Let's assume that a flip probability of $p = 0.5$ represents the initial level of ecosystem resilience $R_{p0.5}$. Expected income $E(y_{Rp0.5})$ then equals to $0.5 * y_L + 0.5 * y_H$ and the expected utility $E[u(y_{Rp0.5})]$ for this level of income is $0.5 * u(y_{Rp0.5}{}^{L}) + 0.5 * u(y_{Rp0.5}{}^{H})$. The risk premium is the maximum amount of money an ecosystem user is willing to pay to avoid any adverse variations in income and to instead receive the expected income $E(y_{Rp0.5})$ for sure. This is indicated by the horizontal red bar in Fig. 1 for the initial risk premium $\Pi(R_{p0.5})$. Improved ecosystem management can increase the resilience by lowering the flip probability from $p = 0.5$ to

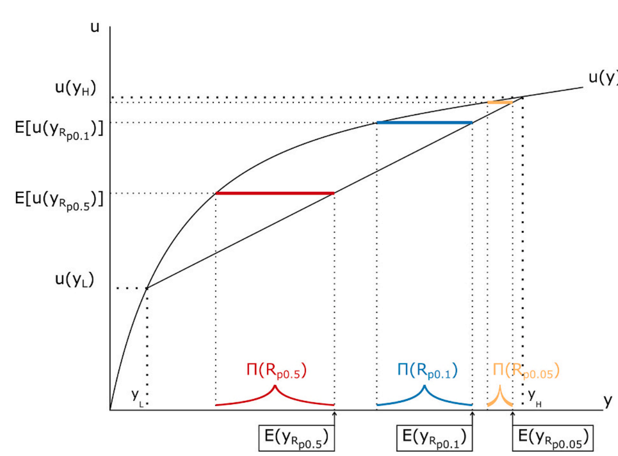

Fig. 1. The insurance value of an ecosystem. The horizontal bars indicate the risk premium, which depends on the probability p with which an ecosystem flips from a high to a low provisioning state. The higher the resilience the lower the risk premium. The insurance value is given by the change in the risk premium due to a change in the level of resilience (i.e., a lower p). Based on Baumgärtner and Strunz (2014).

$p = 0.1$. Expected income increases to $E(y_{Rp0.1})$, with $E(y_{Rp0.1}) > E(y_{Rp0.5})$. The change in the flip probability changes the risk premium to $\Pi(R_{p0.1})$, as indicated by the horizontal blue bar in Fig. 1. Ecosystem management that further reduces the flip probability to $p = 0.05$ increases expected income to $E(y_{Rp0.05})$, while lowering the risk premium to $\Pi(R_{p0.05})$, the horizontal yellow bar. Fig. 1 shows that the risk premium is strictly positive and determined by the level of ecosystem resilience. Following Baumgärtner and Strunz (2014) the insurance value is given by the change in the risk premium due to a change in the level of resilience. In our example, $\Pi(R_{p0.5}) - \Pi(R_{p0.1})$ is the insurance value of ecosystem management that reduces the flip probability from $p = 0.5$ to $p = 0.1$. A numerical example is presented in section A2 in the appendix.

Ecosystem resilience typically emerges from the interaction of different ecosystem services, which are the result of natural capital dynamics. To capture this, Quaas et al. (2019) studied the insurance value of natural capital in a dynamic setting. In particular, they looked at how risk aversion and precautionary ecosystem management affects the natural insurance value. Their results show that to provide natural insurance, ecosystems have to reduce the risk premium of ecosystem managers and users. Also, higher variations in income and well-being call for a more conservative ecosystem management, aligned towards reducing the probability and magnitude of potential future losses. Augeraud-Véron et al. (2019) focused on biodiversity conservation to mitigate variations in agricultural production. They applied a stochastic endogenous growth model to analyze the dynamic effects of biodiversity conservation decisions on agricultural production. Their approach reveals that biodiversity conservation provides a hedge against volatile agricultural production and thus acts as a natural insurance.

Typically, modified agricultural and forest ecosystems are managed with a focus on producing private goods like timber or food. Ecosystem managers aim for an optimal combination of production and conservation, to benefit from natural insurance against income fluctuations according to their individual risk preferences (Paavola and Primmer, 2019). However, ecosystems often cater the needs of several users with divergent interests simultaneously. While for forest managers the natural insurance comes in the form of less volatile timber production and revenues, residents may derive natural insurance from, e.g., the protection against natural hazards. Clearly, these different insurance services are interdependent: changing decisions of the ecosystem manager directly affects the services available to the other users. Particularly the latter are often public goods characterized by non-rivalry and non-excludability (Olschewski et al., 2012; Paavola and Primmer, 2019). Yet, the ecosystems providing them need to be managed and maintained (often privately) to provide the desired services.

Building on the insurance value concept introduced by Baumgärtner and Strunz (2014) and displayed in Fig. 1, we conducted a choice experiment that trades off improved forest management and the associated reduction in hazard risk with the additional costs these measures entail. Our study sets out to elicit preferences for the insurance services provided by forests. Based on these preferences we calculated households' WTP to fund the improved forest management. Our estimates show households' preferences for reducing the flip probability p and changing (i.e., lower) their individual risk premium due to improved forest management. In this setting, the determined WTP corresponds to an annual monetary estimate of the insurance value of forests.

3. Method and data

3.1. Determining the insurance value of ecosystems with choice experiments

Choice Experiments (CE) confront respondents with a set of decision situations, each of which consists of two or more multi-attribute alternatives. As respondents indicate their preference for an alternative, the importance of the attributes and their respective levels can be estimated. This allows to value changes in the provision of goods and services, for which no markets exist (yet). Owing to their flexibility regarding the goods to be valued and the attributes analyzed, CE are a well-established method in welfare analysis (Johnston et al., 2017).

Combining utility theory with the random utility model, CE can be used to estimate two Hicksian welfare measures, the compensating and the equivalent variation (Bergen et al., 2013). Let the utility u an individual n currently experiences depend on the individual's income y_n and the level of some environmental service ES_n^{0} and denote it $u_n(ES_n^{0}, y_n)$. Further, assume that utility is only and positively affected by the amount of ES provided and income y. Improved ecosystem management could increase (i) the provided ES from ES_n^{0} to ES_n^{1} (with $ES_n^{1} > ES_n^{0}$), (ii) ecosystem resilience and thus (iii) $u_n(ES_n^{0}, y_n)$ to $u_n(ES_n^{1}, y_n)$ (with $u_n(ES_n^{1}, y_n) > u_n(ES_n^{0}, y_n)$). The two Hicksian welfare measures can be used to estimate the monetary value the change in ecosystem management has on individual n's income. The compensating variation C_n shows the maximum willingness-to-pay (WTP) to have the change happening: $u_n(ES_n^{1}, y_n - C_n) = u_n(ES_n^{0}, y_n)$, with $C_n > 0$. The equivalent variation E_n, on the other hand, reflects the minimum willingness-to-accept (WTA) to forego it: $u_n(ES_n^{1}, y_n) = u_n(ES_n^{0}, y_n + E_n)$, with $E_n > 0$. Choice experiments vary the amounts of C_n or E_n exogenously. For individuals who are willing to pay a certain amount in order to increase resilience we can assume that $u_n(ES_n^{1}, y_n - C_n) > u_n(ES_n^{0}, y_n)$, and thus, $u_n(ES_n^{1}, y_n - C_n) - u_n(ES_n^{0}, y_n) > 0$. Hence, only differential effects between the different choice options matter and only the marginal effects of C_n are of interest (i.e., income y can be excluded) (Brynjolfsson et al., 2019). The same applies for measuring E_n.

To value the potential increase in ES (i.e., the increase in resilience) brought about by the changed ecosystem management, the random utility model estimates individuals' choice sensitivity to variations in C_n. It decomposes utility u_n into an observable component V_n and an unobservable random error term e_n, such that $u_n(ES_n^{0}, y_n) = V_n(ES_n^{0}, y_n) + e_n$. The observable component is typically assumed to consist of part-worth utilities for each of the attributes describing the change, i.e., $V_n = \beta_0 ES_n^{0} + \beta_1 C$, and may further depend on sociodemographic characteristics z_n. The probability that an individual n now selects a particular choice alternative i in choice task t equals the probability that the utility of the selected choice alternative i is larger or equal to the utility associated with any other alternative j in the choice set T, $p_{nit} = prob\ [(V_{nit} + e_{nit}) \geq (V_{njt} + e_{njt})]$.

Different assumptions regarding the distribution of the error term result in different choice model specifications. The most widely used choice model is the multinomial logit model MNL (Johnston et al., 2017). It assumes that the error term is independently, identically extreme value distributed. This suggests that the observable component V captures the majority of the overall utility, preventing any systematic effect of the error term.

Despite its popularity, the MNL model and its assumptions are restrictive. Unobserved factors that influence one choice situation are likely to affect the following choices as well. Thus, there may be a dependence of choices over time, violating the independence assumption (Botzen and van den Bergh, 2012). What is more, the MNL model estimates average attribute sensitivities across agents and can account for heterogeneity across them only deterministically, by including different sociodemographic characteristics z_n. While this helps to explain parts of the heterogeneity across decision makers, it is unlikely that all relevant sociodemographic characteristics can be captured (Hess and Daly, 2014).

Generally, there are idiosyncratic differences in preferences across respondents in a sample. Incorporating them improves the explanatory power of the model and helps to avoid potential bias in the model estimates. To pick up the random heterogeneity, the model needs to allow for distributions of sensitivities across respondents. Latent class models make use of discrete distributions and allow the analyst to allocate the data in S classes, with S different values for the vector of choice coefficients β. A class allocation model then allocates individuals n

probabilistically to S classes. Here, sociodemographic characteristics can be used to explain the class allocation probability. Eq. 1 shows the probability π_{ns} of individual n falling into class s, where $0 \leq \pi_{ns} \leq 1$, $\forall$ n, s and $\Sigma_{s=l}{}^{S}\pi_{ns} = 1,\ \forall$ n. Here, δ_s is a class specific constant, γ_s is the vector of parameters to be estimated and $g(\cdot)$ indicates the functional form for the utility function for the class allocation model (Hess and Daly, 2014).

$$\pi_{ns} = \frac{e^{\delta_s + g(\gamma_s, z_n)}}{\sum_{l=1}^{S} e^{\delta_l + g(\gamma_l, z_n)}} \tag{1}$$

Typically, latent class models are specified with an underlying MNL model. If individual n falls into class s, $P_{nit}(\beta)$ describes the logit probability of individual n choosing alternative i in choice task t. Eq. 2 shows the likelihood of the observed set of choices for individual n, assuming intra-individual homogeneity in sensitivities (Hess and Daly, 2014).

$$L_n(\beta, \pi) = \sum_{s=1}^{S} \pi_{ns} \left(\prod_{t=1}^{T_n} P_{ni^*t}(\beta_s) \right) \tag{2}$$

WTP measures can then be calculated by looking at the negative ratio between the coefficient of the attribute of interest and the price or cost coefficient. Assuming that the estimated coefficient of the amount of provided environmental service is $\widehat{\beta_{ES}}$ and the estimated cost coefficient is $\widehat{\beta_c}$, the WTP to benefit from extended environmental services is $WTP = -\frac{\widehat{\beta_{ES}}}{\widehat{\beta_c}}$. The standard errors for these ratios can be computed using the delta method (Kanninen, 2007).

We apply a latent class model for the following main reasons. First, in operationalizing the insurance value of forests, estimates for preferences of discrete groups within the sample are more informative than estimating the continuous distribution of preferences across the whole sample. This is particularly true when it comes to potential policy implications our results might have. Second, we are interested in the WTP of households for improved forest management. In a latent class model, WTP is determined as the ratio of a specific attribute's coefficient and the cost coefficient. In a mixed multinomial logit model (MMNL) the WTP is the ratio of two random variables. For many distributions the moments of the WTP distribution do not exist (Daly et al., 2012). Estimation in the WTP space and the use of non-parametric distributions can help to resolve these issues. Nevertheless, given our research focus, we consider the latent class model more suitable.

3.2. The choice experiment

We conducted the choice experiment from October 2019 to February 2020 in seven Swiss municipalities (Fig. 2). Four of these municipalities (Graechen, St. Niklaus, Taesch and Zermatt) are located in the canton of Valais and the others in the canton of Grisons (Davos, Schmitten, Albula/Alvra, Bergün Fillisur). We selected the study sites based on the specific requirements of the different disciplines of our project (forest management, natural hazard modelling, and socio-economics). Further, we wanted to capture institutional differences, such as regulations of the insurance sector. Overall, we invited 10,289 households to participate in our study. Due to the large number of inhabitants in Davos, we reduced the sample by only inviting households, where the main person registered was born in an even year. Due to data privacy regulations, the municipalities Graechen, St. Niklaus and Zermatt could not provide individual address data for the registered households. Therefore, we had to use bulk mailing. For the remaining municipalities we sent personally addressed letters. In all cases, the letter contained a brief description of our research project as well as a link to the survey and the required login data. We administered the survey with the online hosting service provided by Sawtooth. Table 1 provides an overview of the number of invitations sent to each of the municipalities. We aimed at reducing the non-response bias by offering the participation in a lottery for all respondents that completed the survey.

In developing the choice experiment, we involved insurance and reinsurance experts as well as academics from various fields to assure that the attributes and their levels are relevant, realistic and comprehensible. In a second step, we performed a pretest with researchers and technical staff from the Swiss Federal Institute for Forest, Snow and Landscape Research who completed 51 surveys. The purpose of this pretest was to make sure that respondents understand the questions, to trial the online implementation of the survey, and to optimize the design (Johnston et al., 2017).

The choice experiment comprised five attributes with two to six attribute levels each (Table 2). The attribute *"Hazard zone"* indicates the households' risk level related to avalanches and rock falls. These zones are officially defined, periodically updated and represent a risk metric households in our study regions understand and are acquainted with. The assigned colors (red, blue, white) correspond to specific intensities and return periods of avalanche and rock fall events and thus indicate the natural hazard risk faced by the residents in our study regions (BAFU, 2015). The attribute *"Protection extended to infrastructure"* (yes/no) indicates whether improved forest management also leads to better protected rail and road infrastructure. The *"Costing method"* attribute (risk based, lump sum) describes how the additional charges per household are calculated, and the *"Contribution mode"* attribute (voluntary, mandatory) describes how the contributions to the payment scheme are organized. Finally, the *"Additional annual charge per household"* attribute consists of six average monetary levels households are asked to pay to improve forest management. Since we conducted the study in Switzerland the charge is denominated in Swiss Francs (CHF). The average exchange rate between CHF and USD was approximately 1:1 in 2019.

Table 2 provides an overview of the attributes, their respective levels, and a detailed description. We strived to design the CE as realistic as possible, and the chosen levels reflect the manifestations of these attributes in reality. Therefore, three of our attributes have two levels, only. Further, the number of attributes might seem to cause a cognitive burden for the respondents. In this respect, Meyerhoff et al. (2015) analyzed the impact of design dimensions (number of alternatives, attributes, levels, etc.) on CE results. They tested a range of four to seven attributes, and found that the probability of respondents to drop out increases with the number of attributes. Based on our own experience with former CE and given that our five attributes are at the lower end of this range, we found this number of attributes acceptable and not to overstrain the cognitive capabilities of the respondents.

The overall structure of the survey was as follows. First, we briefly provided information about the protection function of forests in Switzerland, and how climate change and socioeconomic developments require a sustainable forest management to maintain the protection function under future conditions. We then formulated a scenario, which constituted the status quo of all households (Option 3). In this status quo, the responding household is assumed to live in the red hazard zone, and protection is not extended to infrastructure. This assumption was crucial to define a common reference situation for all respondents, from which to assess the respective changes. Beside this theoretical reason, we could not include the actual risk status of the respondents in the CE a priori. As explained above, some municipalities could not provide the addresses of their inhabitants due to privacy restrictions. Nevertheless, in the debriefing questions we asked the respondents, in which zone they actually live. This allowed us to control for any effect the hazard zone respondents live in might have on the estimated preferences (compare Table A1 & Table 4).

Since there is no improved forest management in the status quo, the additional costs are zero. By improving forest management in Option 1 and 2, the extent of the red hazard zone, and thus the objective risk, is reduced, and the household now lives in a less risky or even risk-free zone (blue or white, respectively). Based on this scenario, we generated

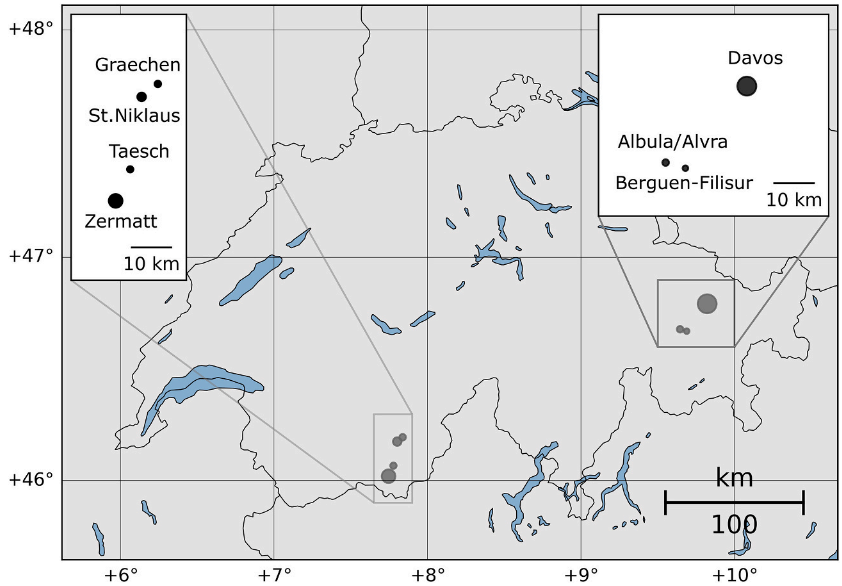

Fig. 2. The seven case-study municipalities. The dot size indicates the number of registered households in each municipality (Davos = 6814, Albula/Alvra = 719, Bergün-Filisur = 1210, St. Niklaus = 1008, Grächen = 670, Täsch = 677, Zermatt = 2598).

Table 1
Invitations sent to each of the municipalities, received responses and response rate.

Municipality	Invitations sent	Responses received	Response rate
Davos	3,407	393	11.5%
Albula/Alvra	719	73	10.2%
Bergün Filisur	1,210	211	17.4%
St. Niklaus	1,008	88	8.7%
Grächen	670	34	5.1%
Täsch	677	32	4.7%
Zermatt	2,598	108	4.2%
Total	10,289	939	9.13%

a D-efficient design in Ngene (ChoiceMetrics, 2018) with twelve choice sets with constant status quo and varying attribute levels in Options 1 and 2. Please see Fig. 3 for an exemplary choice card.

After filling in the twelve choice cards, we asked several debriefing questions to assess whether the respondents understood the questionnaire, felt comfortable answering it and considered the experiment realistic (Johnston et al., 2017). Further, we asked the respondents about (i) their perception of the current state of the protection forest, (ii) where they actually live, (iii) their subjective hazard risk, and (iv) their attitude towards climate change. Additionally, we asked the respondents to state their risk preference. Following Falk et al. (2018) and Mata et al. (2018) we used a scale ranging from 0 to 10, where 0 means *"completely unwilling to take risks"* and 10 means *"very willing to take risks"*. Finally, we collected sociodemographic characteristics of the respondents such as gender, income, education, etc.

The way we designed the choice experiment allowed us to estimate the insurance value of forests as described in Section 2. Based on the status quo, Options 1 and 2 represent situations with improved forest management. This improvement is assumed to increase the resilience against natural hazards, which increases the protection level and reduces the objective risk. This setting is operationalized by reducing the extent of the red and blue hazard zones. It is analogous to a reduction of the system flip probability p and an associated increase in the expected level of income, as indicated in Fig. 1.

The survey, including a full description of the choice experiment, the dataset and a description of it are provided on the environmental data portal and repository of the Swiss Federal Research Institute WSL, *EnviDat*, under doi:*10.16904/envidat.175*.

Table 2
Description of the attributes and their respective attribute levels.

Attribute	Levels	Description
Hazard zone	*Red / Blue / White*	*Red zone:* Significant hazard risk. People are endangered inside and outside of buildings. The immediate destruction of buildings is possible. *Blue zone:* People are hardly endangered inside of buildings. Outside, however, they are. Damages to buildings are possible. *White Zone:* no or negligible threat to people and buildings
Protection extended to traffic infrastructure	*Yes / No*	Indicates via *Yes* or *No*, whether the improved forest management also lead to better protected rail and road infrastructure.
Costing method	*Risk based / Lump sum*	*Risk based:* The annual charge per household depends on the household's specific natural hazard risk. *Lump sum:* Each household contributes the same amount, regardless of its natural hazard risk.
Contribution mode	*Voluntary / Mandatory*	*Voluntary:* The payment of the additional annual charge per household is voluntary. *Mandatory:* The payment is mandatory.
Additional annual charge per household	*CHF 0 / 100 / 300 / 500 / 700 / 900*	The annual amount to be paid per household.

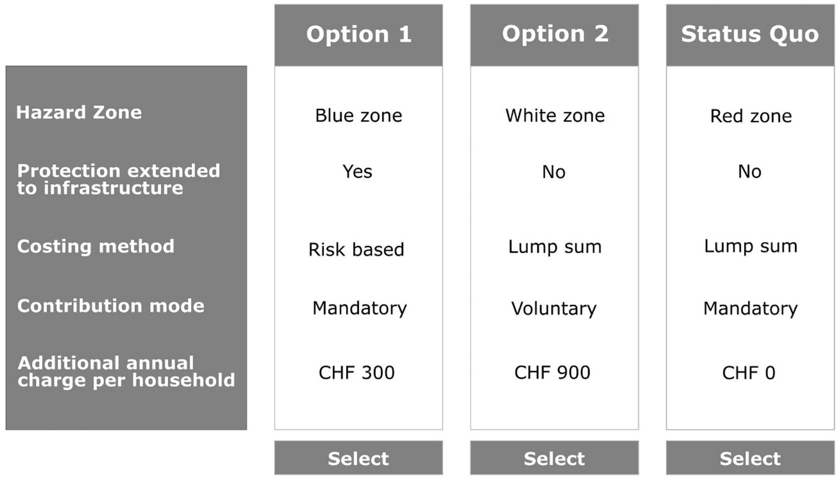

Fig. 3. Example of a choice card.

3.3. Model specification and data

We assume that the utility of improved forest management *IFM* depends on the hazard zone, the protection extended to traffic infrastructure *TI*, the costing method *COS*, the way the contributions are levied *CON*, and the additional annual charge per household *CHARGE*. The basic specification of the utility function for improved forest management in Options 1 and 2 is given by Eq. 3. Eq. 4 shows the utility function for the status quo *SQ*.

$$U_{IFM} = \beta_1 * HZ_{IFM} + \beta_2 * TI_{IFM} + \beta_3 * COS_{IFM} + \beta_4 * CON_{IFM} + \beta_5 * CHARGE_{IFM} + \varepsilon_{IFM} \tag{3}$$

$$U_{SQ} = \beta_1 * HZ_{SQ} + \beta_2 * TI_{SQ} + \beta_3 * COS_{SQ} + \beta_4 * CON_{SQ} + \beta_5 * CHARGE_{SQ} + \varepsilon_{SQ} \tag{4}$$

All attributes except the *CHARGE* variable are categorical. They are dummy coded with the attribute levels of the status quo as base line. This allows us to analyze respondents' WTP for forest management that improves the status quo and increases the protection against natural hazards.

To account for the effect of the reported income on the respondents' cost sensitivity, we estimated an income elasticity. We specified the *CHARGE* variable as shown in Eq. (5), where y_n is the income as reported by respondent n and $\bar{y}$ is the sample mean income. We further controlled for differences in the *CHARGE* attribute between respondents who stated their income and those who did not by interacting a dummy variable $y_{missing}$ (which is equal to 1 when the respondent's income was not stated) with the coefficient $y_{notstated}$ (Sanko et al., 2014).

Specification of the CHARGE variable:

$$\left(y_{notstated} * y_{missing} + \frac{y_n}{\bar{y}} * y_{stated}\right)^{income\ elasticity} * CHARGE \tag{5}$$

This specification of the *CHARGE* variable also affects the calculation of the WTP described in Section 3.1 as now respondents' income and the estimated *income elasticity* have to be considered.

We received 939 questionnaires, of which 303 were incomplete and therefore excluded from the further analysis. Additionally, we dropped respondents who quickly clicked through the survey. For every respondent, Sawtooth's online hosting service records the time spent on each page. All respondents that took less than five minutes for the choice experiment were dropped. Eventually, this left us with 587 respondents and 7,044 observations.

Looking at the sociodemographic characteristics of our respondents, Fig. 4 suggests that our sample covers a broad range of sociodemographic backgrounds. As we focus on seven case study municipalities located in mountain valleys, representativeness at the level of the wider Swiss population is an unsuitable benchmark. Eventually, we want to develop an insurance model adjusted to the forest and natural hazard conditions as well as the preferences of the population in mountainous regions. We therefore included sociodemographic characteristics at the cantonal level and compared it to our sample.[1] Panel (a) in Fig. 4 shows that people between 20 and 30 years as well as those older than 80 years are underrepresented in our sample. At the same time, those between 40 and 70 years are overrepresented. For the age groups between 30 and 40 years and 70 and 80 years, our sample is in line with the actual shares of the demographic statistics for the two cantons. For the disposable monthly income per household, panel (b) shows that households with an income below CHF 10,000 are underrepresented, whereas particularly those with an income between CHF 10,000 and CHF 15,000 are overrepresented. For the educational training no data at the spatial scale of our analysis was available. We therefore reverted to the numbers for the overall Swiss population. In 2017, 43% of the Swiss population aged between 25 and 64 held a university degree or obtained higher vocational education (FSO, 2019). Panel (c) suggests a similar pattern within our sample. As apparent from panel (d), male respondents are overrepresented in our survey. This is due to the fact that, in rural regions, households are commonly registered under their name. To adjust for any potential bias the over- or underrepresentation of particular demographic groups might have, we included these sociodemographic characteristics in our estimations. Among other things, we adjusted for gender, the age of the respondents, as well as the monthly disposable income per household. The results of our estimations are presented in section 4.

The debriefing questions are summarized in Fig. 5. The large majority of respondents considered the choice experiment comprehensible and felt certain about the choices made. Generally, the scenario we presented was considered realistic and the charges required for the improved forest management in Options 1 and 2 were perceived as credible. This shows that the respondents understood the experiment as intended and, thus, ensures the validity of our results.

[1] Data for the age distribution in the two cantons were provided by the Canton of Valais (https://www.vs.ch/de/web/acf/statpop) and the Canton of Grisons (https://www.gr.ch/DE/institutionen/verwaltung/dvs/awt/statistik/Bevoelkerung/Seiten/Bevoelkerungsstand_und_-struktur.aspx). Data for the disposable income per household was obtained from the Swiss Federal Tax Administration (https://www.estv.admin.ch/estv/de/home/allgemein/steuerstatistiken/fachinformationen/steuerstatistiken/direkte-bundessteuer.html#990744579)

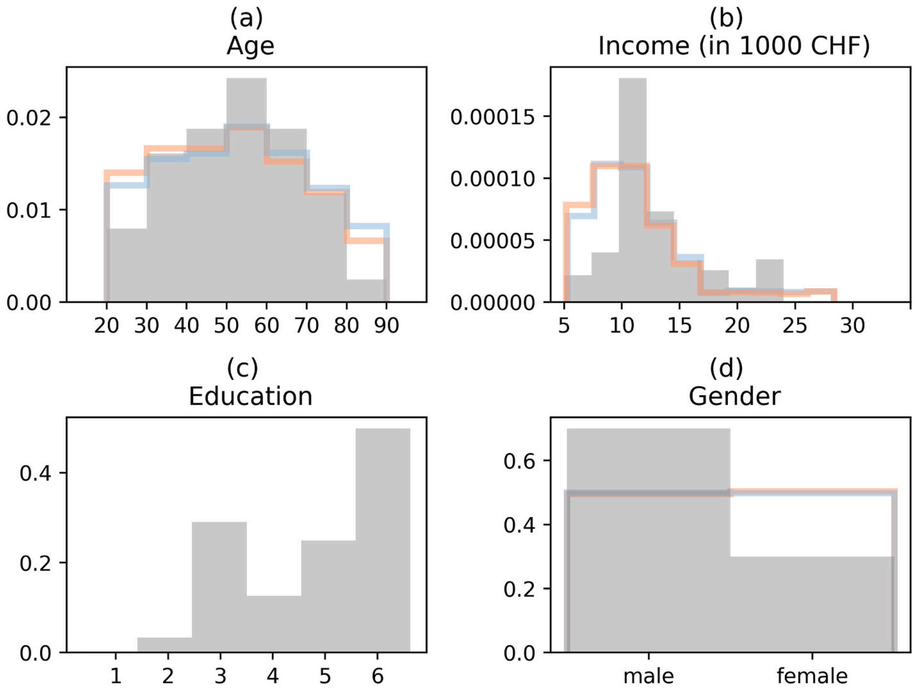

Fig. 4. Sociodemographic characteristics of our sample. Panel (a) shows the histogram for the age of our respondents. Panel (b) reports the monthly disposable income per household in CHF. Panel (c) shows the highest educational qualification per respondent (1: none, 2: high school diploma, 3: vocational school, 4: general qualification for university entrance, 5: higher vocational training, 6: college or university). Panel (d) shows the gender of our respondents. The blue line indicates the histogram of the respective sociodemographic data for the population in the Canton of Grisons. The orange line represents the histogram for the data for the population of the Canton of Valais. (For interpreting the colours, please refer to the web version of this article.)

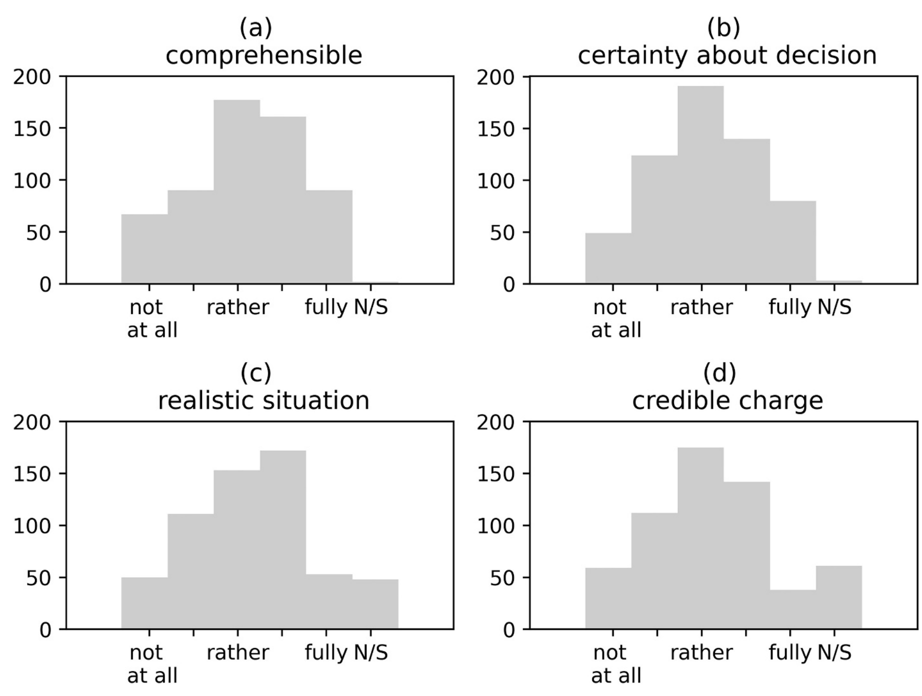

Fig. 5. Summary of the debriefing questions. Respondents were asked to assess the comprehensibility and closeness to reality of the choice experiment as well as the credibility of the charge, and their certainty when making decisions. Scores range from 1 (not at all) to 5 (fully). N/S refers to not stated.

4. Results

To estimate the models with the respective specifications presented in sections 3.1 and 3.3 we used the Apollo package (Hess and Palma, 2019a, 2019b). In a first step, we estimated a basic MNL model. As apparent from column (1) in Table 3, the coefficients for the blue and white hazard zone are both positive and statistically significant. This suggests that households have a clear preference for forest management that reduces their individual avalanche and rock fall risk. Additionally, the results show that households favor forest management that extends the protection to traffic infrastructure. As for the costing method, the basic MNL model shows that households prefer risk-based costing. Voluntary payments are the preferred way of contributing to the suggested payment scheme. As expected, the coefficient for the additional annual charge is significantly negative, as it represents a disutility for households. Additionally, we see that the estimated income elasticity for the cost sensitivity is significantly negative. This suggests that for respondents with a relatively high income, the additional annual charge is less important. Furthermore, our results reveal that there is no significant difference in preferences about the additional annual charge between respondents who stated their income and those who did not.

In a second step, we complemented the basic MNL model with

Table 3
Estimates for MNL models. Column (2) only shows the estimates for the attribute levels. The full results incl. the estimates for the sociodemographic characteristics are shown in Table A1 in the Appendix. Robust standard errors clustered at the level of respondents are given in brackets. For the base levels of the dummy coded variable a coefficient of 0 is reported. The asterisks show the significance level where * indicates $p < 0.1$, ** indicates $p < 0.05$ and *** indicates $p < 0.01$.

		(1) MNL Basic	(2) MNL incl. Socio-demographics
Hazard zone	***White***	1.28***	1.12***
		(0.093)	(0.341)
	Blue	1.15***	0.94***
		(0.089)	(0.330)
	Red	0	0
Protection extended to traffic infrastructure	***Yes***	0.51***	0.29**
		(0.038)	(0.147)
	No	0	0
Costing method	***Risk based***	0.09***	0.33***
		(0.029)	(0.130)
	Lump sum	0	0
Contribution mode	***Voluntary***	0.09***	0.004
		(0.045)	(0.165)
	Obligatory	0	0
Additional annual charge per household	***Charge***	−0.002***	−0.002***
		(0.0001)	(0.0001)
	Income elasticity	−0.32***	−0.09
		(0.109)	(0.09)
	Missing income information	0.1218	0.01
		(0.11)	(0.063)
Number of individuals		*587*	*587*
LL (final)		*−6494.93*	*−6057.605*
Adj. Rho-square		*0.159*	*0.206*
AIC		*13,005.8*	*12,291.21*
BIC		*13,060.7*	*12,894.88*
Estimated parameters		*8*	*94*

sociodemographic characteristics of our respondents. Column (2) in Table 3 shows the estimated preferences for the attribute levels. Full results are presented in Table A1 in the Appendix. The estimated preferences for this specification correspond to the results of the basic MNL model shown in column (1). The coefficients for a switch to the white and blue hazard zone show similar signs and magnitudes. The coefficient for extending protection to traffic infrastructure is still positive, its magnitude, however, becomes smaller. There is now a stronger preference for the risk based costing method than in the basic MNL model. The significant preference for voluntary contributions disappears, once sociodemographic information is accounted for.

Incorporating the sociodemographic characteristics of the respondents reveals how they affect the estimated coefficients of the attribute levels. We found that households from the *Canton of Valais* have a significantly lower preference for improved forest management that reduces individual avalanche and rock fall risk than households from the Canton of Grisons. This is indicated by the significant negative coefficient for the *Canton of Valais* for the hazard zone attributes in Table A1. Furthermore, households from the *Canton of Valais* have a stronger preference to extend the protection to traffic infrastructure and favor voluntary contributions. The latter findings dovetail nicely with the different institutional frameworks governing the insurance of buildings in our two case study regions: While building insurance is mandatory and provided by a cantonal insurance company in the Canton of Grisons, it is voluntary in the Canton of Valais and provided by private insurers, only.

Property owners and respondents with a *second home* in one of our case study municipalities also show a strong preference for risk reduction by means of forest management. Furthermore, both oppose voluntary contributions. Additionally, *second home* owners have a significantly lower preference for risk-based contributions. The same holds for households actually *living in the red hazard zone*. Preferences also vary according to the stated climate change awareness. Respondents who are *concerned about the overall impact of climate change*, have a strong preference to extend the protection to traffic infrastructure. Those who *expect climate change to have a negative impact on the health of forests*, at the same time have a strong preference for improving forest management to reduce natural hazard risks. Respondents who feel that the *responsibility for natural hazard protection is with the public authorities*, show significant lower preferences for better forest management as those *satisfied with the current forest management measures*. Households who considered *the experiment realistic* show strong preferences for improving forest management to reduce avalanche and rock fall risk. At the same time, they oppose voluntary contributions. Interestingly, *households with children* and *elderly respondents* show a strong preference for voluntary contributions and for extending the protection to traffic infrastructure. Households with a monthly disposable income below CHF 5000 (i.e., *low income*) have a significantly lower preference for forest management that reduces avalanche and rock fall risk. *Male respondents* show a lower preference for switching to the blue hazard zone. Furthermore, they have a lower preference for extending protection to traffic infrastructure. Interestingly, households who stated a *low level of risk aversion* have a significantly lower preference for living in the white hazard zone. This, however, is not observed for the blue hazard zone.

The presented results clearly indicate that preferences generally differ among respondents. While the incorporation of sociodemographic characteristics is helpful, there may be further idiosyncratic differences, which cannot be deterministically accounted for by estimating an MNL model (as explained in section 3.1). Therefore, we estimated a latent class model with three classes. This improves the model fit as evident from the Rho-square as well as the log-likelihood statistics. We positively tested the latter for significance using a likelihood-ratio test. Table 4 shows how the preferences vary across the three classes and further indicates how sociodemographic characteristics help to explain the class allocation probability.

As apparent from Table 4, the three classes differ according to the magnitude and sign of the estimated coefficients. Classes 1 and 2 have very similar preferences for forest management that reduces avalanche and rock fall risks to households, and extends protection to traffic infrastructure. The coefficients for the blue and white hazard zone as well as for the additional protection of traffic infrastructure are all significantly positive. For Class 3, on the other hand, the coefficients for the hazard zone attributes are significantly negative, indicating a clear preference for the status quo. Furthermore, Class 3 respondents are indifferent about extending protection to traffic infrastructure. As for the costing mode, only Class 2 shows a clear preference for risk-based pricing, whereas the other classes are indifferent. All classes are indifferent between mandatory and voluntary contributions. As expected, the coefficient for the additional annual charge is significantly negative across the three classes.

With 48%, Class 2 shows the highest class allocation probability. For Class 1 the probability is 31% and for Class 3 it is 21%. Including the sociodemographic characteristics in the class allocation model allows to analyze how they affect the class allocation probability. Interestingly, households who stated a low level of risk aversion and those who feel that the *responsibility for natural hazard protection is with the public authorities* most likely fall into Class 3. The estimates suggest a similar tendency for households from the *Canton of Valais* and respondents who are *satisfied with the current forest management measures*. Here, the estimates for Class 1 and 2 are negative, though not significant for Class 2. *Property owners* and *male respondents* most likely fall into Class 2. The same applies to respondents who expect that *climate change will negatively affect forests* and who are *generally concerned about the impacts of*

Table 4

Estimates for the latent class model with three classes and the class allocation probabilities. Robust standard errors clustered at the level of respondents are given in brackets. For the base levels of the dummy coded variable a coefficient of 0 is reported. The asterisks show the significance level where * indicates $p < 0.1$, ** indicates $p < 0.05$ and *** indicates $p < 0.01$.

		Class 1	Class 2	Class 3
hazard zone	***White***	3.54*** (0.549)	3.34*** (0.368)	−0.65*** (0.276)
	Blue	3.23*** (0.496)	3.21*** (0.363)	−0.47*** (0.22)
	Red	0	0	0
Protection extended to traffic infrastructure	***Yes***	0.49*** (0.132)	0.64*** (0.054)	0.11 (0.199)
	No	0	0	0
Costing method	***Risk based***	0.06 (0.197)	0.099*** (0.148)	−0.08 (0.149)
	Lump sum	0	0	0
Contribution mode	***Voluntary***	0.32 (0.207)	0.06 (0.075)	0.29 (0.189)
	Obligatory	0	0	0
Additional annual charge per household	***Charge***	−0.0055*** (0.0008)	−0.001*** (0.0001)	−0.004*** (0.0006)
	Income elasticity	−0.28*** (0.117)		
	missing income information	0.54 (0.579)		
Sociodemographic characteristics that affect group allocation	***Canton of Valais***	−0.71** (0.346)	−0.23 (0.285)	0
	Low level of risk aversion	−0.57* (0.308)	−0.57** (0.262)	0
	Children	0.54 (0.369)	0.32 (0.355)	0
	Gender	0.02 (0.891)	0.46** (0.225)	0
	Property owner	0.31 (0.398)	0.47* (0.282)	0
	Second home	0.19 (0.331)	0.45 (0.276)	0
	Live in red zone	0.83 (0.828)	0.003 (0.755)	0
	Low income (< CHF 5000 per month)	−0.56 (0.457)	−0.49 (0.353)	0
	High income (> CHF 13,000 per month)	0.06 (0.399)	−0.24 (0.378)	0
	Elderly (> 60 years)	−0.39 (0.357)	0.06 (0.304)	0
	Young (< 30 years)	0.14 (0.561)	0.346 (0.524)	0
	Satisfied with current forest management measures	−0.67** (0.296)	−0.42 (0.263)	0
	Climate change negatively affects forests	0.55 (0.352)	0.80*** (0.277)	0
	Public authorities are responsible for hazard protection	−0.85*** (0.314)	−0.75*** (0.258)	0
	Concerned about climate change impacts	0.02 (0.891)	0.46** (0.225)	0
	Realistic experiment	0.60* (0.333)	0.72** (0.298)	0
Class allocation probability		***0.31***	***0.48***	***0.21***
Number of individuals	*587*			
LL (final)	*−4820.98*			
Adj. Rho-square	*0.37*			
AIC	*9749.96*			
BIC	*10,120.4*			

climate change. Respondents who considered our *experiment as realistic* are unlikely to fall into Class 3.

4.1. Willingness to pay estimates

Tables 3 and 4 show that the magnitude of the estimated coefficients varies across the three models. This directly affects the WTP calculations explained in section 3.1. Fig. 6 summarizes the WTP distributions for the different attribute levels of the hazard zone and the protection extended to traffic infrastructure.

The blue line in Fig. 6 shows the WTP distribution derived from the latent class model. In line with the preferences shown in Table 4, there are three significantly different WTP for the hazard zone attribute levels. Class 1 households would be willing to pay CHF 604 (± 154) for forest management that leads to negligible avalanche and rock fall risks, i.e., the white hazard zone. For forest management that ensures that people are hardly endangered but cannot eliminate the risk to buildings, i.e., the blue hazard zone, Class 1 households have a WTP of CHF 552 (± 141). Table 4 shows that the estimated cost coefficient for Class 2 is smaller than the one for Class 1. This positively affects WTP estimates. As Fig. 6 indicates, the WTP for Class 2 households amounts to CHF 3709 (± 946) for switching to the white hazard zone. For measures that lead to the blue hazard zone they have a WTP of CHF 3562 (± 908). Class 3 households have a clear preference for the status quo. This is also mirrored by their WTP to support an improved forest management. For all levels it is negative; CHF -165 (± 42) for switching to the white hazard zone and CHF -121 (± 31) for the blue hazard zone. This suggests that these households would require a compensation to agree to an improved forest management. Fig. 6(c) shows the WTP for forest management that that extends protection to traffic infrastructure. Here, only households who most likely belong to Class 1 or Class 2 show a significant WTP of 84 (± 21) and 714 (± 182), respectively.

The yellow and the green curve in Fig. 6 depict the distribution for the WTP estimates based on the basic MNL model and the MNL model that incorporates the sociodemographic characteristics of our respondents. The yellow line reveals that the WTP estimates based on the basic MNL model are narrowly distributed around the mean estimates, i.e., CHF 657 (± 174) for switching to the white hazard zone, CHF 594 (± 158) for the blue hazard zone and CHF 263 (± 70) for extending protection to traffic infrastructure. Incorporating the sociodemographic characteristics of our respondents considerably increases the standard errors of the calculated WTP, as we now deterministically account for heterogeneity across respondents. This is indicated by the green line in Fig. 6, and leads to a WTP of CHF 720 (± 493) for the white hazard zone, CHF 631 (± 486) for the blue hazard zone and CHF 321 (± 465) for extending protection to traffic infrastructure. As apparent from Fig. 6, the green line also overlaps with parts of Class 3 from the latent class model (blue line). Thus, for a number of respondents the estimated WTP is negative, affecting the statistical significance of the overall WTP estimates.

Overall, the WTP based on the MNL models are largely in line with the WTP of Class 1 respondents from the latent class model. As the MNL models ignore idiosyncratic differences in preferences among the respondents they fail to capture that one group of respondents is not at all willing to contribute (i.e., Class 3), while another group would be willing to contribute substantially (i.e., Class 2).

5. Discussion

The presented results highlight that the preferences for forest management that reduces avalanche and rock fall risks for households and extends protection to traffic infrastructure vary across households. While the majority of respondents shows clear preferences for this way of risk reduction there are also households who oppose an improved forest management and favor the status quo. This difference in preferences can partly be explained by incorporating the sociodemographic characteristics of the respondents. Beyond that,

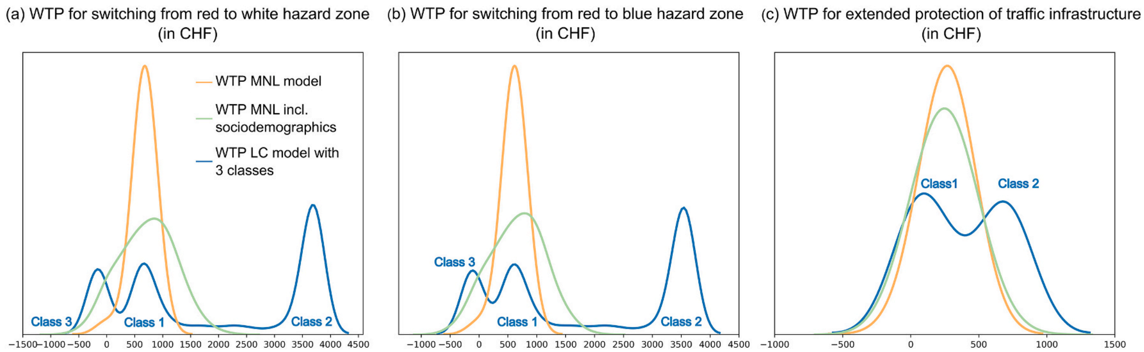

Fig. 6. Willingness to pay (WTP) (in CHF) for forest management that reduces avalanche and rock fall risk to households (panel (a) and (b)) and extends the protection to traffic infrastructure (panel (c)). The blue line indicates the WTP distribution based on the latent class model with three classes. The green line depicts the WTP distribution based on the MNL model that incorporates the sociodemographic characteristics of our respondents. The yellow line shows the WTP distribution for the basic MNL model. (For interpreting the colours, please refer to the web version of this article.)

accounting for idiosyncratic differences across respondents by estimating a latent class model leads to a more precise understanding of their preferences. We find that close to 80% of our respondents clearly prefer forest management geared to the reduction of avalanche and rock fall risks for households and traffic infrastructure. The remaining 20%, however, show a clear preference for the status quo and no interest in improved forest management.

The varying extent to which the estimated models account for differences across decision makers directly affects the estimated WTP. The basic MNL model, which ignores heterogeneity, suggests that households have a WTP of CHF 657 (± 174) for forest management that leads to negligible avalanche and rock fall risks. Once sociodemographic characteristics of the respondents are incorporated the WTP amounts to CHF 720 (± 493). The latent class model adds further granularity to the results and reveals two groups of respondents not captured by the MNL models. While the WTP for Class 1 respondents is largely in line with those from the MNL models, the WTP for Class 2 respondents is significantly higher, i.e., CHF 3,709 (± 946) for forest management that leads to negligible avalanche and rock fall risks. Furthermore, there is one group of respondents, i.e., Class 3, who have a significant negative WTP of CHF -165 (± 42) for contributing to such measures (Fig. 6).

Generally, the positive WTP estimates for the attribute levels of the hazard zone and for extending protection to traffic infrastructure suggest that our respondents attribute a positive monetary value to the risk reduction by improved forest management. Within the theoretical framework presented in section 2 these results can be interpreted as evidence that our respondents assign an insurance value to forests. Particularly those who considered the experiment as realistic and who are concerned about the adverse impacts of climate change are willing to fund improved forest management. On the other hand, respondents with a low level of risk aversion, those who are satisfied with the current forest management measures and the ones who think that the responsibility for hazard protection is with the public authorities most likely disapprove better forest management. These findings are in line with the theoretical framework presented in section 2. First, respondents who considered the experiment as realistic agree that forest management measures positively affect forests' resilience and that resilient forests reduce the risk avalanche and rock fall pose to their individual wealth. Second, people who are concerned about the adverse impacts of climate change are likely to be more risk averse. Particularly at high levels of ecosystem resilience, a higher level of risk aversion increases the insurance value of ecosystems. Third, the lower the level of risk aversion the less concave the utility function depicted in Fig. 1, and the smaller the insurance value of ecosystem services. For complete risk aversion the insurance value is zero (Baumgärtner and Strunz, 2014).

When it comes to realizing the potential WTP revealed by this study, however, it is fair to ask how the different estimates should be dealt with. Generally, we are convinced that it is beneficial to have more granular insights. At the same time, we want to exercise caution regarding the sole reliance on the high WTP measures estimated for class 2 respondents in the latent class model. We suggest to rather focus on the range indicated by the different models, while keeping in mind that a significant share of respondents has a relatively high WTP. For forest management that leads to negligible avalanche and rock fall risk, this implies a WTP of around CHF 660 (± 170) per year and household. Dependent on the way these additional charges are levied, some even have a WTP of around CHF 3,700 (± 950). Moreover, given the public-good character, it is interesting to know why a group of respondents is currently unwilling to contribute. Here, we suggest to look at the sociodemographic characteristics that affect the class allocation probability (Table 4). While it may be hard to directly influence households' risk aversion, targeted information campaigns about the impacts of climate change and the health of forests as well as about the financial burden caused by natural hazards are feasible low-cost ways to promote the insurance value of ecosystem services.

Generally, WTP estimates for non-market goods are context and location specific (Rogers et al., 2019). However, we can relate our results to a few non-market evaluation studies that look at the nexus of ecosystem services and natural hazards. In a meta study, Brander et al. (2013) compiled WTP estimates for three regulating services provided by wetlands, i.e., flood control, water supply and nutrient recycling. The reported mean (median) WTP are USD 6,923 (427)/ha/year for flood control, USD 3,389 (57)/ha/year for water supply, and USD 5,788 (243)/ha/year for nutrient recycling. Petrolia et al. (2014) estimated the WTP of households across the USA for coastal restoration programs to reduce storm surge risk in Louisiana. To increase the number of households protected from storm surge, respondents were willing to make a single payment of USD 151 to increase the protection level to 50% of the households. Olschewski (2013) analyzed the WTP for structural avalanche protection in the Swiss municipality of Andermatt. He found that households would be willing to make a one-time payment between USD 400 and USD 450.

The reasons for differences in WTP estimates are manifold. The magnitude of our results can be attributed to the following study-specific factors. First, in determining the levels for the additional charge per household we were guided by the annual average premium of the cantonal building insurance of Grisons. For an average building with a value of CHF 700,000, it ranges between CHF 200 and CHF 340. For buildings located in hazard zones, additional premia between CHF 210 and 630 apply. Second, the magnitude of the possible changes and thus the prospective hazard risk reduction presented in our scenario is substantial but simultaneously allows us to cover the whole risk spectrum (from high risk to nearly risk free). Third, Swiss households have a relatively high income, providing financial leeway for additional expenses (please see section 3.3). Fourth, when estimating the WTP for improving an ecosystem service that enhances hazard protection it is difficult to isolate this effect from its further positive impacts on the ecosystem (Rogers et al., 2019). While we strived to clearly focus on forests' protection function, we cannot preclude that for some respondents the improved forest management is valuable beyond hazard protection (e.g., for recreational or aesthetical reasons).

It is important to note that choice experiments are usually based on hypothetical scenarios, as the one presented in our case study. Thus, CE are prone to hypothetical bias, which should be minimized. In our case, there are currently no official payment schemes in place that directly transfer payments from private households to forest owners to induce them to manage their forests in a way that improves its protection service. Nevertheless, to enhance the validity and the reliability of our estimates we followed the Contemporary Guidance for Stated Preference Studies by Johnston et al. (2017) in every step, from survey design to model estimation.

6. Conclusions

Our analysis shows that the majority of households in our study regions appreciates the insurance service provided by forests against gravitational natural hazards. The preferences and WTP estimates we elicited by means of a discrete choice study indicate that they assign a substantial insurance value to their protection forests. These estimates can be considered a first step towards operationalizing the insurance value of forest ecosystems at the regional level. They show that -on the demand side- the requirements for implementing payment schemes geared towards operationalizing the insurance value of forests are largely met.

To operationalize and mainstream the insurance value concept in ecosystem management and restoration the rights and obligations of ecosystem service users and providers need to be clearly defined and transaction costs have to be low. Generally, any new governance mechanism should interact with the existing institutional framework (Olschewski et al., 2018). No matter how the governance of insurance service provision eventually is organized (e.g., private to private payment, regulation and liability rules), WTP estimates provide an important basis for a better-informed decisionmaking (Dallimer et al., 2020; Paavola and Primmer, 2019).

Policy makers (and insurance companies) can draw important insights from our results: (i) there is a substantial WTP for reducing risks of natural hazards (beyond current legal requirements); (ii) no one-size-fits-all insurance approach is feasible since preferences and WTP estimates differ among respondents and classes; and (iii) if synced with forest-management and hazard-modelling components, science-based and practice-relevant solutions for the management of natural hazards can be developed.

Based on the results of our study we see the following main direction for future research. First, it is vital to understand why households are currently unwilling to contribute to the payment scheme and how they can be incentivized to chip in. Second, the way the annual additional charges are eventually levied needs to consider the diverging preferences of those willing to contribute. Third, on the supply side, the forest owners have to agree with the scheme. Forest management aimed to improve the protection against natural hazards is not necessarily in the (self-)interest of forest owners who rather focus on generating revenues by producing timber as a private good. Thus, contract design issues, such as contract length, the extent of required management changes and efficient ways of monitoring as well as liability aspects need to be discussed and assessed from both the supply and demand perspective. As to that, another open question is how many forest owners need to be included in the scheme to actually improve protection levels, and how many potential demanders need to join the scheme to have a pool of insured households big enough to spread the risk effectively. Once these issues are resolved, the insurance value of forests can better be integrated into nature-based climate change adaptation and disaster risk management.

Declaration of Competing Interest

None.

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Appendix A. Appendix

A.1. Full results for the MNL estimation including sociodemographic characteristics of the respondents

Table A1
Full results for the MNL estimation including sociodemographic characteristic of the respondents. Robust standard errors clustered at the level of respondents are given in brackets. For the base levels of the dummy coded variable a coefficient of 0 is reported. The asterisks show the significance level where * indicates $p < 0.1$, ** indicates $p < 0.05$ and *** indicates $p < 0.01$.

(*continued on next page*)

Table A1 (*continued*)

			(1) MNL Basic	(2) MNL incl. Socio-demographics
Hazard zone	***White***		1.28***	1.12***
			(0.093)	(0.341)
		Canton of Valais		−0.62***
				(0.221)
		Low level of risk aversion		−0.36*
				(0.200)
		Children		0.30
				(0.233)
		Gender		−0.22
				(0.212)
		Property owner		0.41**
				(0.206)
		Second home		0.63***
				(0.218)
		Live in red zone		0.16
				(0.444)
		Low income (< CHF 5000 per month)		−0.59**
				(0.269)
		High income (> CHF 13,000 per month)		0.15
				(0.282)
		Elderly (> 60 years)		−0.29
				(0.242)
		Young (< 30 years)		0.57
				(0.361)
		Satisfied with current forest management measures		−0.48**
				(0.196)
		Climate change negatively affects forests		0.59***
				(0.226)
		Public authorities are responsible for hazard protection		−0.72***
				(0.199)
		Concerned about climate change impacts		0.16
				(0.215)
		Realistic experiment		0.82***
				(0.207)
	Blue		1.15***	0.94***
			(0.089)	(0.330)
		Canton of Valais		−0.47**
				(0.217)
		Low level of risk aversion		−0.29
				(0.196)
		Children		0.31
				(0.229)
		Gender		−0.34*
				(0.203)
		Property owner		0.40**
				(0.203)
		Second home		0.49**
				(0.209)
		Live in red zone		0.01
				(0.415
		Low income (< CHF 5000 per month)		−0.48*
				(0.265)
		High income (> CHF 13.000 per month)		0.165
				(0.274)
		Elderly (> 60 years)		−0.16
				(0.234)
		Young (< 30 years)		0.39
				(0.353)
		Satisfied with current forest management measures		−0.49***
				(0.189)
		Climate change negatively affects forests		0.76***
				(0.218)
		Public authorities are responsible for hazard protection		−0.72***
				(0.195)
		Concerned about climate change impacts		0.14
				(0.209)
		Realistic experiment		0.73***
				(0.202)
	Red		0	0

(*continued on next page*)

Table A1 (*continued*)

		(1) MNL Basic	(2) MNL incl. Socio-demographics
Protection extended to traffic infrastructure	***Yes***	0.51***	0.29**
		(0.038)	(0.147)
	Canton of Valais		0.25**
			(0.102)
	Low level of risk aversion		−0.13
			(0.080)
	Children		0.19**
			(0.093)
	Gender		−0.22**
			(0.095)
	Property owner		0.09
			(0.092)
	Second home		0.11
			(0.088)
	Live in red zone		−0.18
			(0.139)
	Low income (< CHF 5000 per month)		−0.13
			(0.114)
	High income (> CHF 13,000 per month)		−0.13
			(0.098)
	Elderly (> 60 years)		0.31***
			(0.104)
	Young (< 30 years)		−0.17
			(0.127)
	Satisfied with current forest management measures		−0.03
			(0.079)
	Climate change negatively affects forests		0.05
			(0.095)
	Public authorities are responsible for hazard protection		−0.10
			(0.086)
	Concerned about climate change impacts		0.26***
			(0.088)
	Realistic experiment		0.11
			(0.078)
	No	0	0
Costing mode	***Risk based***	0.09***	0.33***
		(0.029)	(0.130)
	Canton of Valais		−0.08
			(0.073)
	Low level of risk aversion		0.01
			(0.062)
	Children		−0.03
			(0.072)
	Gender		−0.01
			(0.069)
	Property owner		0.05
			(0.071)
	Second home		−0.22***
			(0.063)
	Live in red zone		−0.39***
			(0.146)
	Low income (< CHF 5000 per month)		−0.04
			(0.093)
	High income (> CHF 13.000 per month)		−0.002
			(0.079)
	Elderly (> 60 years)		−0.11
			(0.075)
	Young (< 30 years)		−0.07
			(0.132)
	Satisfied with current forest management measures		0.11*
			(0.059)
	Climate change negatively affects forests		−0.05
			(0.082)
	Public authorities are responsible for hazard protection		−0.01
			(0.070)
	Concerned about climate change impacts		−0.12
			(0.079)
	Realistic experiment		−0.06
			(0.061)
	Lump sum	0	0

(*continued on next page*)

Table A1 (*continued*)

		(1) MNL Basic	(2) MNL incl. Socio-demographics
Contribution mode	***Voluntary***	0.09***	0.004
		(0.045)	(0.165)
	Canton of Valais		0.31***
			(0.106)
	Low level of risk aversion		−0.06
			(0.100)
	Children		0.21*
			(0.109)
	Gender		0.16
			(0.104)
	Property owner		−0.21**
			(0.104)
	Second home		−0.25**
			(0.103)
	Live in red zone		−0.04
			(0.156)
	Low income (< CHF 5000 per month)		0.24
			(0.155)
	High income (> CHF 13,000 per month)		−0.15
			(0.129)
	Elderly (> 60 years)		0.21*
			(0.125)
	Young (< 30 years)		0.24
			(0.211)
	Satisfied with current forest management measures		0.15
			(0.093)
	Climate change negatively affects forests		−0.12
			(0.121)
	Public authorities are responsible for hazard protection		0.27***
			(0.105)
	Concerned about climate change impacts		0.11
			(0.113)
	Realistic experiment		−0.24**
			(0.095)
	Obligatory	0	0
Additional annual charge per household	***Charge***	−0.002***	−0.002***
		(0.0001)	(0.0001)
	Cost income elasticity	−0.32***	−0.09
		(0.109)	(0.09)
	Missing income	0.1218	0.01
		(0.11)	(0.063)
Number of individuals		*587*	*587*
LL (final)		*−6494.93*	*−6057.605*
Adj. Rho-square		*0.159*	*0.206*
AIC		*13,005.8*	*12,291.21*
BIC		*13,060.7*	*12,894.88*
Estimated parameters		*8*	*94*

A.2. Numeric example for the framework introduced in section 2

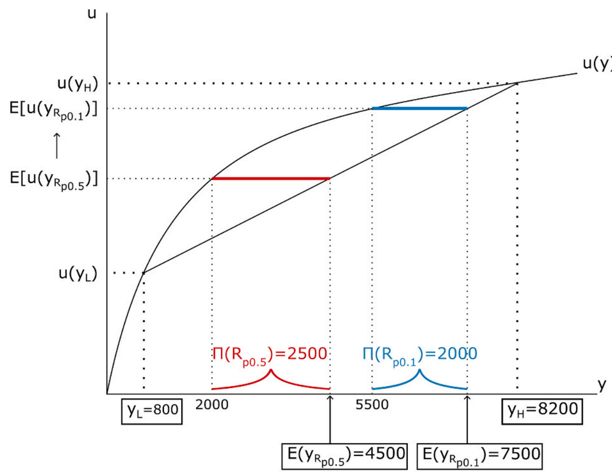

Fig. A2. Numeric example for the framework introduced in section 2. (For interpretating the colours in this figure, please refer to Fig. 1 or the web version of this article.)

Fig. A2 shows a numeric example for the framework introduced in section 2. Income in the high ecosystem provisioning state y_H amounts to CHF 8,200, while in the low provisioning state income y_L is CHF 800. When there is a 50% chance of a flip from the high to the low provisioning state, i.e., $p = 0.5$, the expected income $E(y_{Rp0.5})$ amounts to CHF 4500. The risk premium $\Pi(R_{p0.5})$ is indicated by the red line and shows the maximum amount the ecosystem user is willing to pay to avoid an adverse variation in income and to instead receive the expected income $E(y_{Rp0.5})$ for sure. It amounts to CHF 2,500. Improved ecosystem management now increases the resilience by lowering the flip probability from $p = 0.5$ to $p = 0.1$. Expected income $E(y_{Rp0.1})$ increases to CHF 7,500 and the risk premium $\Pi(R_{p0.1})$ is now CHF 2,000 (blue line). The insurance value is given by the change in the risk premium due to a change in the level of resilience $\Pi(R_{p0.5}) - \Pi(R_{p0.1})$. For the numeric example shown in Fig. A2 this amounts to CHF 500.

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