J. For. Res. (2022) 33:553–564
https://doi.org/10.1007/s11676-021-01371-3

ORIGINAL PAPER

Diverging rationalities between forest fire management services and the general public after the 21st-century mega-fires in Greece

Andreas Y. Troumbis[1] · Kostas Kalabokidis[2] · Palaiologos Palaiologou[2]

Received: 30 April 2021 / Accepted: 15 June 2021 / Published online: 5 July 2021

Abstract Wildfire risk related to hazards on people and assets is expected to increase in the face of climate change, especially in fire-prone environments such as the Mediterranean Basin. Distinguishing rationalities, i.e., the complex profile of multi-thematic, wildfire-related perceptions that collectively characterize and quantify all of a society's responses, its interrelations, and influence on its insights, are of primary importance to understand the degree of preparedness and the direction that wildfire management policies are moving. Greece is a country that suffered mega-wildfire events during the first years of the twenty-first century. This paper presents a scheme of advanced multivariate statistical procedures applied on standard social survey questionnaires to uncover different or similar rationalities between fire management services and the general public. Profession-centered versus message-oriented rationalities is defined. They differ mainly on the priorities attributed to strengthening personnel and equipment capacities versus the need for public education and awareness. Both are evaluated against the needs of long-term risk assessment and forest management policies in Greece. The main conclusion is that Greek society, although traumatized by recent fire disasters, is not yet prepared for long-term strategic forestry adaptation and planning.

The online version is available at http://www.springerlink.com

Corresponding editor: Yu Lei

✉ Andreas Y. Troumbis
atro@aegean.gr

[1] Department of Environment, University of the Aegean, 81100 Mytilene, Lesvos Island, Greece

[2] Department of Geography, University of the Aegean, 81100 Mytilene, Lesvos Island, Greece

Keywords Wildfire · Qualitative research · Rationality · Fire governance · Public · Perception · Risk assessment

Introduction

Wildfires are randomly determined but recurrent biophysical events of most terrestrial ecosystems in Earth's natural history, as accumulated paleo-fire records and developing research prove (Rius et al. 2012; Leys et al. 2016; Marlon 2020). As an integral part of most ecosystems functioning and development, wildfire multi-scale events materialize combinations of physical, anthropogenic, and social-ecological drivers varying or evolving in time and space, which cause a flame to become a large fire plume. Particular sets of drivers determine different aspects of wildfire events. For instance, combined oxygen, heat, and fuel determine fire as a *physical phenomenon* (e.g., Bakhshaii and Johnson 2019). Variations in vegetation, climate, topography, and human activities determine *fire regime* in the sense of location, timing or seasonality and frequency of fire, the typical size of the fire, and its severity in terms of the amount of biomass burned (Archibald et al. 2013). Social-ecological, exogenous or endogenous drivers which describe patterns of modernization (Buizer and Kurz 2016), globalization (Ruane et al. 2018) and transitions (Oliveira et al. 2017), such as demography, agriculture, forestry, husbandry and food production systems, land-use change, monetary value and real estate pressures, and institutional framework influence *fire risk* and *hazard* aspects (Hardy 2005).

One might attempt an extended suite of verisimilar generalizations and predictions based on the abundant literature (> 6000 papers listed in the Web of Knowledge/Science) relevant to the above aspects of fire, i.e., the physical phenomenon, geo-history and ecology, fire regime, and fire risks

and hazards. Anthropogenic fire causes and drivers became preponderant following cultural transformations towards the modern and post-modern world. Fire regimes, risks and hazards are inherently connected to global change, i.e., climate and land-use change, alteration of the physicochemical quality of the environment, and biodiversity erosion (Poljansek et al. 2019). As far as climate change is concerned, wildfires are both causes of carbon emissions and imbalances in carbon sink-source ratios (sequestered quantities as biomass and soil organic matter) (Loehman RA 2020). Further, climatic transitions in fire-prone biomes, such as the Mediterranean Basin, towards fire-facilitating conditions are systematically predicted under several climate scenarios (Moss et al. 2010). Increment in temperature, increase in fuel dryness and reduction of rainfall and relative humidity, increase in extreme climatic events causing prolonged droughts and hot spells, are expected to substantially impact fire risk, severity, and burned area (Moriondo et al. 2006). Overall, climate change projections suggest an increase in days conducive to extreme wildfire events by 20 to 50% in these disaster-prone landscapes (Marlon 2020; Tedim et al. 2020). The physical phenomenon is gradually transformed into a social, administrative and organizational complex challenge that requires a Coupled Human and Natural Systems (CHANS)-based risk framework (Kline et al. 2017; Shindler et al. 2017), i.e., the joint assessment of biophysical risk and adaptive capacity feedbacks that affect the potential for effective mitigation in large spatial, temporal and social scales.

The issue of rationalities, in the sense of Douglas (1994), i.e., the complex profile of multi-thematic wildfire-related perceptions that collectively characterize and quantify all of a societal group's responses, their interrelations and influence its perceptions identity (Troumbis and Hatziantoniou 2018) is of primary importance to understanding how social institutions evaluate wildfire disturbances in their multiple aspects. In this context, it is essential to uncover diverging rationalities between the general public and wildfire-related professionals (firefighters, forest managers, practitioners, civil-protection agents). In the era of participatory decision-making in environmental issues, co- and adaptive-management (St-Laurent et al. 2018), uncovering divergences versus convergences in rationalities between fire and forest service members and the general public (St-Laurent et al. 2019) regarding wildfire impacts upon the environment, biodiversity and production infrastructures and capital is of strategic important information on societal response to global change. In this direction, IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) adopted a conceptual framework integrating into a circular explanatory scheme various components of human-nature relationships (Díaz et al. 2015; IPBES 2019) where the previous issues acquire particular importance. Further, Pascual et al. (2017) thoroughly analyzed the significance of various aspects of human values on these issues as attitudes, behavior, preferences or value-measurement might systematically differ.

Fire in Greek civilization is a foundational concept that became ecumenical after *Prometheus'* myth of human freedom and knowledge. Greece is a Mediterranean territory badly affected by wildfires and poor management of its forest capital since ancient times, as referred to in the works of Homer, Plato, Heraclitus, and Anaximenes (Sallares 1991). The modern data time series on wildfire events in Greece goes back to 1955 (see Methods section).Currently, one can find Greek annual wildfire reports in the European Forest Fire Information System (EFFIS 2020) and the official records of the Hellenic Fire Service from 2000 onwards (Hellenic Republic 2020). However, during the last 15 years, the mega-fires of 2007 and a single small-scale crown fire during 2018 (1400 ha burned) with human casualties caused *trauma* in Greek society (Mellon et al. 2009) and among firefighters in particular (Psarros et al. 2018). The 2018 wildfire affected the community of Mati, east of Athens, and caused 102 fatalities (Goldammer et al. 2019), making it the second-deadliest wildfire event worldwide since 2001 (the first being the 2009 Black Saturday bushfires in Australia that killed 180 people).

At the European Union level (EU), repeated Eurobarometer surveys (especially after 1992) focus on Europeans' attitudes towards biodiversity (European Commission 2019a) and climate change (European Commission 2019b), but wildfires per se are not included, either as a cause or as an effect as a result of both these planetary level change phenomena. However, EU cross-countries and regional culture variations in attitudes towards biodiversity still exist (Troumbis 2021). Palaiologou et al. (2021b) published a systematic description of a sample of Greek citizens' attitudes towards forest fires, revealing interesting variations between socio-demographic groups. In this study, we revisit the original Palaiologou et al. (2021b) survey with the explicit goal to apply advanced multivariate statistics to determine whether fire management agencies that include the Hellenic Fire Service and Forest Service (both FS henceforth) have adopted systematic rationality regarding forest fire effects differing from the general public one. If a reality, such a condition should be considered pivotal in planning mitigation versus adaptation policies for Greek forests under climate change conditions (Kalabokidis et al. 2002, 2015) and promote efficient public engagement. We ask three questions, all tested with advanced multivariate statistical analysis: (1) Can we deduce fire management agency tenure after socio-demographic descriptors?, (2) Can we uncover diverging rationalities between fire management agents and the general public using multinomial logistic regression on averaged Likert data?, and, (3) Can we distinguish diverging rationalities through factor analysis, weighted multinomial regressions and receiver operating characteristic (ROC) classification?

Materials and methods

To understand the perceptions and assess the FS agents' and the general public's rationalities regarding wildfires in Greece, a multi-leveled survey and multi-thematic questionnaire were created to collect empirical data (Palaiologou et al. 2021b). The questionnaire was designed to be as short but inclusive as possible, straightforward, easy to understand, cover the relevant dimensions of wildfire-related rationalities, and understand key aspects of what is considered important regarding wildfire effects. It was administered to a sample of approximately 300 potential respondents (both by personal emails and through a web-based qualtrics questionnaire), interested or related in some way to wildfire phenomena. Respondents were located throughout Greece, i.e., the 13 Regions and all their subordinate territorial Administrative Prefectures and Forestry Offices. The sampling procedure was non-probabilistic and convenient, and participants were not compensated. The response rate was approximately 30%, with 111 responses, of which 106 had no missing data (see Palaiologou et al. 2021b, Table 2 for job classification of respondents). The error margin due to sampling size at 95% confidence interval, is ± 3.5%. The overall survey included 22 themes, eight with multi-thematic Likert scaled (1–5) sub-questionnaires, eight socio-demographic descriptors or questions, and the rest were multiple choice non-ranked or ordered questions. For a complete description of the questionnaire and descriptive analysis of data, refer to Palaiologou et al. (2021b).

The original survey data set was re-organized along three axes. The first axis was mono-thematic and treated as the dependent variable (DV) in most statistical procedures. According to their declared Job Type (Forest or Fire Service), we classified individual participants into a binary categorical variable [0, 1] as agents or members of the FS category versus all others considered general public. The general public category included individuals interested in forest fire issues but not actively involved in forest fire suppression or prevention.

The second axis was comprised of six socio-demographic descriptors per participant, gender, age, employment status, and personal engagement in fire events. Therefore, they were treated as independent variables (IV) in some statistical procedures.

The third axis refers to domains or areas of concern such as various classes of fire effects, e.g., environmental, economic, psychological. Also, it included interpretation of causes and drivers of a fire at regional versus a national scale, and forest management and policy issues, e.g., the use of prescribed burning as a fuel reduction method or potential governance re-organization or legislation changes.

Each of these domains or areas of concern was multi-thematic and scrutinized through specific questionnaires developed in a Likert format in most cases. The 5-point Likert scale was formulated in different linguistic forms or even inversed rationally in some instances to avoid biased responses. Table 1 presents a summary of the structure of the survey.

Since our goal was the verification of significant differences in rationality and perception archetypes between FS and the general public regarding the multiple aspects of fire effects, causes, risks and prospective fire management policies, the statistical strategy adopted follows a multiple-stage procedure, examining, through different lenses, issues and thematic discontinuities in the surveyed sample. The first stage used binary logistic regression to estimate an individual's probability of belonging to the reference category FS, after its independent socio-demographic characteristics. The second stage used a series of multinomial cumulative-linked generalized linear models for domains or areas of concern. In this case, Job Type class, i.e., FS versus GP (general public), was an independent variable, and the mean value across Likert-scaled answered questionnaires per domain, area of concern, or non-ordered answers for the rest are dependent variables. Predicted probabilities were used after this model to classify individuals.

For the third stage, given the ambivalent preliminary results after the second stage, exploratory factor analysis (EFA) was used to reduce the large set of questions into some factors or sub-dimensions (components). This stage was crucial in this survey since most of the domains or areas of concern are addressed through Likert-scale measured multiple questions per issue. Further, the qualitative constitution of components per issue might indirectly indicate differences between FS and the general public. Technically, we used direct oblimin rotations for factor analysis for the various individual Likert items. Factors were extracted until the eigenvalue fell below 1 and a minimum loading of 0.40 used to allocate an item into different components. Indices were then created for use in a new set of regression analyses (second stage) by weighting each statement's score loaded on each factor (component).

The fourth stage utilized a ROC curve analysis to classify individuals into the reference category FS versus general public, i.e., to search the sensitivity versus specificity of the binary logistic model (first stage) predicted probabilities and the significance of the area under the curve (AUC) as a metric of the deviance from the null hypothesis (AUC = 0.5; indicating no-difference between FS and GP categories). ROC curve analysis was also used as a classification method for differences between the FS and GP categories for the various domains or areas of concern. For the fifth stage, multiple variables snowflakes (or spider-graphs) were constructed with the following procedure: questions and their constituent items that presented the highest and lowest ROC classification performance (fourth stage) were identified for both FS

Table 1 Summary description of independent and dependent variables used in the various statistical procedures: PCA/factor analysis, binary logistic regressions, and ROC classifications. According to the method used, variables of a specific domain or area of concern were treated either as independent variables (IV) or dependent variables (DV)

Name[a]	Variable	Type	Description
Job class	DV	Categorical	Dummy variable (0,1) for FS versus GP; FS is the reference category (= 1)
Socio-demographic descriptors			
Gender (Q3.5)	IV	Nominal	Two categories, male and female; Female is the reference category (= 1)
Age (Q3.3)	IV	Scaled classes	Six categories of 10-year each, ascending order, from 18–24 to 65–74
Education (Q3.4)	IV	Ordinal	Six categories ascending, from high-school to doctorate
Employment status (Q3.1)	IV	Ordinal	Seven categories, inactive to a full-time employee, non-ranked/ordered
Experience type (Q2.5)	IV	Ordinal	Five categories, non-ranked/ordered
Personal involvement in fire events (Q2.3)	IV	Scaled classes	Six categories ascending, from 0 to > 10
Domain/area of concern			
Environmental impacts			
Conservation-related effects (Q1.5)	IV or DV	Components (continuous)	Eight categories, non-ranked, each Likert-scale rated (FA, DO)
Aesthetic-related effects (R) (Q1.6)		Components (continuous)	Five categories, non-ranked, each Likert-scale rated (FA, DO)
Economic impacts			
Infrastructure damages (R) (Q1.9)	IV or DV	Components (continuous)	Eleven categories, non-ranked, each Likert-scale rated (FA, DO)
Economic losses (R) (Q1.10)		Components (continuous)	Eight categories, non-ranked, each Likert-scale rated (FA, DO)
Psychological impacts			
Human casualties/fatalities (Q1.7)	IV or DV	Components (continuous)	Three categories, non-ranked, each Likert-scale rated (FA, DO)
Infrastructure damages (Q1.8)		Components (continuous)	Two categories, non-ranked, each Likert-scale rated (FA, DO)
Interpretation of causes/drivers			
Regional level fires (Q1.2)	IV or DV	Ordinal	10 categories, non-ranked/ordered
National level fires (Q1.3)		Ordinal	10 categories, non-ranked/ordered
Post-fire reduction of vegetation recovery (Q1.4)		Components (continuous)	10 categories, non-ranked, each Likert-scale rated (FA, DO)
Forest management practices			
Complexity of fire suppression (Q1.11)	IV or DV	Ordinal	Eight categories, non-ranked/ordered
Use of prescribed fire for fuel reduction (Q2.1)		Components (continuous)	Seven categories, non-ranked, each Likert-scale rated (FA, DO)
Policies to be adopted			
Perceptions of wildfire (Q2.2)	IV or DV	Ordinal	Seven categories, non-ranked/ordered
Targeted priorities (Q2.4)		Ordinal	10 categories, non-ranked/ordered

[a]#Q: code number of questions presented and analyzed

R: Regional; FS: Forest or Fire Service; GP: General Public; FA: Factor Analysis; DO: Direct Oblimin

and GP categories. Categorical differences between items per selected question were then calculated and arranged in snowflake diagrams (or spider-graphs). Finally, for the sixth stage, we applied an independent-pairs *t*-test on data concerning preferences of the FS and GP categories for priority policies to be adopted to face wildfire hazards.

All statistical procedures were performed on IBM SPSS statistics software, v.26 (Darren and Mallery 2019). Significance levels, threshold values for particular tests follow standards provided in reference texts (Field 2013; Pituch and Stevens 2016). Calculations for the fifth stage were performed on Excel spreadsheets.

Results

Deducing fire management agency tenure after socio-demographic descriptors

The combined binary logistic regression and ROC curve classification of six socio-demographic descriptors (Table 1) is presented in Fig. 1. One hundred and six participants (95.5% of the sample of 111 individuals) were included in the procedure. The five excluded individuals were those with missing values in one or more descriptors. Omnibus tests of binary logistic model coefficients were significant at $p = 0.000$; the Hosmer and Lemeshow test achieved a value of 0.998 (df = 7), indicating significance of the goodness-of-fit of the model; the constant of the model equaled − 0.707, significant at $p = 0.001$; the percentage of correct prediction of classification of individuals in the two categories (FS vs. GP) was 92.5%. ROC curve classification (reference category FS) applied upon binary logistic predicted probabilities gave an AUC sensitivity versus (1-specificity) value = 0.872; this value was highly significant at $p = 0.001$. The overall model quality value was 0.81, much higher than the value 0.5 that indicates that a model is no better than a random one. Therefore, FS agents' socio-demography is significantly divergent from the general public.

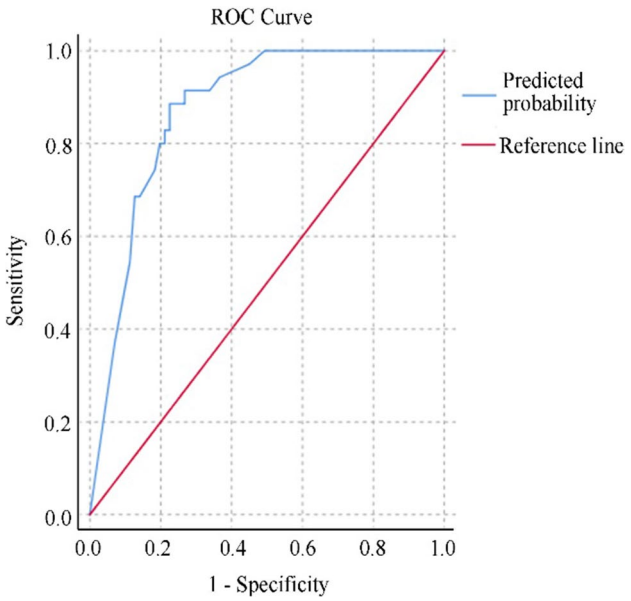


Fig. 1 ROC sensitivity versus (1-specificity) classification curve (blue line) of binary logistic regression predicted probability for FS tenure after socio-demographic descriptors. AUC value = 0.872, significantly differing from the reference line (red line) corresponding to AUC value = 0.5

Multinomial logistic regression on averaged Likert data to uncover diverging rationalities

This sub-section focuses primarily on the technical aspects or interpretational limitations of multinomial logistic regression on Likert-scaled and/or non-ranked/ordered ordinal questionnaires. There are examples in the literature where the mean (or sum) of Likert-scale values across a series of questions per theme or item is used as an "indicator" or a "scale score" generation procedure upon which multinomial or binary regression is applied. The predicted probabilities are estimated to draw inferences, mainly when dichotomies or cut-off discontinuities are investigated (Sullivan and Artino 2013). Indicatively, such approaches assume that there is no clear distinction between self-reported motivations, satisfaction, security feeling and so on; further, they assume that the question order has no impact on self-reported states of mind.

Indicative results of this procedure applied in our case are presented cautiously to explore the kind of information one could expect in similar issues. Table 2 summarizes the results of Question Q1.4 "Post-fire reduction of vegetation recovery" which consists of 10 different 5-point Likert-scale items, answered by one hundred eleven participants (no missing data). The generic question as presented to participants was as follows: "Based on your experience and knowledge, please rate the effect of the following negative factors on reducing the regeneration and vegetation recovery potential after a wildfire, for the prefecture of Greece where you reside for longer". Non-parametric tests procedure on one-sample Kolmogorov–Smirnov test (K–S), means and standard deviation (SD) of Likert-scale responses per item are presented (Table 2). The null hypotheses were that the mean value of Likert-scale responses is randomly distributed and that responses per item are not correlated (Table 3). These are the prerequisites for distinguishing divergences between the two compared categories.

Figure 2 presents the ordination of 5-point Likert scale individual responses (n = 111) on the 10 items in a two-dimensional plane constructed after the mean response value across the items (y-axis), and the difference between this value and the corresponding predicted probability by multinomial logistic regression (x-axis). Again, individuals are distinguished graphically according to FS versus GP tenures. As expected, individual responses were arranged around the mean Likert-scale value; a notable finding from this ordination was that mean Likert values were predominantly negative, meaning that the predicted probabilities were lower in most individual cases.

The combination of results presented in Tables 2 and 3 and Fig. 2 reject the null hypotheses. Data were normally and non-randomly distributed (Kolmogorov–Smirnov test; mean/variance comparison significantly different

Table 2 Indicative example and summary statistics for the null hypotheses of randomly distributed 5-point Likert-scale responses. Ten items composed the list of factors; K-S test: one-sample Kolmogorov–Smirnov test

Item code	Item question	Mean ± SD /item	Overall mean ± SD	K-S test	Mean/Variance comparison
Q1.4.1	Post-fire grazing	3.45 ± 1.28	3.26 ± 0.57	0.096	3.26/0.331 (=9.85)
Q1.4.2	Burned vegetation at non-reproductive age	3.45 ± 1.03		2-tailed asymptotic significance:	
Q1.4.3	Steep burned slopes	3.52 ± 1.01		0.013	
Q1.4.4	Poor quality and shallow soil type	3.28 ± 1.04			
Q1.4.5	Illegal activities on burned areas	3.66 ± 1.11			
Q1.4.6	Smoldering effect during wildfire	3.05 ± 1.02			
Q1.4.7	Recent fire activity inside the affected area	3.6 ± 1.18			
Q1.4.8	Urban/tourism pressure on burned areas	3.29 ± 1.21			
Q1.4.9	Threats from insects or pathogens	2.50 ± 0.88			
Q1.4.10	Absence of unburned enclaves	2.87 ± 1.06			

Table 3 Correlations among the 10 different 5-point Likert-scale items for the Question Q1.4 "Post-fire reduction of vegetation recovery", answered by 111 participants

		Q1 .4 .1	Q1 .4 .2	Q1 .4 .3	Q1 .4 .4	Q1 .4 .5	Q1 .4 .6	Q1 .4 .7	Q1 .4 .8	Q1 .4 .9	Q1 .4 .10
Q1 .4 .1	Pearson Correlation	1	0.431**	0.152	0.095	−0.038	0.030	0.140	−0.200*	0.102	0.162
	Sig. (2-tailed)		0.000	0.111	0.321	0.695	0.757	0.143	0.035	0.285	0.090
Q1 .4 .2	Pearson Correlation	0.431**	1	0.340**	0.200*	0.075	0.174	0.318**	0.111	0.242*	0.244*
	Sig. (2-tailed)	0.000		0.000	0.036	0.433	0.068	0.001	0.248	0.011	0.010
Q1 .4 .3	Pearson Correlation	0.152	0.340**	1	0.477**	−0.025	0.130	0.361**	0.054	0.301**	0.415**
	Sig. (2-tailed)	0.111	0.000		0.000	0.791	0.175	0.000	0.577	0.001	0.000
Q1 .4 .4	Pearson Correlation	0.095	0.200*	0.477**	1	0.130	0.189*	0.321**	0.000	0.338**	0.326**
	Sig. (2-tailed)	0.321	0.036	0.000		0.173	0.047	0.001	0.996	0.000	0.000
Q1 .4 .5	Pearson Correlation	−0.038	0.075	-0.025	0.130	1	0.160	0.234*	0.485**	0.057	0.017
	Sig. (2-tailed)	0.695	0.433	0.791	0.173		0.092	0.013	0.000	0.550	0.859
Q1 .4 .6	Pearson Correlation	0.030	0.174	0.130	0.189*	0.160	1	0.522**	0.199*	0.261**	0.273**
	Sig. (2-tailed)	0.757	0.068	0.175	0.047	0.092		0.000	0.037	0.006	0.004
Q1 .4 .7	Pearson Correlation	0.140	0.318**	0.361**	0.321**	0.234*	0.522**	1	0.209*	0.233*	0.387**
	Sig. (2-tailed)	0.143	0.001	0.000	0.001	0.013	0.000		0.028	0.014	0.000
Q1 .4 .8	Pearson Correlation	−0.200*	0.111	0.054	0.000	0.485**	0.199*	0.209*	1	0.236*	0.078
	Sig. (2-tailed)	0.035	0.248	0.577	0.996	0.000	0.037	0.028		0.013	0.418
Q1 .4 .9	Pearson Correlation	0.102	0.242*	0.301**	0.338**	0.057	0.261**	0.233*	0.236*	1	0.369**
	Sig. (2-tailed)	0.285	0.011	0.001	0.000	0.550	0.006	0.014	0.013		0.000
Q1 .4 .10	Pearson Correlation	0.162	0.244*	0.415**	0.326**	0.017	0.273**	0.387**	0.078	0.369**	1
	Sig. (2-tailed)	0.090	0.010	0.000	0.000	0.859	0.004	0.000	0.418	0.000	

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

from 1), and most of the 10 items were correlated significantly in a pairwise Pearson correlation matrix (2-tailed) at $p < 0.05$ or $p < 0.01$. The same procedure was applied in all domains or areas of concern presented in Table 1, and the results were similar in all cases. Therefore, this procedure was unsuitable for distinguishing different rationalities between FS agents and the general public.

Distinguishing diverging rationalities through factor analysis, weighted multinomial regressions and ROC classification

This sub-section presents the combined statistical procedures of the third and fourth stages described in the Methods section. Figure 3, which presents the final classification

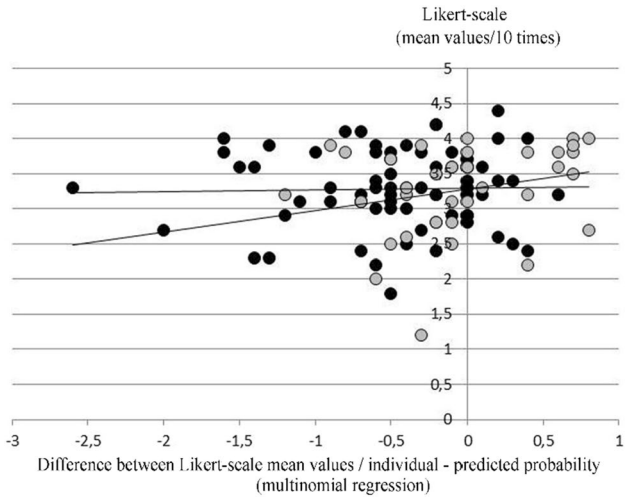


Fig. 2 Ordination (scatter plot) of 111 individual responses in a two-dimensional plane constructed after the Likert-scale mean values/10 items versus the difference between these values/individual and their multinomial regression predicted probability. Black dots: general public; black line: linear regression, slope = 0.024; $r^2 = 7 \times 10^{-4}$. Grey dots: forest management agencies; grey line: linear regression, slope = 0.3; $r^2 = 3 \times 10^{-2}$

of FS agents versus GP with ROC curves, and Table 4 that shows the exploratory factor analysis results supported the following interpretations:

First, there is an intra-FS agents' variation in the valuation of different wildfire-related domains or areas of concern. Using the AUC metric as an indicator of the importance attributed by FS agents to them, one can deduce that ROC curves are significantly different from the sensitivity versus (1-specificity) reference line (AUC = 0.5), except for the case of "psychological impacts" (Questions 1.7 and 1.8). Among those significant, it is feasible to hierarchize individual domains or areas of concern along an AUC gradient, in a sequence where negative factors of "post-fire reduction of vegetation recovery" (Question 1.4, AUC significance $p = 0.000$) are at the top, and "conservation-related effects" (Question 1.5, AUC $p = 0.043$) at the bottom.

Second, given that the general public category's respective ROC curves are inversely symmetrical to FS, the same statistical conclusions on their significance may be made. However, the AUC hierarchization gradient is also inverted. Third, the cut-offs for the various AUC values indicate the quality of the classification analysis. Within the FS agent category, the question on "post-fire reduction of vegetation recovery" receives a "good test" and the rest of the significant questions a "fair test" quality label. The "conservation-related effects" are labeled "good" tested for the GP category, and the rest are "fairly" tested.

Figure 4 presents an overall synthesis of the above results regarding divergent rationalities between FS agents and GP following the fifth stage of analysis. We compared the two categories based on their factor analysis loads/item differences in the highest versus the lowest ROC analysis performance. As shown in the previous paragraphs, these are the tandem "post-fire reduction of vegetation recovery" (Question 1.4, with eight items) and "conservation-related effects" (Question 1.5, with eight items). The snowflake diagram (or spider-graph) showed that there are indeed remarkably diverging rationalities among the two categories.

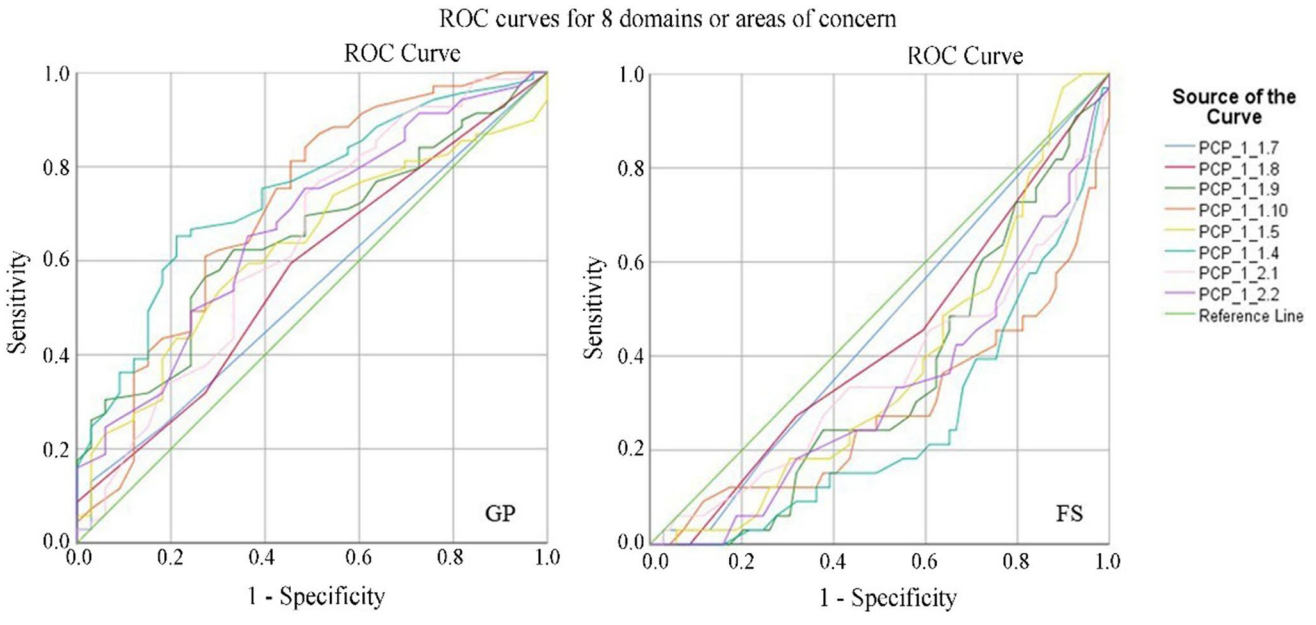
Finally, as shown in Fig. 5, the two rationality categories, FS agents and GP, significantly differ in the mixture of policies to be adopted to face wildfire hazards (Levene's test: F = 0.006; df = 104; 2-tailed *t*-test $p = 0.167$).

Discussion

The issue of public attitudes and perceptions regarding wildfire effects is an active field of qualitative research in a wide range of scientific domains from forestry (Floress et al. 2019; St-Laurent et al. 2019) and economy (Nielsen-Pincus et al. 2014; Purnomo et al. 2017) to choice theory and risk assessment (Maguire and Albright 2005; St-Laurent et al. 2018; Poljansek et al. 2019), and post-trauma psychology (Mellon et al. 2009; Psarros et al. 2018). Differences in attitudes and perceptions between societal sections and/or within the services mandated to deal with fire events, fire regimes, risks and hazards, and forest management, especially concerning planetary change processes, have also been reported (Asah et al. 2014; Rodriguez-Franco and Haan 2015; Steinführer 2015; St-Laurent et al. 2019). Although inscribed within the latter framework, our analysis addresses, for the first time to the best of our knowledge, the issue of rationalities in wildfire perceptions. We handled a complex set of typical multi-thematic wildfire-related questions to collectively characterize and quantify all of a societal group's responses, their interrelations, and influence on its perceptions identity.

The results affirm that different rationalities can be distinguished. The Forest/Fire Service agents presented a profession-centered view of the phenomenon, whereas the general public a message-oriented one. The first gave priority to job, practice, and short-term capacity building. The second group focused on longer-term environmental matters in the broad sense as they stand out in the current public sphere and discourse, e.g., biodiversity conservation and landscape transitions.

Although interesting per se, a distinction in a Mediterranean country such as Greece afflicted by wildfires, poses disturbing questions about the degree of pro-active assessment, prevention planning and preparedness in the face of increasing fire risks and climate changes. As in many countries, the Greek Civil Protection Agency releases daily fire danger assessments during the fire season (May 1–October 31),



AUC metrics for ROC curves for 8 domains or areas of concern

	GP	Asymptotic Sig.[b]	FS	Asymptotic Sig.[b]
Test Result Variable(s)	Area		Area	
PCP_1_1.7	0.539	0.522	0.461	0.522
PCP_1_1.8	0.573	0.234	0.427	0.234
PCP_1_1.9	0.651	0.014	0.349	0.014
PCP_1_1.10	0.712	0.001	0.288	0.001
PCP_1_1.5	0.624	0.043	0.376	0.043
PCP_1_1.4	0.743	0.000	0.257	0.000
PCP_1_2.1	0.640	0.023	0.360	0.023
PCP_1_2.2	0.672	0.005	0.328	0.005

Fig. 3 ROC curve classification of eight domains or areas of concern of fire management agencies (FS) versus general public (GP); summary of AUC metrics and significance per domain or area of concern are presented in the attached composite table. Correspondence between codes of sources of curves and their relative definition are presented in Table 1

based mainly on a non-systematic, qualitative and empirical assessment approach. However, fire danger assessment at a regional scale is tactical, whereas the real strategic challenge is long-term fire risk assessment. The latter includes, besides fire danger, fire vulnerability i.e., " the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards" (UNISDR 2009). The assets that are potentially susceptible to fire damage are people, especially in the wildland-urban interface, and natural assets through their intrinsic ecological value and their socio-economic monetary value (De Groot et al. 2012).

Considering the time frame during which the questionnaire ran, i.e., a decade after the acute economic crisis that heavily impacted environmental issues in Greece (Troumbis and Zevgolis 2020), it seems reasonable to assert that Greek society is not ready to envisage long-term wildfire risks and policies. Although distinct policies are characteristic of the diverging rationalities, e.g., the FS agents require more equipment and personnel or the general public emphasizes citizens' education, there is remarkable convergence on improving collaboration among fire management/suppression agencies.

The national fire management policy is suppression oriented, as described in the official general plan for fire management, "Iolaus", targeting mainly in supporting the Fire Service's work to suppress wildfires and respond to post-fire emergency conditions. As described in Palaiologou et al. (2018, 2020, 2021a), policies governing fuel management and the use of prescribed burn as a fuel treatment have seen only minor adjustments over the past 45 years. In addition,

Table 4 Exploratory factor analysis results, number of factors (components) per question and items and number of items/question classified in more than one factor (component)

Domain/area of concern		Items #	Components (Factors)	# Items in > 1 factor	KMO measure	Bartlett's test	Df/significance	Total variance explained (%)
Environmental impacts	Conservation-related effects (Q1.5)	8	1	0	0,869	684.4	28/0.000	100
	Aesthetic-related effects (Q1.6)	5	3	1				83
Economic impacts	Infrastructure damages (Q1.9)	11	3	1	0.756	593.2	55/0.000	67.9
	Economic losses (Q1.10)	8	2	0	0.762	287.5	28/0.000	59.1
Psychological impacts	Human casualties/fatalities (Q1.7)	3	1	0	0,710	177.6	3/0.000	100
	Infrastructure damages (Q1.8)	2	1	0	0.500	95.3	1/0.000	100
Interpretation of causes/drivers	Regional level fires (Q1. 2)	10	1	0	0.500	7.2	1/0.007	62.7
	National level fires (Q1.3)	10	1	0	0.500	7.2	1/0.007	62.7
	Post-fire reduction of vegetation recovery (Q1.4)	10	3	1	0.684	239.7	45/0.000	57.8
Forest management practices	Complexity of fire suppression (Q1.11)	8	2	2				65.4
	Use of prescribed fire for fuel reduction (Q2.1)	7	2	1	0.793	193.1	21/0.000	59.1
Policies to be adopted	Perceptions of wildfire (Q2.2)	7	3	2	0.467	93.9	21/0.296	53.7
	Targeted priorities (Q2.4)	10	1	0	0.500			50.2

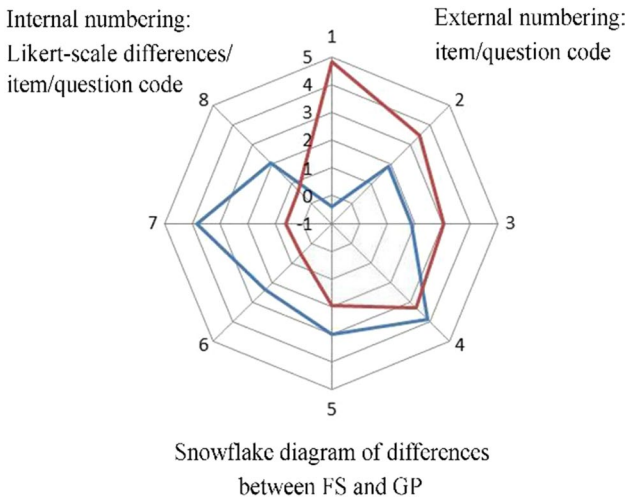


Fig. 4 Snowflake diagram of differences in factor analysis loads Likert-scale values between the highest and lowest ROC analysis model quality for the categories fire management agencies (FS—red polygon) and the general public (GP—blue polygon)

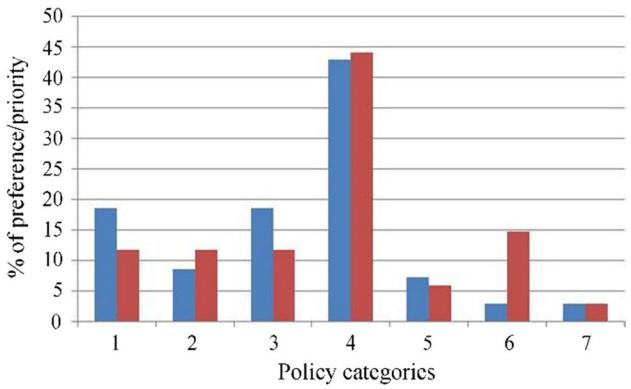


Fig. 5 Preference (%) of fire management agencies (red bar) versus the general public (blue bar) for wildfire hazard reduction. Policy categories: (1) Better education and knowledge for individuals and communities; (2) Define and map forests and properties; (3) Forest fuel reduction efforts; (4) Improvement of the collaboration among the fire management/suppression agencies; (5) Strict penalties for arsonists; (6) Buying new aerial firefighting units/Hiring more firefighters; (7) Other

the unbalanced funding of suppression activities compared to prevention results in the application of fuel management projects that are insignificant in extent and effectiveness in reducing wildfire spread and behavior. These policies fail dramatically when multiple events occur concurrently under extreme weather, and suppression resources are inadequate, especially in rugged or isolated locations. This misgovernance became evident to most fire management officials only recently.

No matter the starter, both the fire service and the general public point at the chronic pathology of misfunctioning public administration. We can speculate that people would adopt the same preference profile for many aspects of policy-making and implementation. Interestingly, it seems to be the main cause for Greece's economic default and a primary goal of administrative reform that led to the 'world-famous' Troika's *Memoranda of Understanding* for Economic Adjustment Programmes (2010–2018) between Greece and the International Lenders (International Monetary Fund, EU Member States, and European Central Bank). Specifically, in the last MoU associated with the so-called "Grexit" debate, in July 2015, under the pillar 'A modern State and Public Administration', which is considered a key-priority of the programme [p. 5], one may read [p. 24–25]: "On land use, […] the Government will reconvene the inter-ministerial spatial planning committee, with participation of the independent experts. Based on its advice and in agreement with the institutions, the Government will propose […] a time-bound roadmap for selected improvements of the spatial planning law, including on parts of the land use categories, and for the full adoption of secondary legislation […] in order to ensure that the legislation effectively facilitates investment, and streamlines and shortens planning processes while allowing for the necessary safeguards. … The authorities will adopt the Presidential Decree on forestry definitions […] and fully implement the forestry law […]. In addition, the authorities will […] adopt the legal framework for nationwide cadastral offices […] (key deliverable)…".Therefore, it is remarkable that both rationalities show low prioritization on structural policy components such as the definition and mapping of forests in Greece. The country does not have, as of 2020, a final cadastral, definitive forest maps, and a clear land-use plan. Simultaneously and counterintuitively, rural re-afforestation progresses due to land abandonment and domestic migration of rural residents to major urban setups (Papanastasis and Kazaklis 1998; MacDonald et al. 2000; Benayas et al. 2007). These two facts explain much of the conflictual positions of landowners and stakeholders and the critical role of the human factor in the vast majority of wildfires, either deliberate or accidental (Camia et al. 2013). Instead of asking for fast completion of the strategic infrastructure of spatial mapping and planning, i.e., the core prerequisite for any viable policy on human-nature relationships in the perspective of global climate change and risk assessment, both categories converge on the repression of arsonists.

Based on the Law 4619/2019—article 264, whoever intentionally ignites an illegal fire (i.e., not for agricultural purposes during periods that burning is allowed) can be punished with incarceration for (1) at least one year if the resulting fire caused substantial damages to property or possessions; (2) up to ten years imprisonment if the fire threatened human lives; and, (3) at least ten years if the fire caused fatalities. In cases of unintentional ignitions for all the above cases, the penalty is imprisonment of up to three years or a fine. The penalty is considered "mild" and has shown little effect on changing people's attitudes towards using fire during the high fire risk season. For example, although an unintentional ignition caused more than 100 fatalities in the wildland-urban interface of Athens during 2018, this did not prevent new ignitions of similar characteristics from burning thousands of hectares in the same region in 2021. While offender-based strategies to reduce arson are necessary, without the essential understanding of criminological evidence that will be systematically compiled in relation to 'what', 'who', 'why', 'where' and 'when' an arson takes place (Cozens and Christensen 2011), it is difficult to plan and enforce effective arson reduction programs. An informed plan for the repression of arsonists should have the traits of behavioral and proactive situational programs that can prevent and mitigate arson by decreasing rewards, increasing risks, and removing excuses for deliberate fire-setters, particularly when very few of them are caught (Christensen 2008).

Conclusions

We have shown that the distinction between rationalities is technically feasible using typical questionnaire data gathering. In the case of wildfires, two rationality schemes are discernable between Forest Service/Firefighting agents and the general public. However, both rationalities mainly focus on short-term tactical responses to wildfire hazards. Wildfire risk assessment methodologies and governance policies are urgently needed in Greece to predict climate and social-ecological changes, and wildland-urban transitions.

Authors contribution AYT, KK and PP are the contributors to this research (from conception to submission).

Funding No funding received for this research.

Declarations

Conflict of interest The authors declared that they have no conflicts of interest.

Ethical approval No ethical issues (experimentation on humans and/or animals) to this work

References

Archibald S, Lehmann CE, Gómez-Dans JL, Bradstock RA (2013) Defining pyromes and global syndromes of fire regimes. Proc Natl Acad Sci 110(16):6442–6447

Asah ST, Guerry AD, Blahna DJ, Lawler JJ (2014) Perception, acquisition and use of ecosystem services: human behavior, and ecosystem management and policy implications. Ecosyst Serv 10:180–186

Bakhshaii A, Johnson EA (2019) A review of a new generation of wildfire–atmosphere modeling. Can J for Res 49(6):565–574

Benayas JR, Martins A, Nicolau JM, Schulz JJ (2007) Abandonment of agricultural land: an overview of drivers and consequences. CAB Rev Perspect Agric Veterinary Sci Nutr Nat Res 2(57):1–14

Buizer M, Kurz T (2016) Too hot to handle: depoliticisation and the discourse of ecological modernisation in fire management debates. Geoforum 68:48–56

Camia A, Durrant T, San-Miguel-Ayanz J (2013) Harmonized Classification Scheme of Fire Causes in the EU Adopted for the European Fire Database of EFFIS. Publications Office of the European Union, Luxembourg, p 51

Christensen W (2008) The prevention of bushfire arson through target hardening. Flinders J Law Reform 10(3):693–713

Cozens P, Christensen W (2011) Environmental criminology and the potential for reducing opportunities for bushfire arson. Crime Prev Community Saf 13(2):119–133

Darren G, Mallery P (2019) IBM SPSS statistics 26 step by step: a simple guide and reference, Sixteenth. Routledge, New York, USA, p 402

De Groot R, Brander L, Van Der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L (2012) Global estimates of the value of ecosystems and their services in monetary units. Ecosyst Serv 1(1):50–61

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A (2015) The IPBES Conceptual Framework—connecting nature and people. Current Opinion Environ Sustainability 14:1–16

Douglas M (1994) Risk and Blame: Essays in Cultural Theory. Routledge, London, UK, p 336

EFFIS (2020) European Forest Fire Information System, Joint Research Centre: Forest Fires in Europe, Middle East and North Africa. European Commission, Publications Office, Luxembourg. https://effis.jrc.ec.europa.eu/. Accessed 11 June 2021

Field A (2013) Discovering statistics using IBM SPSS statistics, 4th edn. SAGE Publications, p 916

Floress K, Huff ES, Snyder SA, Koshollek A, Butler S, Allred SB (2019) Factors associated with family forest owner actions: a vote-count meta-analysis. Landsc Urban Plan 188:19–29

Goldammer J, Xanthopoulos G, Eytixidis G, Mallinis G, Mitsopoulos I, Dimitrakopoulos A (2019) Prospects for the Management of Forest and Landscape Fires in Greece (In Greek). The Global Fire Monitoring Center (GFMC);Secretariat of the Global Wildland Fire Network; UNISDR Wildland Fire Advisory Group; International Wildfire Preparedness Mechanism; International Fire Aviation Working Group, Athens, Greece. 80 p.

Hardy CH (2005) Wildland fire hazard and risk: Problems, definition, and context. Ecol Manag 211:73–82

IPBES (2019) Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. The IPBES global assessment report on biodiversity and ecosystem services: Summary for policy makers. Bonn, Germany. 56

Kalabokidis KD, Gatzojannis S, Galatsidas S (2002) Introducing wildfire into forest management planning: towards a conceptual approach. For Ecol Manage 158(1–3):41–50

Kalabokidis K, Palaiologou P, Gerasopoulos E, Giannakopoulos C, Kostopoulou E, Zerefos C (2015) Effect of climate change projections on forest fire behavior and values-at-risk in southwestern Greece. Forests 6(6):2214–2240

Kline JD, White EM, Fischer AP, Steen-Adams MM, Charnley S, Olsen CS, Spies TA, Bailey JD (2017) Integrating social science into empirical models of coupled human and natural systems. Ecol Soc 22(3):25. https://doi.org/10.5751/ES-09329-220325

Leys B, Higuera PE, McLauchlan KK, Dunnette PV (2016) Wildfires and geochemical change in a subalpine forest over the past six millennia. Environ Res Lett 11(12):125003

Loehman RA (2020) Drivers of wildfire carbon emissions. NatClim Change 10:1070–1071

MacDonald D, Crabtree JR, Wiesinger G, Dax T, Stamou N, Fleury P, Gutierrez Lazpita J, Gibon A (2000) Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J Environ Manage 59(1):47–69

Maguire LA, Albright EA (2005) Can behavioral decision theory explain risk-averse fire management decisions? For Ecol Manage 211:47–58

Marlon J (2020) What the past can say about the present and future of fire. Quatern Res 96:66–87

Mellon RC, Papanikolau V, Prodromitis G (2009) Locus of control and psychopathology in relation to levels of trauma and loss: Self-reports of Peloponnesian wildfire survivors. J Traum Stress Off Publ Int Soc Traum Stress Studies 22(3):189–196

Moriondo M, Good P, Durao R, Bindi M, Giannakopoulos C, Corte-Real J (2006) Potential impact of climate change on fire risk in the Mediterranean area. Climate Res 31:85–95

Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, Van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T (2010) The next generation of scenarios for climate change research and assessment. Nature 463(7282):747–756

Nielsen-Pincus M, Moseley C, Gebert K (2014) Job growth and loss across sectors and time in the western US: the impact of large wildfires. Forest Policy Econ 38:199–206

Oliveira TM, Guiomar N, Baptista FO, Pereira JMC, Claro J (2017) Is Portugal's forest transition going up in smoke? Land Use Policy 66:214–226

Palaiologou P, Ager AA, Nielsen-Pincus M, Evers C, Kalabokidis K (2018) Using transboundary wildfire exposure assessments to improve fire management programs: a case study in Greece. Int J Wildland Fire 27:501–513

Palaiologou P, Kalabokidis K, Ager AA, Day MA (2020) Development of comprehensive fuel management strategies for reducing wildfire risk in Greece. Forests 11(8):789

Palaiologou P, Kalabokidis K, Ager AA, Galatsidas S, Papalampros L, Day MA (2021a) Spatial optimization and tradeoffs of alternative forest management scenarios in Macedonia. Greece Forests 12(6):697

Palaiologou P, Kalabokidis K, Troumbis AY, Day MA, Nielsen-Pincus M, Ager AA (2021b) Socio-ecological perceptions of wildfire management and effects in Greece. Fire 4(2):18. https://doi.org/10.3390/fire4020018

Papanastasis VP, Kazaklis A (1998) Land Use Changes and Conflicts in the Mediterranean-Type Ecosystems of Western Crete. In: Rundel PW, Montenegro G, Jaksic FM (eds) Landscape Disturbance and

Biodiversity in Mediterranean-Type Ecosystems. Springer, Berlin Heidelberg, Berlin, Heidelberg, pp 141–154
Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Dessane EB, Islar M, Kelemen E (2017) Valuing nature's contributions to people: the IPBES approach. Current Opin Environ Sustainability 26:7–16
Pituch KA, Stevens JP (2016) Applied multivariate statistics for the social sciences: Analyses with SAS and IBM's SPSS, 6th edn. Routledge, New York, USA, p 814
Poljansek K, Casajus Valles A, Marin Ferrer M, De Jager A, Dottori F, Galbusera L, Garcia Puerta B, Giannopoulos G, Girgin S, Hernandez Ceballos MA, Iurlaro G, Karlos V, Krausmann E, Larcher M, Lequarre AS, Theocharidou M, Montero Prieto M, Naumann G, Necci A, Salamon P, Sangiorgi M, Raposo ML, Trueba Alonso C, Tsionis G, Vogt J, Wood M (2019) Recommendations for National Risk Assessment for Disaster Risk Management in EU: Where Science and Policy Meet. JRC Science for Policy Report, European Union, Luxembourg
Psarros C, Theleritis C, Kokras N, Lyrakos D, Koborozos A, Kakabakou O, Tzanoulinos G, Katsiki P, Bergiannaki JD (2018) Personality characteristics and individual factors associated with PTSD in firefighters one month after extended wildfires. Nord J Psychiatry 72(1):17–23
Purnomo H, Shantiko B, Sitorus S, Gunawan H, Achdiawan R, Kartodihardjo H, Dewayani AA (2017) Fire economy and actor network of forest and land fires in Indonesia. Forest Policy Econ 78:21–31
Rius D, Vannière B, Galop D (2012) Holocene history of fire, vegetation and land use from the central Pyrenees (France). Quatern Res 77(1):54–64
Rodriguez-Franco C, Haan TJ (2015) Understanding climate change perceptions, attitudes, and needs of forest service resource managers. J Sustain for 34(5):423–444
Ruane AC, Antle J, Elliott J, Folberth C, Hoogenboom G, Croz DM-D, Müller C, Porter C, Phillips MM, Raymundo RM (2018) Biophysical and economic implications for agriculture of+ 1.5 and+ 2.0 C global warming using AgMIP Coordinated Global and Regional Assessments. Climate Res 76(1):17–39
Sallares R (1991) The ecology of the ancient Greek world. Cornell University Press, Ithaca, New York, p 598
Shindler B, Spies T, Bolte J, Kline J (2017) Integrating ecological and social knowledge: learning from CHANS research. Ecol Soc 22(1):26. https://doi.org/10.5751/ES-08776-220126
Steinführer A (2015) Citizens wanted. Changing roles in the provision of public services in rural areas. Spatial Res Planning 73(1):5–16
St-Laurent GP, Hagerman S, Kozak R (2018) What risks matter? Public views about assisted migration and other climate-adaptive reforestation strategies. Clim Change 151(3):573–587
St-Laurent GP, Hagerman S, Findlater KM, Kozak R (2019) Public trust and knowledge in the context of emerging climate-adaptive forestry policies. J Environ Manage 242:474–486
Sullivan GM, Artino ARJ (2013) Analyzing and interpreting data from Likert-type scales. J Grad Med Educ 5(4):541
Tedim F, Leone V, Coughlan M, Bouillon C, Xanthopoulos G, Royé D, Correia FJ, Ferreira C (2020) Extreme wildfire events: the definition. In: Extreme Wildfire Events and Disasters. Elsevier, pp 3–29
Troumbis AY (2021) Imbalances in attitudes of European citizens towards biodiversity: Did the communication of the European Biodiversity Strategy work? Journal for Nature Conservation (in press)
Troumbis AY, Hatziantoniou MN (2018) Too much, too fast, too complex or too strange? Asymmetric sequences in public opinion regarding biodiversity conservation in Island social-ecological setups. Biodivers Conserv 27(6):1403–1418
Troumbis AY, Zevgolis Y (2020) Biodiversity crime and economic crisis: Hidden mechanisms of misuse of ecosystem goods in Greece. Land Use Policy 99:105061
European Commission (2019a) Special Eurobarometer 481: Attitudes of Europeans towards Biodiversity. European Union. p 18. https://ec.europa.eu/clima/sites/clima/files/support/docs/report_2019_en.pdf. Accessed 11 June 2021
European Commission (2019b) Special Eurobarometer 490: Climate Change. European Union. p 130. https://ec.europa.eu/clima/sites/clima/files/support/docs/report_2019_en.pdf. Accessed 11 June 2021
UNISDR (2009) UNISDR terminology on disaster risk reduction. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland. p 30.