Analysis of the stakeholder perceptions and trends of forest fire occurrence in the Alpine region

MASTER THESIS

submitted by

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Abstract

Understanding the stakeholders' perception about the main challenges and drivers for fire management in the Alpine region is important in ensuring a successful implementation of integrated fire management strategies. This study analyzes the differences among the perceptions of three groups of stakeholders (authorities, scientists, and action forces) regarding fire management. An online survey and a forest fire experts workshop were conducted to document the different opinions regarding the main factors and trends for fire ignition, present and future challenges in firefighting as well as priorities for implementing fire management options across the Alpine region. The analysis indicated that there are significant differences between the group of authorities, scientists, and action forces regarding the perception of the number of fires, burnt areas, and future trends. Action forces tend to estimate the overall future trend for the burnt area significantly higher than the other groups in all countries.

Concerning the natural factors, all respondents identified precipitation, temperature, and wind as the most important factors driving the present and future fire regime. In terms of socio-economic factors, all groups listed recreational activities, rural abandonment, and awareness of landowners as the main drivers of the present and future fire regime. Regarding the priorities for controlling the fire situation, no significant differences in the perceptions of the respondents were found. The key challenges in fighting forest fire in the present and future were missing/insufficient air support, water availability, simultaneous occurrence of several large fires and the expected high costs by large and/or long-lasting fires. Based on the findings of this study conclusion for an integrated fire management in the Alpine region are made.

Keywords: Forest fires, challenges, stakeholder perception, natural factors, social-economic factors, Alpine region.

Zusammenfassung

Für eine erfolgreiche Umsetzung von Strategien des Waldbrandmanagements im Alpenraum ist die Einschätzung von Stakeholdern zu den wichtigsten Herausforderungen wichtig. Die Studie zielt darauf ab, die Unterschiede in der Wahrnehmung von drei Gruppen von Stakeholdern (Behörden, Wissenschaftler, Einsatzkräfte) in Bezug auf die Trends und treibenden Faktoren für die Entzündung von Waldbränden zu analysieren. Mittels einer online Umfrage und eines Expertenworkshops wurden die Ansichten der Akteure in der Region dokumentiert. Außerdem wurden die Prioritäten für das Waldbrandmanagements und die gegenwärtigen und zukünftigen Herausforderungen in der Waldbrandbekämpfung analysiert. Es zeigte sich ein signifikanter Unterschied zwischen Behörden, Wissenschaftlern und Einsatzkräften hinsichtlich der Wahrnehmung über die Anzahl der Brände, die Größe der Brandflächen und der zukünftigen Trends. Dabei schätzen Einsatzkräfte die zukünftige Brandfläche deutlich höher ein als die anderen Gruppen in allen Ländern.

In Bezug auf die natürlichen Faktoren stimmten alle Befragten darin überein, dass Niederschlag, Temperatur und Wind in der Zukunft die drei wichtigsten Treiber des gegenwärtigen Feuerregimes sein werden. In Bezug auf die sozioökonomischen Faktoren waren sich alle Gruppen einig, dass Freizeitaktivitäten, Landflucht und das generelle Bewusstsein der Landeigentümer wichtige Faktoren für das gegenwärtige und zukünftige Feuerregime sind. Hinsichtlich der prioritären Maßnahmen zur Kontrolle der Feuersituation gab es keine Unterschiede in der Wahrnehmung der Befragten. Die wichtigsten Herausforderungen für die gegenwärtige und zukünftige Waldbrandbekämpfung sind für alle Befragten die fehlende oder unzureichende Unterstützung durch Helikopter, eine ausreichende Wasserverfügbarkeit, das gleichzeitige Auftreten mehrere Großbrände und die hohen Kosten durch große oder lang andauernde Brände. Die Erkenntnisse der Arbeit erlauben die Formulierung von Schlussfolgerungen für ein integrales Waldbrandmanagement im Alpenraum.

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Acronyms and Abbreviations Used

AT	Austria
BDIFF	Base Data on Incendies of Forests in France
CH	Switzerland
DE	Germany
EC	European Commission
EFFIS	European Forest Fire Information System
EU	European Union
FR	France
GFMC	Global Fire Monitoring Centre
IT	Italy
LI	Liechtenstein
NGO	Non-Governmental Organization
SD	Standard deviation
SL	Slovenia
WUI	Wildland-Urban Interface
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research

1. INTRODUCTION

1.1 Problem statement

In recent years, forest fire has rapidly become a highly important subject area due to its increasing threat to health and human activities as well as negative impacts on the environment (Zotta et al., 2020). With the effect of climate change, warmer air can contain more water, more evaporation, and rising temperatures lead to drier vegetation and soil and more droughts (Jones et al., 2017), which are seen to be positively correlated to forest fire occurrence.

The European Alpine is one of the regions affected by annual forest fires (Valese et al., 2011). In particular, the slopes exposed to the south in the Alpine region are affected by forest fires due to vegetation being drier, resulting in a higher spreading potential (Müller et al., 2020). In addition, under the different emission scenarios, the temperature is expected to increase from 2 to 6 °C in the Alpine region for future years (Alpine Convention, 2014). Also, the precipitation being expected to decrease in summer, but there are more prolonged droughts, and longer heat waves are expected to happen annually (Gobiet et al., 2014).

Moreover, the Alpine region is facing changing socio-economic conditions such as rural abandonment and recreational activities. Not only does rural abandonment make more flammable areas with increased fuel accumulation, but it also leads to major uncontrolled practices of pastoral burning (Müller et al., 2020; Pezzatti et al., 2013). Besides, the increase in recreational activities means more and more tourists have the potential to cause incidents of forest fires in the summer. All this will lead to enormous damages in protection forests and increasing vulnerability to natural hazards as well as a result in high costs up to millions of euros for fire suppression and required restoration measures.

On the other hand, several research projects on the topic of the Alpine forest fires, such as FIRIA (Fire risk and vulnerability of Austrian forests under the impact of climate change), EUSALP (EU strategy for the Alpine region) have provided analysis and scientific evidence regarding the occurrence, distribution, causes, and characteristics of forest fires in the Alpine region (Vacik et al., 2011). Moreover, case studies related to fuel management and fire behavior modeling in the Alpine area have also been implemented (Arpaci et al., 2013; Müller et al., 2013). Especially in Austria, along with the success of the Austrian Forest Fire Research Initiative (AFFRI) project, a

forest fire database, a forest fire blog, and a Web-GIS portal have been launched to standardize the data on forest fires and supporting research on fire risks and events in 2013 (Vacik et al., 2013).

More recently, the EUSALP project has been shown that there are differences in prevention measures for large forest fires in different countries in the Alps (Müller et al., 2020). There are differences in the fire occurrences and the implementation of forest fire management in the Alpine region. In order to increase the understanding of the key drivers, more research is needed to explore stakeholders' perceptions and perspectives on fire management that have occurred and future trends. At the same time, it is important to study the stakeholder perceptions to understand their motives for implementing measures as well as learn about their experiences and opinions. This can help to ensure government organizations and decision-makers in the successful implementation of any policy (Costa and Menichini, 2013; Dwivedi et al., 2016).

However, there is a lack of studies which focus on the stakeholder's perception of forest fires in the Alpine region. In addition to the limited knowledge of stakeholders and communities about forest fires, more attention needs to be given to awareness raising activities on forest fire prevention in the Alps (Müller et al. 2020). Besides, a weakness being regularly pointed out in fire management activities is the lack of participation of the related stakeholders in European countries (Aguilar & Montiel, 2011). Stakeholders with their own socio-environmental values are often in conflict with each other, because of the different perspectives on the ecological value of fires, where empirical data are often lacking (Mierauskas & Pereira, 2013; Ryan et al., 2013). For instance, there is no clear understanding about the role of prescribed and wildland fires as essential ecologic processes for the management of landscape (Pereira et al., 2014).

Therefore, this present study would like to contribute to a more thorough understanding of the fire management in the Alpine region by examining and analyzing the perceptions of different stakeholders. It is hoped that the outcome of this study will contribute to the research gaps in the forest fire management in the Alps, as well as provide an overview of the forest fire management's stakeholders, thereby informing managers and decision-makers to improve management strategies.

1.2. Objectives and hypotheses

As discussed in the previous section, the goal of this present study is to examine and analyze the perceptions of the related stakeholders in the context of forest fires and their management. Accordingly, two objectives can identify: (i) to address the differences in the perceptions of stakeholders about the trends and driving factors of forest fire ignition; (ii) to assess the stakeholders' perceptions about fire management activities and challenges of forest fight fighting.

In this context, the hypotheses are formulated as follows:

1) There are significant differences between Authorities, Scientists, and Action forces regarding the perception of current forest fire occurrence and future trends in the Alpine region.

2) The drivers for forest fire ignitions depend on natural and socio-economic factors and differences between the Alpine region countries.

3) The Authorities, Scientists, and Action forces exhibit significant differences in their opinions about the priorities for fire management options in different countries.

4) Barriers in stakeholders’ collaboration hinder the successful implementation of forest fire management practices.

2. MATERIAL AND METHODS

2.1. Study area

The study is in the Alpine region was defined mountainous region in Central Europe according to the action plan on the EU Strategy for the Alpine Region by European Council in 2015, which concerns seven countries, including Austria, France, Germany, Italy, Slovenia, Liechtenstein, and Switzerland.

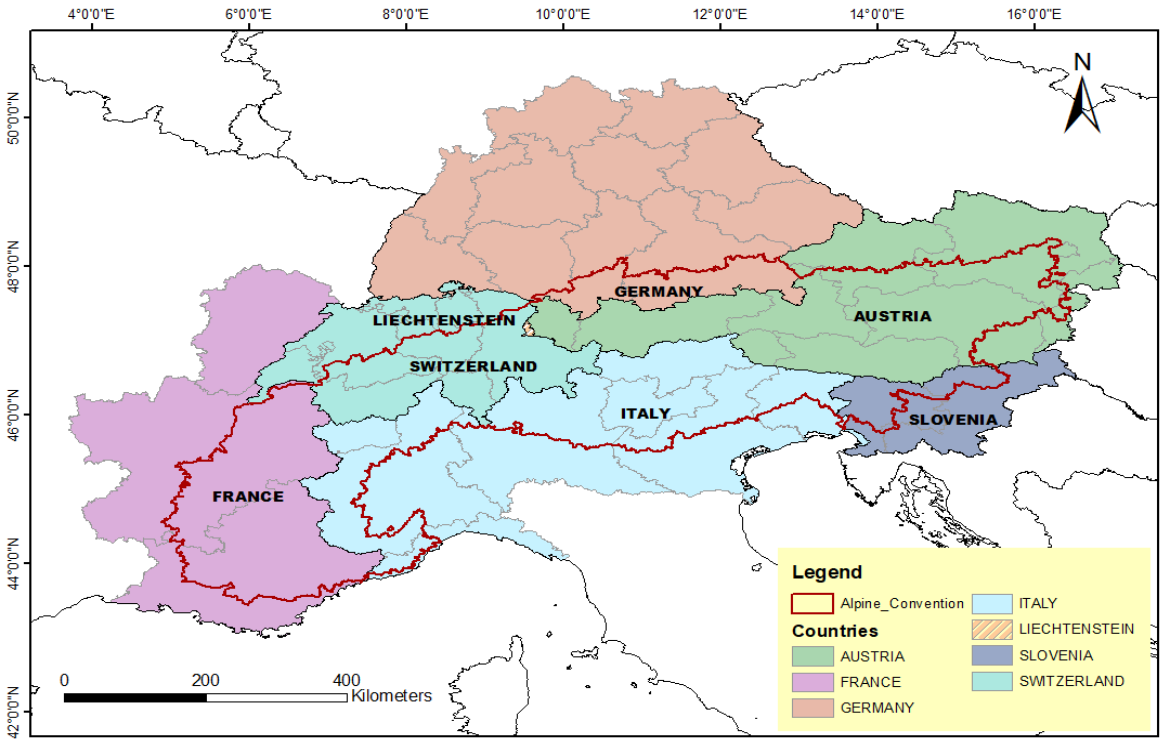

Figure 1: Map of the study area in the Alps according to the Alpine Convention; only Liechtenstein is no data available for this study.

Due to the differences between the locations and topography, the climate in the Alpine region is complicated. It is a high-altitude area, with the highest peak elevation up to 4 810m above sea level (Mont Blanc peak). This characteristic creates different sub-climates here, including Mediterranean, Continental, Atlantic, and Polar. Therefore, there are many different types of ecosystems in the Alpine region.

The Alpine region has a population of more than 14 200,000 inhabitants and an average population density of 74.6 inhabitants/km² (European Environment Agency, 2012). The population is mainly concentrated in easily accessible areas such as valleys and urban centers where convenient transportation routes are convenient. In contrast, remote terrain areas have a low population and tend to face the challenge of population decline (Permanent Secretariat of the Alpine Convention, 2015).

Over the past decades, there have been many changes in land use and management in the Alpine region. They are all closely linked to the goals of developing key economic sectors in the region. Three main types of land use are classified as open spaces with little or no vegetation, shrub, and forests. Highlights may include a major change in the reduction of the proportion of land used for agricultural purposes in each country in the region as well as an intensification of the remaining area for forestation (Permanent Secretariat of the Alpine Convention, 2015).

In terms of economy, the Alpine region has a rapidly growing economy. Industry accounts for the highest proportion and is followed by services and agriculture. From 1990 to 2000, the number of jobs in the agroforestry sector has decreased, despite the fact that this sector is considered to play an essential role in conserving nature (Permanent Secretariat of the Alpine Convention, 2015). Instead, the tourism industry has proved to have important in the future in the Alpine region.

Table 1. Fire situation in the Alpine countries according to number of fires, burned area, fire size and yearly ratio of burned forest. No data available for Liechtenstein. Sources: National/ Regional databases, EFFIS reports, Forest fire workshop Vienna, Müller et al., 2020.

	Austria	**France**	**Germany**	**Italy**	**Slovenia**	**Switzerland**
Total area in the Alpine region (km2)	69 277	40 786	11 197	73 786	13 763	33 360
Forest area in the Alpine region (km2)	28 921	14 099	4 036	22 623	7 238	9 929
Mean annual number of forest fires	122	214	No data	1 043**	37	105
Mean annual burned forest area (ha)	64	818	No data	9 984	201	515
Median size of a forest fire	< 0.1 ha	1 ha	< 0.1 ha	1ha	0.5 ha	< 0.1 ha
Yearly ratio of burned area (ha) *	0.22	5.8	No data	44.13	2.77	5.19

** Average burned area per year per 10 000 ha of forest area*

** For Italy mean annual number of fires is related to all documented wildfires*

The table above presents some critical aspects of the fire situation in the Alpine region's six countries. It can be seen from the table that Austria is the country with the highest forest area in the region. However, Italy is the country which has the highest number of annual forest fires and the most burned forest area in the Alpine region. In the second place is France. Among the six countries, both Italy and France have the largest median size of the forest fire of 1 hectare. The median size of the forest fire in Slovenia is 0.5 hectares, and less than 0.1 hectares in Austria, Germany and Switzerland. The yearly ratio of the burned area varies significantly among the six countries, with 44.13 hectares in Italy and 0.22 hectares in Austria. In the Alpine region, the most recent most massive wildfires happened in Italy in 2017.

2.2. Data collection

In this study, the data was collected based on the results of a survey and a workshop with forest fire experts of the three different stakeholder groups Authorities, Scientists, and Action forces. The multi-lingual online survey was conducted by the Institute of Silviculture in the context of the research study on "Forest fires in the Alps: State of knowledge and future challenges" which identified the main processes, legal bases and major challenges in fire prevention, fire suppression and post-fire management as well as explored the main driving factors for fire ignition and propose possible options for an integrated fire management in the future for the Alpine region.

The questionnaire contained three main parts with eight sections (Appendix B). In this survey, a standard definition of forest fire was chosen based on the study of Müller et al. (2020) to assess the perceptions of the stakeholders, "Forest fire: Uncontrolled fire in forested area (including clearcuttings, young forest, coppice, and vegetation at the alpine forest border), independent of fire type (smouldering fire, surface fire, crown fire), size and cause (e.g., also burning tree from lightning)."

The first part of the questionnaire aimed to assess the trends in fire regime in the Alpine region. The questions focused on the stakeholder's perception of the fire situation and trends as well as the importance of natural and socio-economic factors as drivers of the fire regime both in the present and future of the region. In addition, the second part of the questionnaire included the question about forest fires prevention and suppression aspects. It consisted of three sections respectively fire danger assessment, forest management and forest fire fighting to better understand the different perception among the stakeholder's groups of the Alpine region. Moreover, the last part of the questionnaire assessed the participants opinion about the role of political frameworks and risk governance. Through questions regarding the forest fire policies and decision-making process, the stakeholders could express their preferences regarding the options for forest fire management planning and implementation of forest fire prevention measures at local or national level.

The second source of data for the study originate from the results of a forest fire experts workshop held in Vienna in June 2019. In this workshop, participants including Scientists, Authorities and

Action forces discussed the outcomes of the survey through a panel on forest fires experts. Also, they shared success stories on fire management in different countries across the Alpine region.

2.3. Target stakeholder groups

With the following specific definitions:

Authorities: Renowned persons in civil service responsible for or mainly engaged in planning and conducting measures for forest fire prevention or aftercare measures on a transregional or nationwide basis (e.g., members of forest authorities, members of advisory services, operators of early warning systems).

Scientists: Renowned persons with a scientific background in fire research or active in forest fire monitoring and modelling on a nationwide or pan-European basis.

Action forces: Renowned persons from fire brigades, aerial firefighting, police, or national army responsible for or main focus on forest fire fighting on a transregional or nationwide basis.

2.4. Data analysis

The comparison of the stakeholder perceptions of the number of forest fires and burnt areas was determined by the received responses to the questions about the number of forest fires and burnt areas in the survey. The estimation levels were arranged as follows: "1: Strong decrease, 2: Decrease, 3: Constant progression, 4: Increase, 5: Strong increase". Each level of estimation was presented in the percentage of the total responses received. At the same time, a statistical test was performed to check the differences in the responses to the number of forest fires and of the burnt areas of the stakeholders and the countries in the Alpine region. The Kruskal-Wallis test was applied to consider the p-value of 0.05 (Kruskal and Wallis, 1952). If significant differences were identified, a Dunn's test post-hoc (1964) with the Hochberg method would be conducted to identify the differences within stakeholder groups (Hochberg and Tamhane, 1987). The statistical analysis was conducted by the RStudio software for Windows.

Drivers for forest fire ignitions depending on natural and socio-economic factors and differences between the countries in the Alpine region were identified via the responses of each driver's level of importance in the present and the future. The levels of importance include: "1: Very low, 2:

Low, 3: Moderate, 4: High, 5. Very high". A table presenting the differences in each stakeholder group's perceptions for each factor in considerations of three stakeholder groups was conducted. The standard deviation and mean values were presented to highlight the importance related to each factor. Furthermore, graphs showing the percentage of the participants' selection related to the level of importance in each country were used in order to present the perception of the natural, economic and social factors driving forest fire ignitions in each country.

Regarding the stakeholder perceptions of the priorities of the forest fire management options, the clustered bar charts were used to show the percentage of each option including "1: Very efficient, 2: Efficient, 3: Less efficient, 4: Not efficient and 5: Not applicable", compared with the total responses of participants in different groups of stakeholders.

The Stacked Bar Charts were applied to visualize the perception of each stakeholder group of the Alpine region regarding the barriers and challenges of the collaboration among stakeholders specifically, and the forest fire management in the Alpine region in general.

Finally, the ATLAS.ti 8 software was used to link and group the assessments of different aspects of the forest fire management, which were mentioned and discussed in the workshops and in scientific materials.

3. RESULTS

3.1. Comparison of the stakeholder's perception of the number of forest fires

3.1.1. Perception about number of forest fires among stakeholder groups

The donut chart in figure 2 below illustrates the answers of Authorities, Scientists and Action Forces, to the question about their estimated level of the number of fires in the future. Answers vary from level 1 to level 5, which is equivalent to the levels from 'strong decrease' to 'strong increase'.

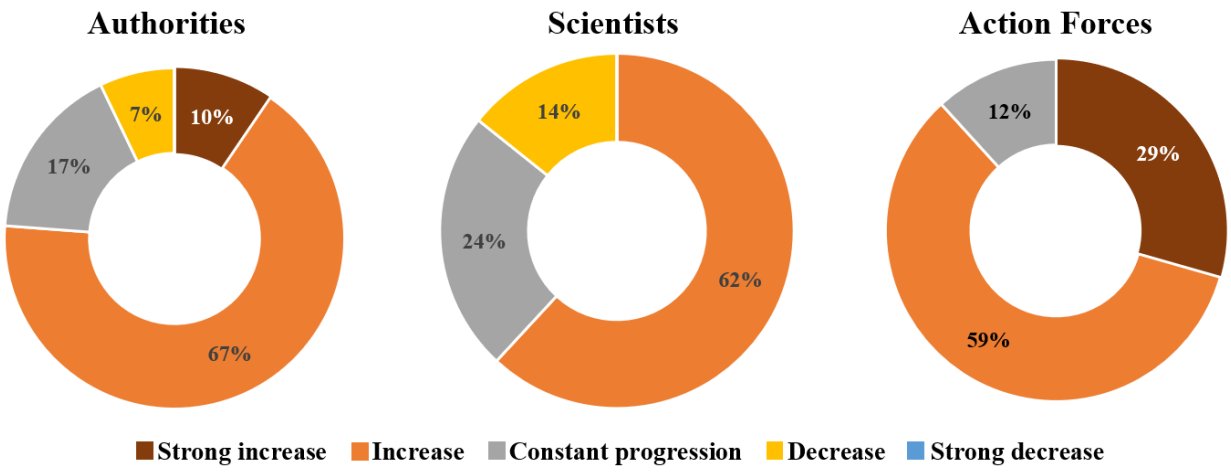

Figure 2. *The perception levels of the number of forest fires among three stakeholder groups (estimates in %)*

From the graph, it is apparent that none of the groups thought there would be a strong decrease (level 1) in the number of fires for the next ten years. Instead, Scientists chose the answers which range from level 2 (decrease) to level 4 (increase). Authorities had the most diverse answers, including four levels from 2 (decrease) to 5 (strong increase). Action Forces, on the other hand, expected the level of fire number to vary from 3 (constant progression) to 5 (strong increase).

At level 2 (decrease), only a few Scientists and Authorities estimated a decrease in the number of fires, whereas none of the Action Forces shared the same opinion.

All of three groups chose both level 3 (constant progression) and 4 (increase). However, the more popular choice between the two was level 4, when the majority of Scientists, Authorities, and Action Forces estimated an increase in the number of fires for the next ten years.

Estimation of a level 5 (strong increase) in the number of fires was shared by a few stakeholders of the Authorities and Action Forces groups, whereas no Scientists expected this level 5 of fire numbers to happen in the future.

The Kruskal - Wallis test, in this case, was significant (p = 0.009), thus, the result from the dunnTest showed that Action Forces and Scientists had the p-value adjusted with the Bonferroni method of 0.006; therefore, there was a significant difference between these two groups. Thus, the Scientists group estimated that the overall future trend for the number of fires in the Alpine region would be significantly lower than the one estimated by the Action Forces group.

3.1.2. Perception about number of forest fires among six countries

Figure 3 shows the stakeholders' estimation of the level of fire number among six countries of the Alpine region. Answers vary from level 1 to level 5, equivalent to the levels from 'strong decrease' to 'strong increase'.

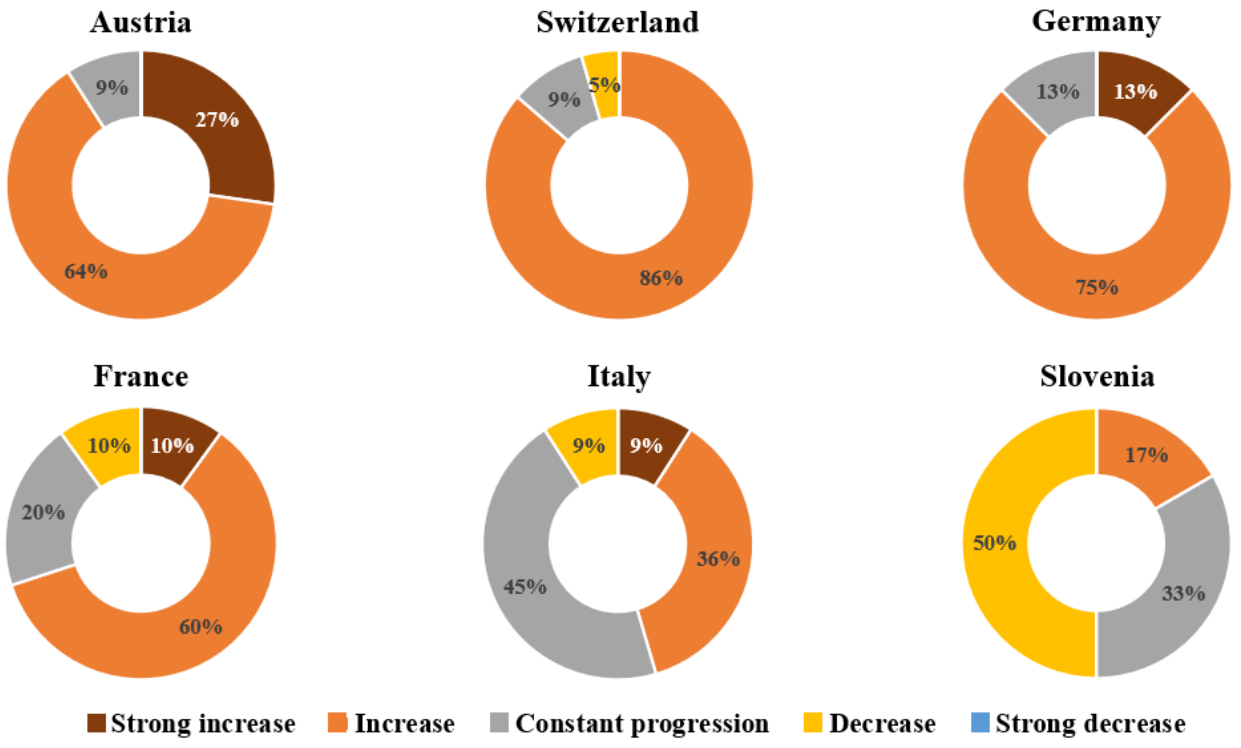

***Figure 3**. The perception levels of number of forest fires among six countries (estimates in %)*

It can be seen that the overall number of fires in the region is expected to vary from decrease (level 2) to strong increase (level 5). None of the stakeholders from the six countries believe there would be a strong decrease (level 1) in this context.

The graph shows that an increase in the number of fires (level 4) was the most popular perception of stakeholders from all countries, with the majority of them from all except Slovenia. The second most popular view was a constant progression of the number of fires (level 3), which was shared by stakeholders from all countries except Germany.

Among the countries of the northern Alps, only Switzerland expected that there could be a decrease in the number of fires (level 2). By contrast, all countries of the southern Alps share this same view that the number of fires would decrease (level 2).

In the northern Alps, only Austria and Germany expected the level of fire number to strongly increase (level 5). Countries of the southern Alps seemed to agree on every level of fire number, except Slovenia did not think that there would be a strong increase (level 5) as a future trend.

The Kruskal-Wallis rank test ($p = 0.001$) and dunnTest showed that the p values adjusted with the Bonferroni method were less than 0.05 in three groups of countries which were Austria and Slovenia ($p = 0.001$), Switzerland and Slovenia ($p = 0.047$), and Germany and Slovenia ($p = 0.016$). Therefore, there was a significant difference between the two countries of each group.

3.2. Comparation of the stakeholder's perception of burnt areas

3.2.1. Perception about burnt areas among three stakeholder groups

The donut chart in figure 4 below shows the level of burnt areas estimated for the future by Scientists, Authorities, and Action Forces. These levels vary from 1 (strong decrease) to 5 (strong increase).

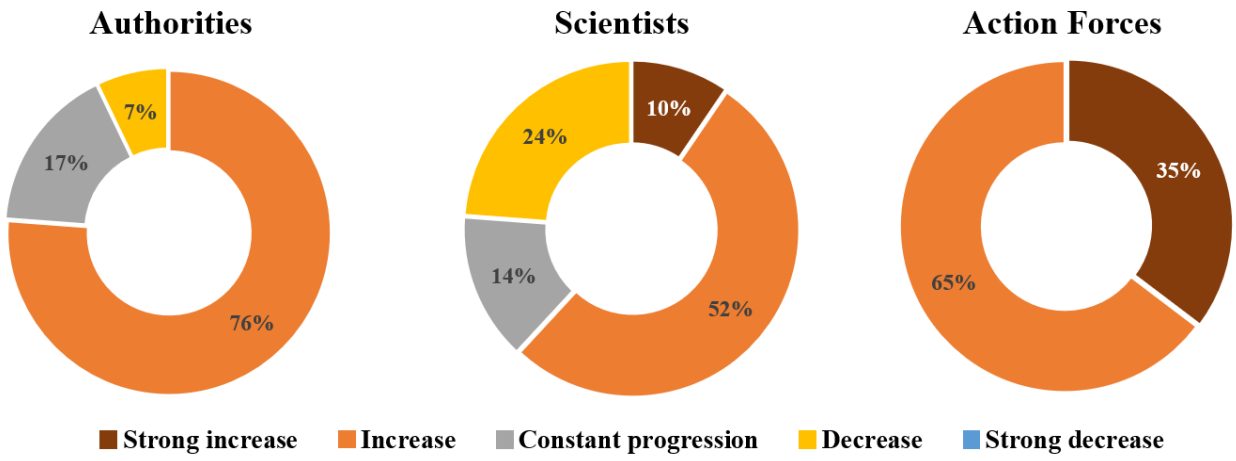

***Figure 4**. The perception levels of the burnt area among three stakeholder groups (estimates in %)*

As the graph shows, none of the groups expected the level of burnt areas to strongly decrease (level 1) as a future trend. However, Scientists expected that all of the four levels from 2 (decrease) to 5 (strong increase) would likely happen. Authorities did not think there would be a strong increase in the level of burnt areas, with their choice of level from 2 (decrease) to 4 (increase). Action Forces, however, chose only two levels for their answers, which are 4 (increase) and 5 (strong increase).

From the graph, it is apparent that the majority of Scientists, Authorities, and Action Forces believed there would be an increase (level 4) in the level of burnt areas in the next ten years. This level 4 is also the only similarity of answer choice across the three groups.

Kruskal-Wallis rank test results with a p-value of 0.0005; thus, statistically there was a difference among groups of stakeholders. The dunnTest showed that the p values adjusted with the Bonferroni method were less than 0.05 in the group of Action Forces and Authorities ($p = 0.002$) and the group of Action Forces and Scientists ($p = 0.001$). Therefore, the Action Forces group estimated that the overall future trend for the burnt area would be significantly higher than the other groups in all countries.

3.2.2. Perception about burnt areas among six countries

Figure 5 illustrates the level of burnt areas for the overall future trend perceived by respondent from six countries of the Alpine region.

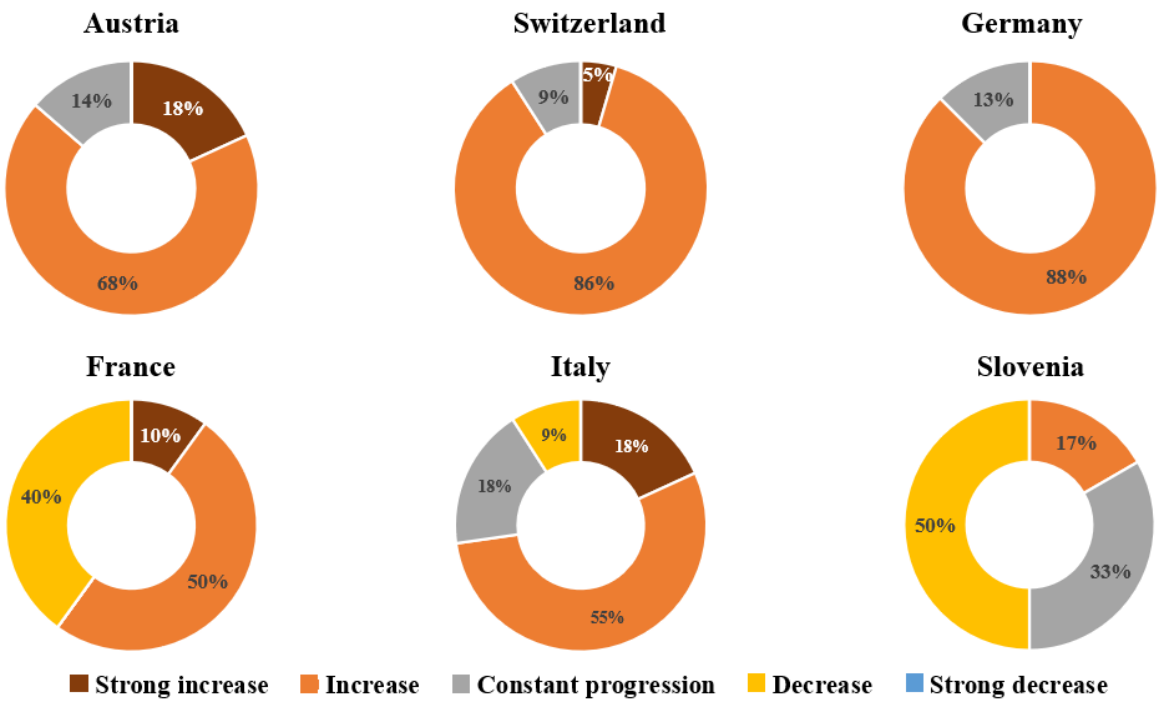

Figure 5. *The perception levels of burnt area among six countries (estimates in %)*

It is apparent from the graph that none of the stakeholders of the six countries thought that there would be a strong decrease (level 1) in the level of burnt areas as a future trend. However, the overall level of burnt areas was expected to vary from decrease (level 2) to strong increase (level 5). The majority of stakeholders from all of the countries believe that there would be an increase (level 4) in the level of burnt areas. Additionally, a constant progression in the level of burnt areas (level 3) was a shared view of the stakeholders from all countries except France.

There is one significant difference between countries of the northern Alps and those of the southern from the data. None of the stakeholders from Austria, Switzerland, and Germany expected the level of burnt areas to decrease (level 2), whereas this level of burnt areas was a shared view among the stakeholders in France, Italy, and Slovenia.

Within the countries of the northern Alps, stakeholders from Germany did not share the same view with those from Austria and Switzerland that there could be a strong increase in the level of burnt areas (level 5).

Within the countries of the southern Alps, while the stakeholders from France and Italy expected the level of burnt areas to strongly increase (level 5), those from Slovenia did not believe so.

According to the Kruskal-Wallis rank sum test results and dunnTest, there are two groups of countries that have the p-value adjusted with the Bonferroni method of less than 0.05. They are Austria and Slovenia (p = 0.004), and Switzerland and Slovenia (p= 0.013). Consequently, there was a statistically significant difference between two countries within each group.

3.3. Natural factors preconditions and trend

3.3.1. Natural factors in the present fire regime

Table 2 illustrates the stakeholders' answers to the questions about the importance of the six natural factors as drivers for the present fire regime in the Alpine region of their respective country.

Table 2. Average rank of the importance of the natural factors as drivers for the present fire regime in the alpine region of your country (from 1 - very low to 5 - very high);

Natural factors	Action Forces [SD]	Authorities [SD]	Scientists [SD]	Average
Precipitation	3.6 [±1.1]	3.8 [±0.94]	3.9 [±1.0]	3.8
Temperature	3.3 [±1.2]	3.3 [±1.0]	3.5 [±0.9]	3.4
Wind	3.5 [±1.2]	3.6 [±1.1]	3.9 [±1.0]	3.7
Fuel quality in forests (moisture, structure, compactness)	3.2 [±0.9]	3.0 [±0.9]	3.1 [±0.9]	3.1
Fuel load in forests (biomass, deadwood content)	3.3 [±1.1]	2.9 [±0.9]	3.2 [±1.0]	3.1
Atmospheric stability (lightnings)	2.8 [±1.1]	2.4 [±1.0]	2.6 [±1.1]	2.6

From the table, “Precipitation”, “Wind”, and “Temperature” were the top three most important natural factors for the stakeholders. All of these three factors share the same pattern in the level of importance for the stakeholders, with the highest-ranking from Scientists, then Authorities, and Action Forces.

“Fuel quality in forests” and “Fuel load in forests” came next in the ranking with relatively high importance for the stakeholders. Across the stakeholders' groups, “Fuel quality in forests” and “Fuel load in forest” had the highest ranking from Action Forces, then Scientists and Authorities.

"Atmospheric stability" was the least important natural factor for the three groups of stakeholders in comparison to other natural factors. In fact, Action Forces and Scientists thought "Atmospheric stability" to have medium importance, whereas, for Authorities, "Atmospheric stability" had a slightly lower than medium importance.

3.3.2. Natural factors in the future fire regime

Table 3 illustrates the three groups of stakeholders' responses to the importance of the six natural factors for the future trend in the Alpine region of their respective country.

Table 3. Average rank of the importance of natural factors as drivers <u>for the future trend fire regime</u> in the alpine region of your country (from 1 - very low to 5 - very high importance in approx. 10 years);

Natural factors	Action Forces [SD]	Authorities [SD]	Scientists [SD]	Average [SD]
Precipitation	4.5 [±0.6]	4.5 [±0.6]	4.3 [±1.1]	4.4
Temperature	4.2 [±0.9]	4.1 [±0.9]	4.1 [±0.8]	4.1
Wind	4.1 [±1.2]	4.0 [±0.9]	4.3 [±1.0]	4.1
Fuel quality in forests (moisture. structure. compactness)	3.9 [±0.9]	3.3 [±1.0]	3.5 [±1.1]	3.5
Fuel load in forests (biomass. deadwood content)	3.9 [±1.2]	3.3 [±1.1]	3.5 [±1.1]	3.6
Atmospheric stability (lightnings)	3.2 [±1.2]	2.8 [±1.1]	3.1 [±1.2]	3.0

The table shows the same ranking of the level of importance of natural factors as in the previous table with some differences in the rankings of "Temperature", "Wind" and "Fuel load in forest". In this case, "Temperature" and "Wind" were equally important factors for the stakeholders in the future (4.1). "Fuel load in forests" had the higher importance (3.6) than "Fuel quality in forests" (3.5) in this context.

"Precipitation" had the highest level of importance (4.4) among the six natural factors and the highest-ranking from Action Forces (4.5) and Authorities (4.5). "Temperature" had the highest

ranking from Action Forces (4.3), whereas “Wind” was the most important factor for Scientists (4.3).

However, the importance of "Fuel quality in forests" and "Fuel load in forests" were the same for the stakeholders for present and future trends. "Fuel quality in forests" and "Fuel load in forests" were still the most important factors for Action Forces, in comparison with other stakeholders. Both of these factors were ranked second highest by Scientists, then by Authorities.

“Atmospheric stability” was still considered the least important factor among the six natural factors (3.0), with the lowest ranking from Authorities (2.8).

Across the two tables, it is apparent that, on average, there is a significant difference in the level of importance of the six natural factors in the present and future trends. In fact, for Scientists, Authorities and Action Forces, all of the six natural factors were more important in the future trend fire regime than in the present trend.

Last but not least, Action Forces always perceived the level of importance of “Fuel quality in forests” to be higher than the other two groups did, both in the present and the future trends. However, there is a big difference in the perception of Action Forces group between the present and the future trends (3.2 and 3.9), while of Authorities (3.0 and 3.3) and Scientists (3.1 and 3.5).

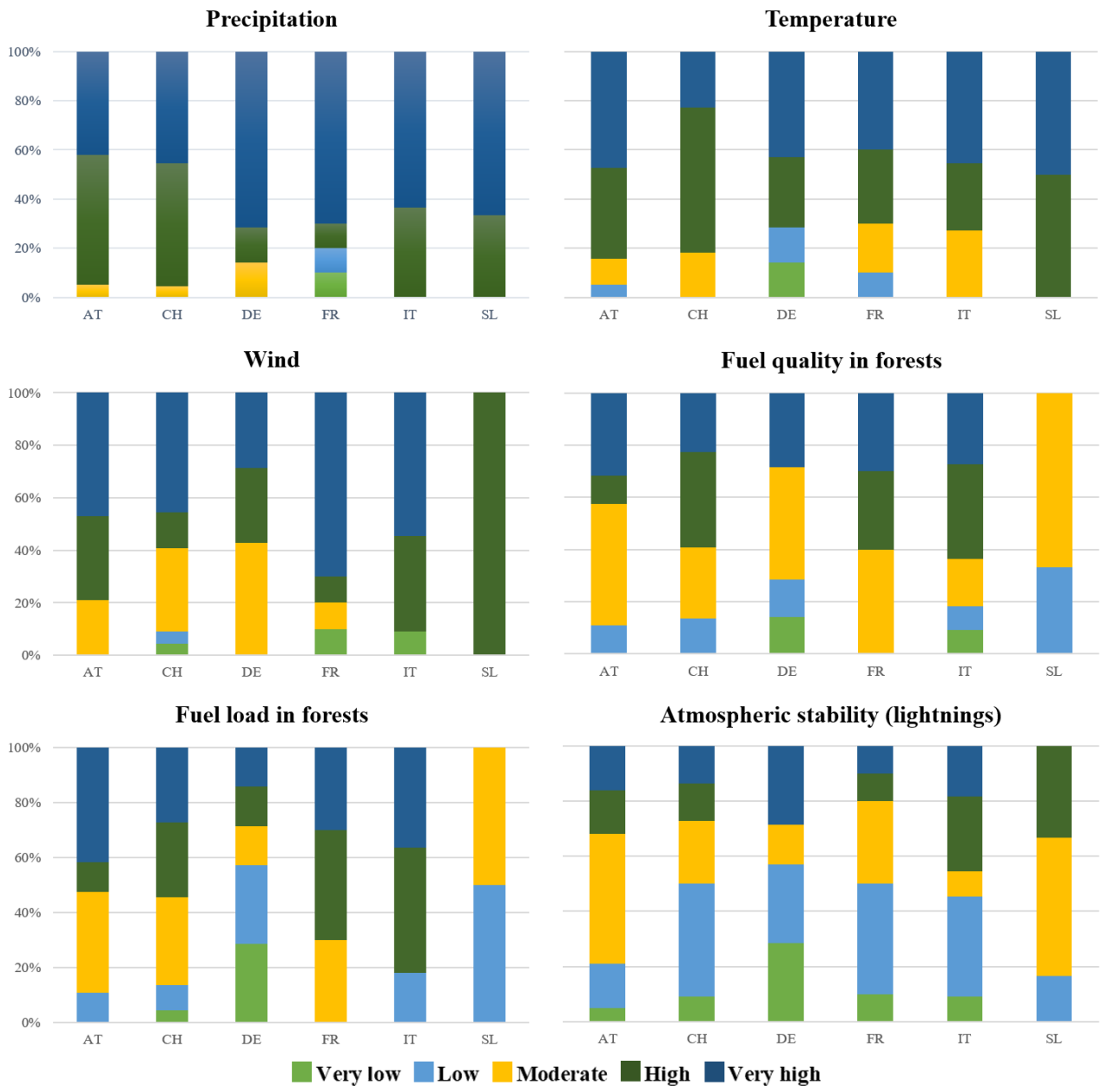

Figure 6*. Perception about the importance of natural factors for the future trend among six countries (estimates in %).*

"Precipitation" was considered to be of high and very high importance as a driver for the future trend by most of the stakeholders from all of the six countries “Temperature” was estimated to have from moderate to very high levels of importance in Switzerland, Italy and Slovenia. The minority of stakeholders from Austria and France also considered “Temperature” of low

importance, whereas some stakeholders from Germany thought that “Temperature” had very low importance in the future trend.

All of the stakeholders from Slovenia estimated “Wind” to be a highly important driver for the future trend. However, a minority of stakeholders from Switzerland, France, and Italy considered the factor “Wind” to be of very low importance in this context.

The importance of "Atmospheric stability" varied in all levels of importance from very low to very high in the estimation of the stakeholders from Austria, Switzerland, France, and Italy. None of Germany's stakeholders considered "Atmospheric stability" to be highly important, and none from Slovenia consider saw "Atmospheric stability" as a factor of very low or very high importance.

“Fuel quality in forests” was considered to have moderate importance by some stakeholders across the six countries.

The stakeholders from Switzerland and Germany estimate “Fuel load in forests” to have varying importance from very low to very high. In Slovenia, “Fuel load in forests” was considered to be of only low and moderate importance.

3.4. Socio-economic factor preconditions and trends

3.4.1. Socio-economic factor in the present fire regime

Table 4 illustrates the importance of the eight socio-economic factors as drivers for the present fire regime in the Alpine region of the stakeholders' country.

Table 4. Average rank of the importance of the socio-economic factors as drivers <u>for the present fire regime</u> in the alpine region of your country (from 1 - very low to 5 - very high)				
Socio-economic factors	**Action Forces [SD]**	**Authorities [SD]**	**Scientists [SD]**	**Average [SD]**
Recreational activities	3.4 [±1.1]	3.2 [±1.0]	3.2 [±1.0]	3.3
Rural abandonment	3.9 [±0.9]	2.2 [±1.1]	2.9 [±1.2]	3
Owner awareness	3.3 [±1.1]	2.5 [±1.1]	2.8 [±1.1]	2.9
Change in forest management	3.6 [±0.9]	2.3 [±0.8]	2.8 [±0.9]	2.9
Traditional uses of fires	2.7 [±0.9]	2.8 [±1.0]	2.6 [±1.0]	2.7
Administrative reforms	3.2 [±1.0]	2.3 [±1.0]	2.1 [±1.0]	2.5
Change of infrastructure	2.7 [±1.0]	2.4 [±1.2]	2.4 [±0.9]	2.5
Intentional fires (arson)	2.6 [±0.9]	2.0 [±1.1]	2.6 [±0.9]	2.4

From the table, it is apparent that, on average, all Action Forces, Authorities, and Scientists rated “Recreational activities” as the most important socio-economic driver (3.3). “Rural abandonment” was ranked second (3.0). “Owner awareness” (2.9) and “Change in forest management” (2.9) came in the third place of the ranking. “Traditional uses of fires” (2.7) was ranked immediately after those factors. “Administrative reforms” and “Change of infrastructure” came in fifth place with an equal level of importance (2.5). “Intentional fires” is the socio-economic factor which was considered to be the least important driver for the present trend in this context (2.4).

“Recreational activities” was considered to be the most important factor by all of three groups of stakeholders, namely Action Forces (3.4), Authorities (3.2) and Scientists (3.2). While for the four factors of “Rural abandonment”, “Change in forest management”, “Owner awareness” and “Administrative reforms”, both Authorities and Scientists considered these factors to be less important than Action Forces did, especially Rural abandonment was considered to be of high importance by Action Forces (3.9).

"Traditional uses of fires" was estimated to be relatively important (2.7) by all of the three stakeholder groups.

"Change of infrastructure" had the same importance for both Authorities and Scientists, which was slightly less than the medium level of importance (2.4), whereas its importance was seen differently by Action Forces, with a higher level of importance (2.7). "Intentional fires" was considered of slightly more than medium importance for Action Forces and Scientists (2.6), whereas Authorities thought of "Intentional fires" as the least important factor among all of the eight studied factors (2.0).

3.4.2. Socio-economic factor in the future fire regime

Table 5 illustrates the answers of the three stakeholder groups to the questions about the importance of the eight socio-economic factors as drivers for the future trend in the Alpine region.

Table 5. Average rank of the importance of socio-economic factors as drivers <u>for the future trend</u> in the alpine region of your country. (from 1 - very low to 5 - very high)

Socio-economic factors	Action Forces [SD]	Authorities [SD]	Scientists [SD]	Average [SD]
Recreational activities	3.1 [±1.0]	3.3 [±1.1]	3.1 [±1.0]	3.2
Rural abandonment	3.5 [±1.1]	2.5 [±1.2]	3.1 [±1.6]	3.0
Owner awareness	3.3 [±1.0]	2.7 [±1.3]	3.1 [±1.2]	3.0
Change in forest management	3.3 [±1.0]	2.6 [±1.0]	2.9 [±1.1]	2.9
Traditional uses of fires	3.0 [±0.9]	2.7 [±1.1]	2.4 [±0.8]	2.7
Administrative reforms	2.9 [±0.8]	2.5 [±1.2]	2.5 [±1.3]	2.6
Change of infrastructure	2.4 [±1.0]	2.4 [±1.2]	2.4 [±1.0]	2.4
Intentional fires (arson)	2.5 [±1.3]	2.1 [±1.1]	2.7 [±0.8]	2.4

On average, it can be seen that "Recreational activities" was the most important factor (3.2) for the stakeholders. "Owner awareness" and "Rural abandonment" shared the second place in the ranking (3.0), and "Change in forest management" came in the third place (2.9). Next in the ranking were "Traditional uses of fires" (2.7) and "Administrative reforms" (2.6). "Change of infrastructure" and "Intentional fires" were the least important factors for the stakeholders in this context.

The top three most important factors were perceived to be of relatively high importance by both Action Forces and Scientists (from 3.1), especially (3.5) for "Rural abandonment" from the Action Forces. However, Authorities had different ratings of level of importance for "Recreational activities", "Owner awareness", and "Rural abandonment" (3.3; 2.7; 2.5, respectively). "Owner awareness" was considered to be quite important by both of Action Forces and Scientists (3.3; 3.1, respectively); whereas this factor was less important for Authorities (2.7).

"Traditional uses of fires" had a high rating of importance for Action Forces (3.0), whereas for Authorities and Scientists the level of importance of this factor varied (2.7; 2.4, respectively). The factors of "Administrative reforms", "Change of infrastructure" and "Intentional fires", interestingly, were rated under (3.0) in the level of importance by Action Forces, Authorities, and Scientists.

Between this table and the previous one, it can be seen that "Recreational activities", "Owner awareness" and "Rural abandonment" were the most important socio-economic factors for both present and future trends. Action Forces and Scientists tended to have similar opinions of the level of importance for most of the factors, whereas the levels of importance varied for Authorities.

Another significant result is that the Action Forces group expected the level of importance of "Rural abandonment" to decrease from (3.9) in the present to (3.5) in the future, while both of Authorities and Scientists groups perceived that "Rural abandonment" would have an increasing level of importance in forest ignition in the future. Despite the decrease, the importance level of "Rural abandonment" was still rated higher by Action Forces than by other two groups, both in the present and the future trends.

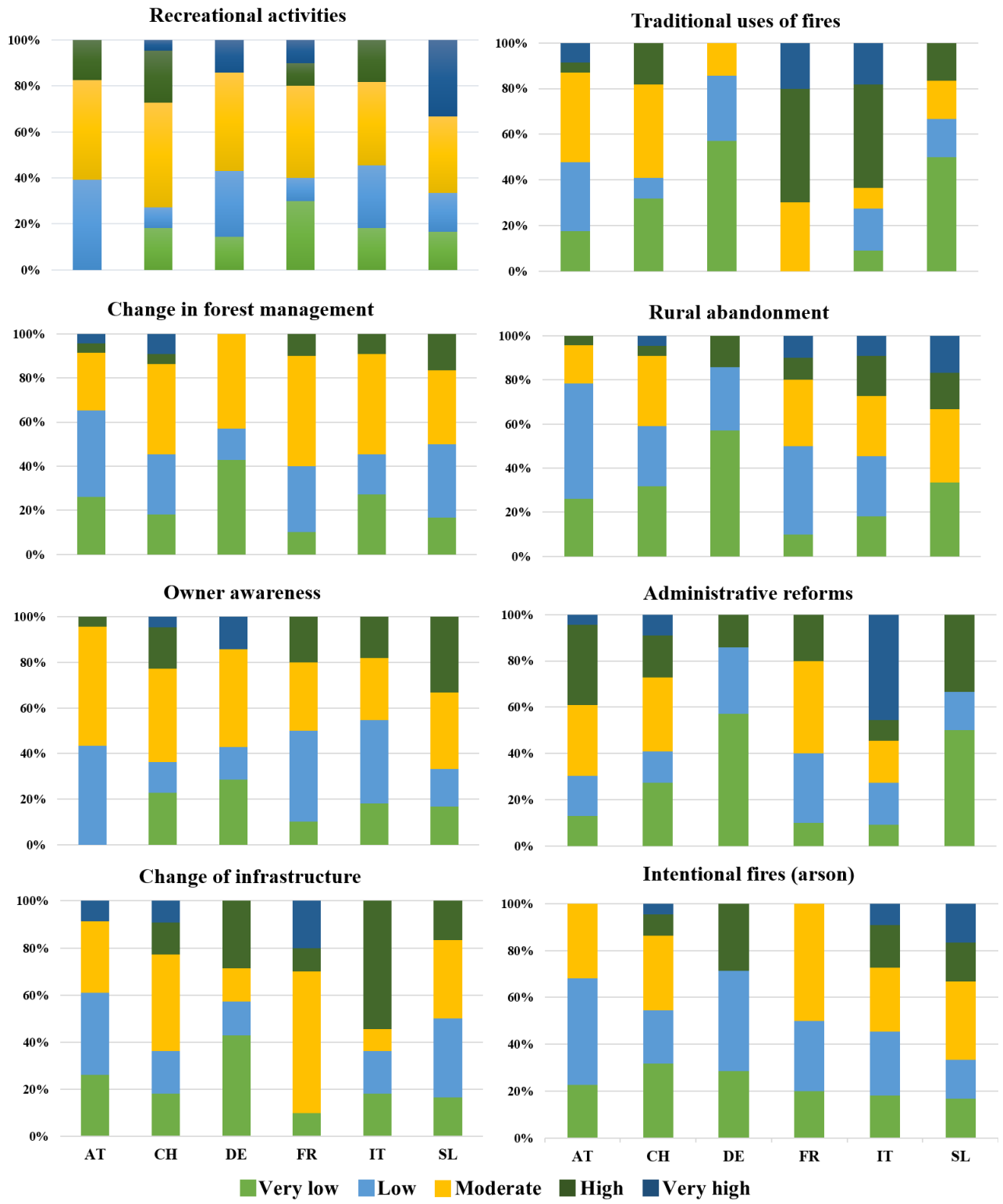

Figure 7*. Perception about the importance of socio-economic factors for the future trend among six countries (estimates in %).*

3.5. Comparison of the priorities for fire management options among stakeholder groups

3.5.1. Authorities

Figure 8 illustrates the Authorities' evaluation of the estimated efficiency in controlling the forest fire situation in the respective country.

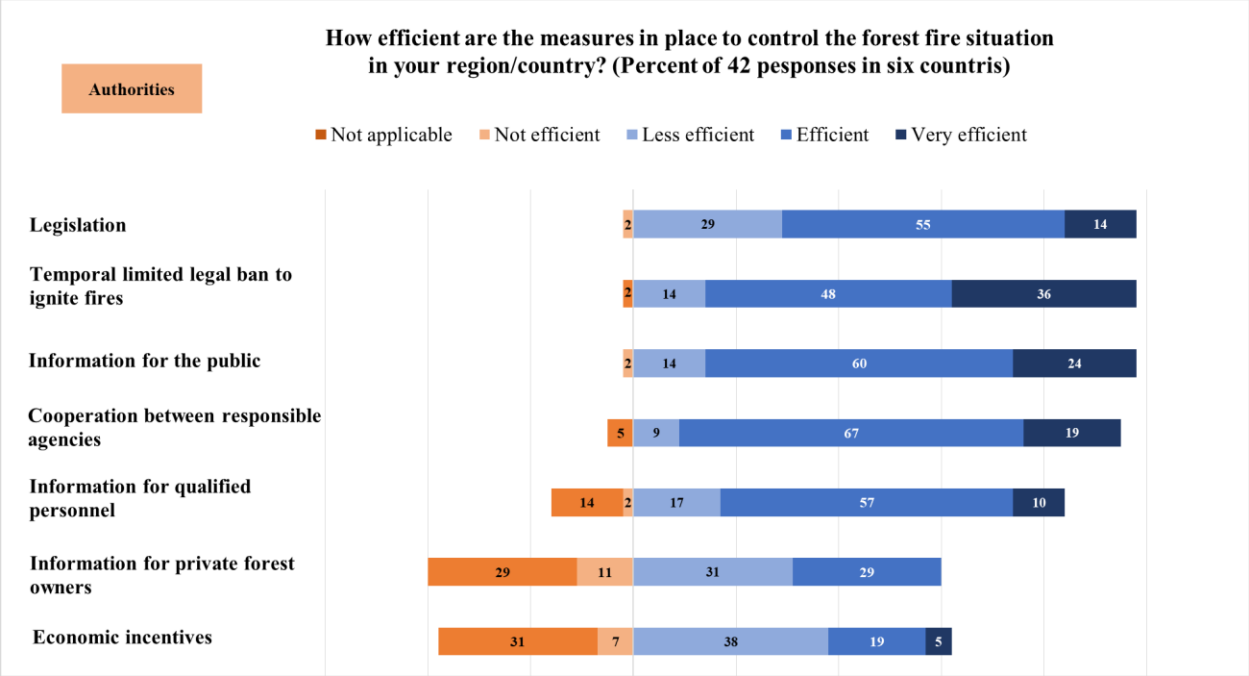

Figure 8. *Authorities' perception about the estimated efficiency in controlling the forest fire situation (estimates in %).*

From the data, it can be seen that "Cooperation between responsible agencies" was the first priority for Authorities as 86% of them considered it to be an efficient and very efficient measure. Both of "Temporal limited legal ban to ignite fires" and "Information for the public" were ranked second in the list of priority with 84% of Authorities listing them as efficient and very efficient measures.

"Legislation" and "Information for qualified personnel" were the third and fourth highest priorities in this context, with 69% and 67% of Authorities perceiving them to be efficient and very efficient, respectively.

"Information for private forest owners" measure was the second-lowest priority with only 29% of Authorities considering it to be efficient and 31% thinking it to be less efficient. "Economic incentives" was considered to be of lowest priority as only 24% of Authorities perceiving it as an

efficient and very efficient measure, whereas 38% of them perceiving it to be a less efficient measure.

3.5.2. Scientists

Figure 9 illustrates the Scientists' evaluation of the estimated efficiency in controlling the forest fire situation in the respective country.

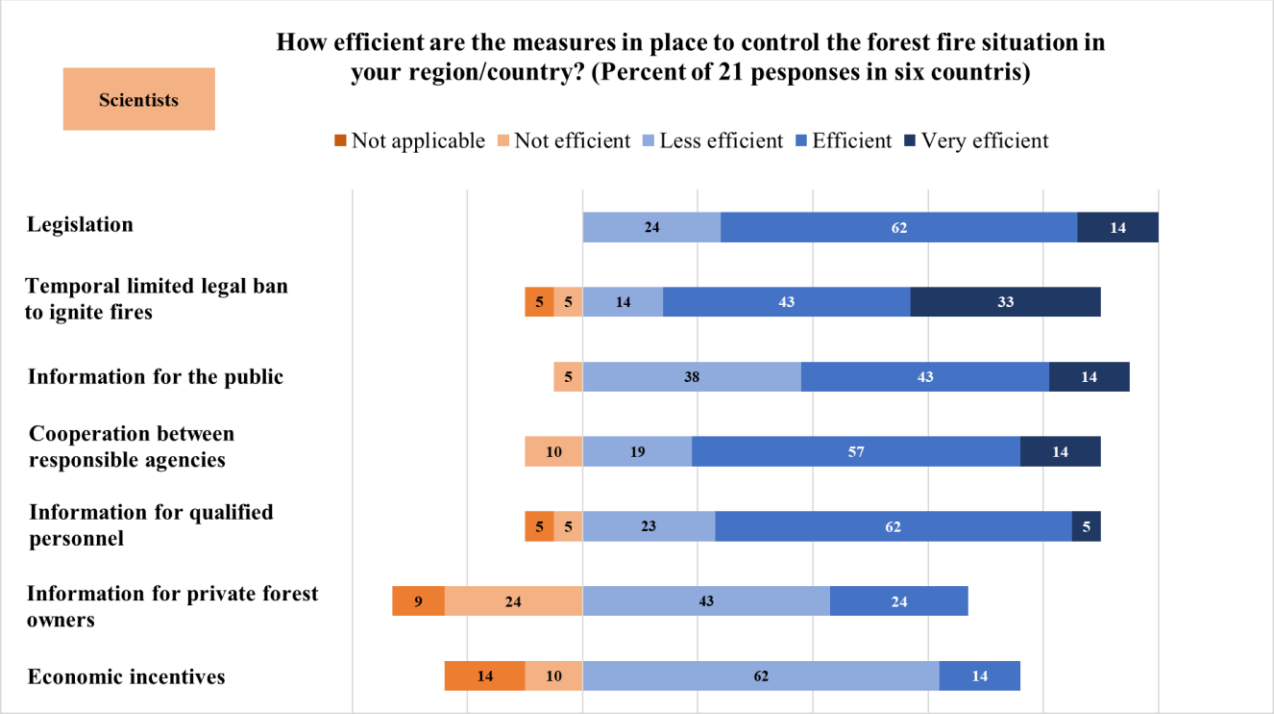

Figure 9. *Scientists' perception about the estimated efficiency in controlling the forest fire situation (estimates in %).*

It can be seen from the data that “Legislation”, “Temporal limited legal ban to ignite fires” were the measures of the highest priority for Scientists, with 76% of them estimating them to be efficient and very efficient measures.

“Cooperation between responsible agencies”, “Information for qualified personnel” and “Information for the public” were ranked as the second, the third, and fourth priority with 71%, 67%, and 57% of Scientists listing them as efficient and very efficient measures, respectively.

“Information for private forest owners” was listed as the second-lowest priority, with 24% of Scientists evaluating it as efficient and 43% of them considering it to be less efficient. “Economic

incentives" was the measure of the lowest priority with only 14% of Scientists perceiving it as efficient, whereas for 62% of Scientists, "Economic incentives" was a less efficient.

3.5.3. Action forces

Figure 10 illustrates the Action Forces' evaluation of the estimated efficiency in controlling the forest fire situation in the respective country.

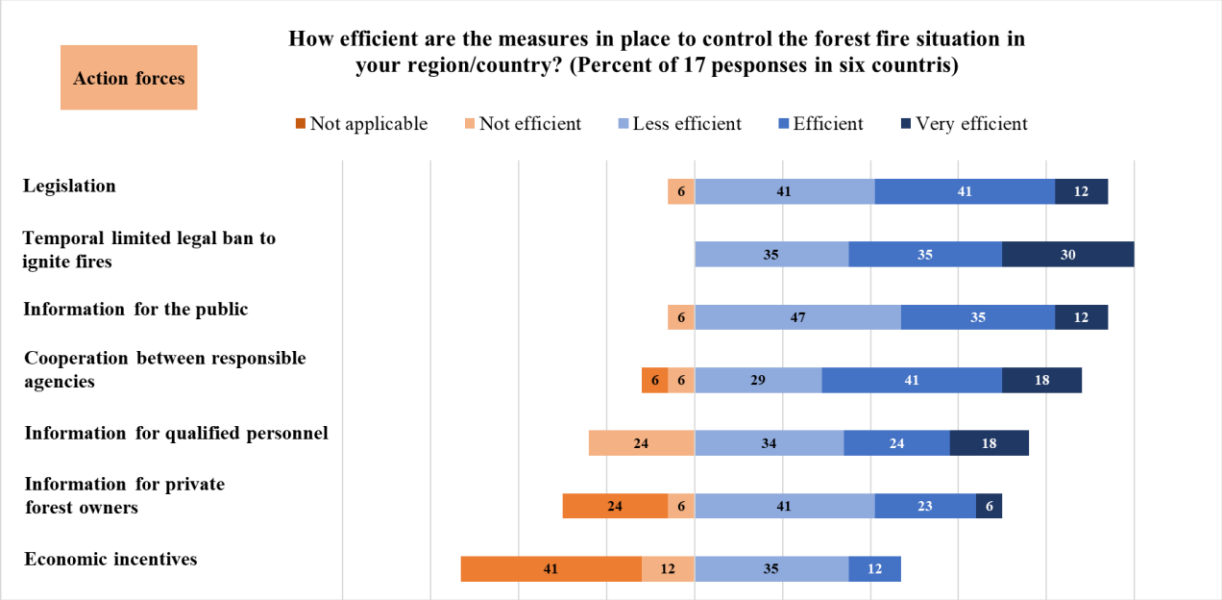

Figure 10. *Action forces' perception about the estimated efficiency in controlling the forest fire situation (estimates in %).*

"Temporal limited legal ban to ignite fires" was the top priority as 65% of Action forces listing it as an efficient and very efficient measure. None of them perceived this measure to be not efficient or not applicable. "Cooperation between responsible agencies", "Legislation" and "Information for the public" came in the second, third, and fourth place of priority, with 59%, 53%, and 47% of Action Forces listing them to be efficient and very efficient measures, respectively.

The top lowest priorities were "Economic Incentives", "Information for private forest owners" and "Information for qualified personnel". Specifically, 42% of Action forces listing "Information for qualified personnel" as an efficient and very efficient measure, 29% having the same evaluation for "Information for private forest owners", making it the second-lowest priority. Only 12% of Action Forces saw "Economic incentives" to be an efficient measure, whereas 53% of them thought of it as a not efficient and not applicable measure.

Across the three graphs, it is apparent that the top three priorities for Authorities, Scientists, and Action Forces were "Temporal limited legal ban to ignite fires", "Cooperation between responsible agencies" and "Legislation". The two measures with the lowest priorities for the three groups of stakeholders were "Economic incentives" and "Information for private forest owners".

Apart from the seven measures listed in the survey, respondents could suggest additional measures which they thought to be efficient to control the forest fire situation in their respective region. The suggested measures were daily fire danger prediction, patrol of critical zones, reduction of fuel biomass, attack of incipient fires, burning ban all year round, prescribed burning, boards with danger levels, cartography of priority areas, and joint expert consultations.

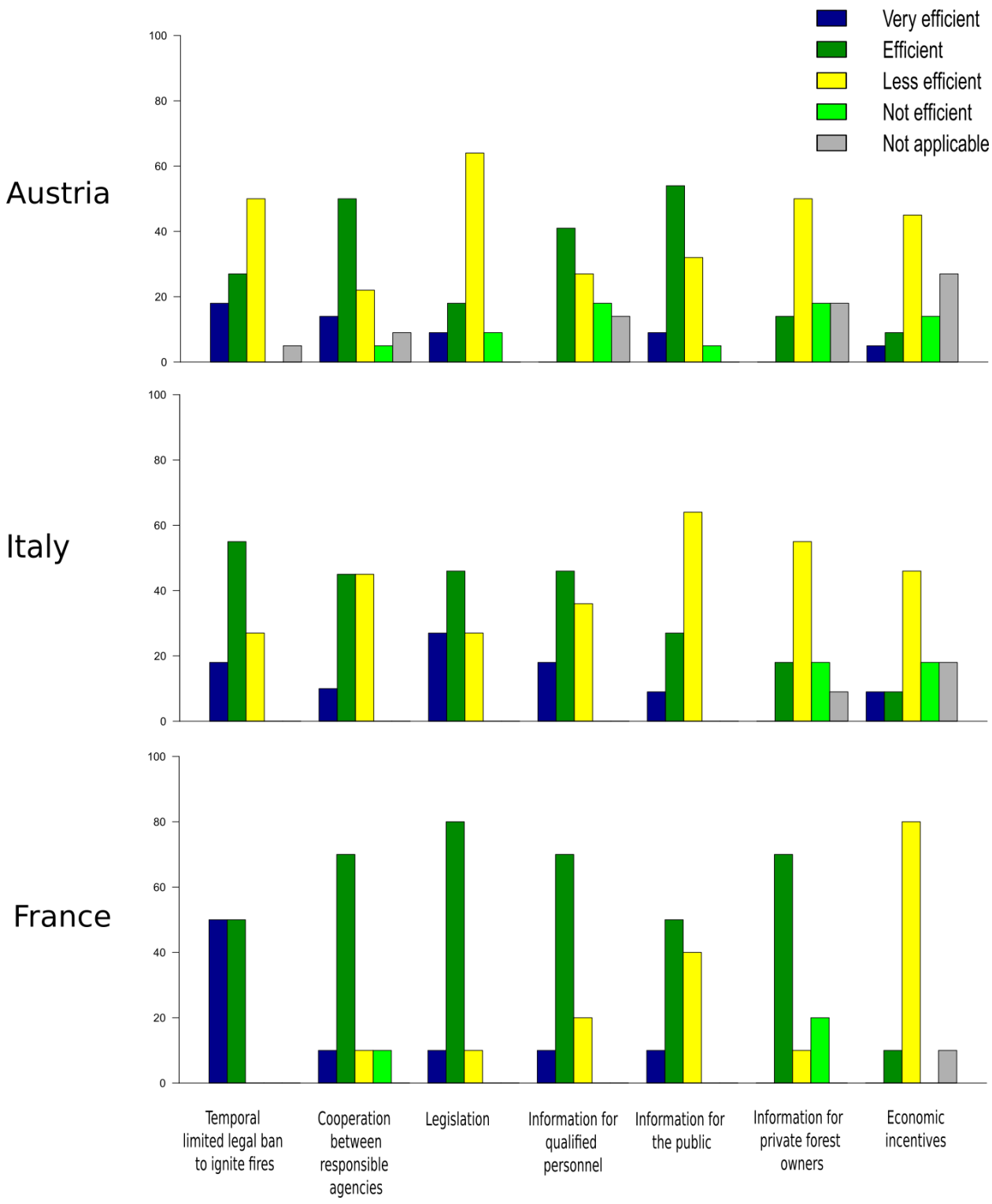

Figure 11. *Respondents' perception about the estimated efficiency in controlling the forest fire in Austria, Italy, and France (estimates in % from 23, 11 and 10 respondents from Austria, Italy, and France)*

Figure 11 illustrates the responses of stakeholders from three countries of the Alpine region including Austria, Italy, and France. "Legislation" was considered an efficient measure by 80% of the stakeholders from France, and 46% of the stakeholders from Italy, whereas only 18% of the stakeholders from Austria shared the same view. Furthermore, while only a small number of stakeholders from France and Italy considered "Legislation" a less efficient measure (10% and 27%, respectively), the majority of stakeholders from Austria (64%) perceived this measure to be less efficient.

A “Temporal limited legal ban to ignite fires” was seen by half of stakeholders from Austria as a less efficient measure, while only 27% of stakeholders from Italy considered this, and none from France shared the same view. 50% of the stakeholders from France and 55% of the stakeholders from Italy considered this measure efficient, whereas only 27% of the stakeholders from Austria share the same opinion. The measure “Temporal limited legal ban to ignite fires” was also considered very efficient by half of the stakeholders from France, while only a small percentage of 18% of those from Austria and Italy had the same impression. Additionally, 5% of the stakeholders from Austria considered this measure not applicable, whereas none from Italy and France shared the same view.

“Information for the public” was seen as a very efficient measure by a relatively small percentage of stakeholders from Austria, Italy, and France (9%, 9%, 10%, respectively). The highest percentage of the stakeholders from Austria and France (54% and 50%, respectively) perceived it as an efficient measure, whereas the highest number of stakeholders from Italy (64%) saw it as a less efficient measure. Additionally, 5% of the stakeholders from Austria considered this measure not efficient, while none from Italy and France shared the same view.

“Information for qualified personnel” was not seen as a very efficient measure by the stakeholders in Austria, while 18% and 10% of the stakeholders in Italy and France saw it as a very efficient measure. The majority of stakeholders from Austria, Italy, and France shared the same perspective that “Information for qualified personnel” was an efficient measure (41%, 46%, 70%, respectively). Additionally, this measure was considered not efficient and not applicable by the stakeholders in Austria (18% and 14%, respectively), whereas none from Italy and France shared similar perspective.

For "Information for private forest owners", the majority of stakeholders from Austria and Italy perceived it to be a less efficient measure (50% and 55%, respectively), while only 10% of the stakeholders in France shared the same view. In fact, 70% of the stakeholders from France considered this to be an efficient measure, while the percentage of the stakeholders in Austria and Italy sharing the similar opinion was very low (14% and 18%, respectively). All of the three countries had relatively the same percentage of stakeholders who considered this measure not efficient (18%, 18%, 20% for Austria, Italy, and France, respectively). 18% of the stakeholders from Austria, and 9% from Italy perceived this measure to be not applicable, while none from France shared the similar perspective.

For "Economic incentives" was seen by the highest percentage of stakeholders from Austria, Italy, and France as a less efficient measure (45%, 46%, 80%, respectively). All of the three countries also had relatively the same percentage of stakeholders who perceived it to be an efficient measure (9%, 9%, 10% for Austria, Italy, and France). A small number of stakeholders from Austria and Italy thought of it as a very efficient and not efficient measure, while these two perceptions were not available in France.

“Cooperation between responsible agencies” was commonly seen as an efficient measure by the highest percentage of stakeholders from all of the three countries (50%, 45%, 70% for Austria, France, and Italy, respectively). Additionally, 45% of the stakeholders in Italy saw it as a less efficient measure, while the percentage of stakeholders from Austria and France sharing the same perspective was only 22% and 10%. A small percentage of stakeholders from Austria, Italy and France (14%, 10%, 10%, respectively) also considered it as a very efficient measure. 5% of the stakeholders from Austria and 10% of those from France perceived this measure to be not efficient, while none from Italy shared the same view. Additionally, only a small percentage of stakeholders from Austria (9%) thought that this was not an applicable measure.

3.6. Barriers in stakeholders’ collaboration

3.6.1. Authorities

Figure 12 illustrates the perception of Authorities which barriers hinder a successful implementation of forest fire management practices in the present and future.

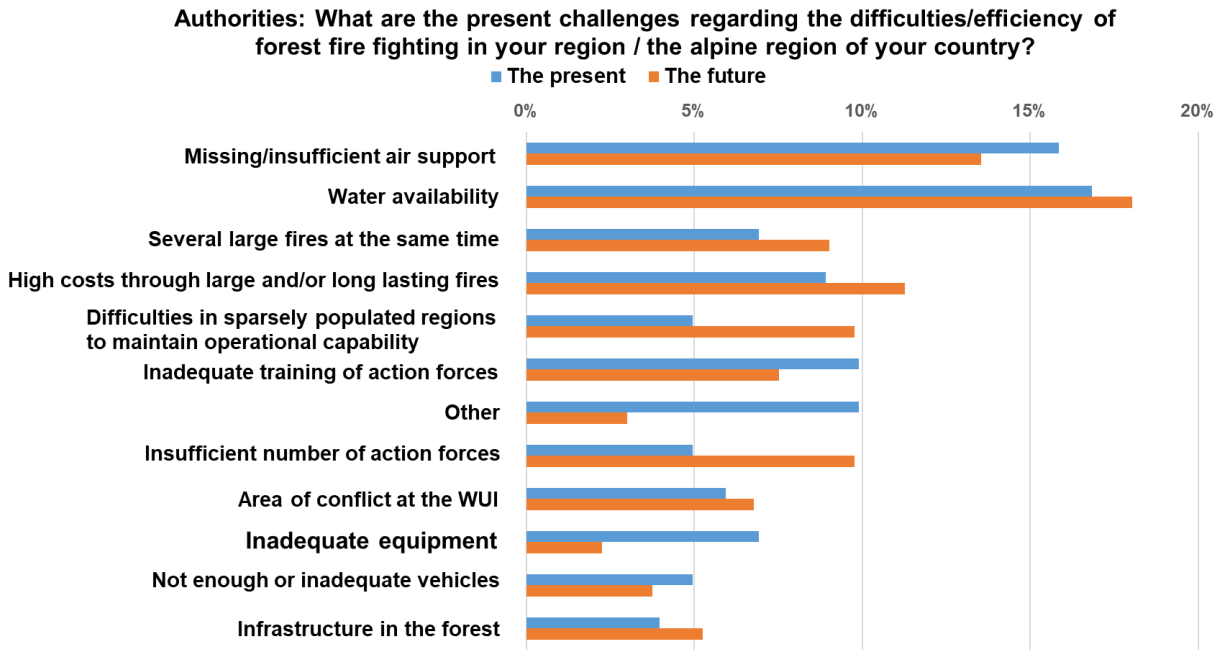

Figure 12. Authorities ' perception about different challenges for the present and future of forest fire fighting (estimates in %).

For the present forest fire fighting, "Water availability", and "Missing/insufficient air support" were the two most common challenges for Authorities, with 17% and 16% of them choosing these two options, respectively. In the third place were "Inadequate training of action forces", and "Other", with 10% of responses for each option. In the fourth, fifth, and sixth place were "High costs through large and/or long-lasting fires", "Inadequate equipment", "Several large fires at the same time", and "Area of Conflict at the wildland-urban-interface" with 9%, 7%, 7%, 6% of Authorities opting for these challenges, respectively. The second least common challenges for Authorities were "Insufficient number of action forces", "Not enough or inadequate vehicles", and "Difficulties in sparsely populated regions to maintain operational capability" with 5% of responses each. The "Infrastructure in the forest" was seen as the least common challenge for Authorities, with only 4% of the respondents choosing this option.

For the future forest fire fighting, the top three challenges for Authorities were "Water availability", "Missing/insufficient air support", and "High costs through large and/ or long-lasting fires", with 18%, 14%, and 11% of Authorities choosing these options, respectively. In the fourth place were "Insufficient number of action forces", and "Difficulties in sparsely populated regions to maintain operational capability" with 10% of responses for each option. "Several large fires at

the same time" came in the fifth place with 9% of responses, "Inadequate training of action forces" the sixth place with 8%, "Area of conflict at the wildland-urban-interface" the seventh with "Infrastructure in the forest", "Not enough or inadequate vehicles", "Other", and "Inadequate equipment" were seen as the least common challenges for Authorities, with 5%, 4%, 3%, and 2% of responses respectively.

3.6.2. Scientists

Figure 13 illustrates the perception of Scientists for different challenges for the present and future in fighting forest fires.

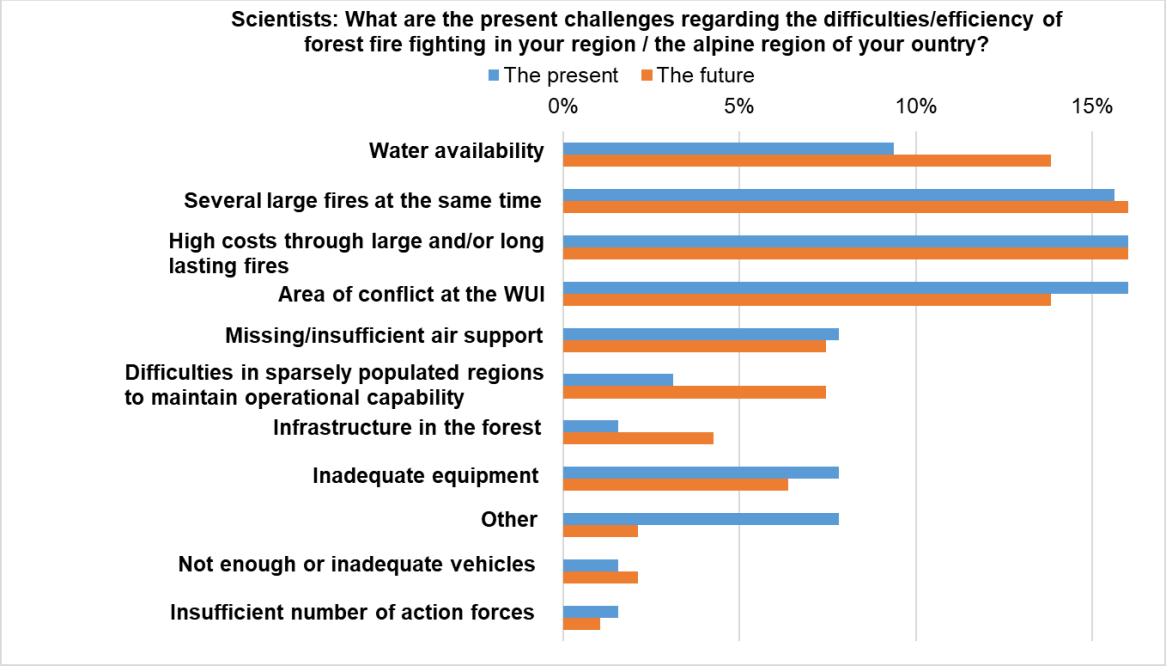

Figure 13. *Scientists' perception about different challenges for the present and future of forest fire fighting (estimates in %).*

For the present forest fire fighting, the top four challenges of Scientists were "Area of conflict at the wildland-urban-interface" (19%), "High costs through large and/or long-lasting fires" (17%), "Several large fires at the same time" (16%) and "Water availability" (9%). Listed as the fifth common challenges by 8% of Scientists were "Inadequate equipment", "Inadequate training of action forces", "Missing/insufficient air support" and "Other". "Difficulties in sparsely populated regions to maintain operational capability" was the second least common challenge with only 3% of responses. The least common challenges for Scientists in this context were "Insufficient number

of action forces", "Not enough or inadequate vehicles" and "Infrastructure in the forest", with only 2% of Scientists agreeing on these options.

For the future of forest fire fighting, the top two challenges for Scientists were "Several large fires at the same time" and "High costs through large and/or long-lasting fires", with 19% and 17% of responses, respectively. In the third place were "Water availability" and "Area of conflict at the wildland-urban-interface" with 14% of Scientists choosing these options. "Missing/insufficient air support" and "Difficulties in sparsely populated regions to maintain operational capability" shared the fourth place in the most common challenges with 7% of responses each. The fifth common challenge was "Inadequate equipment" with 6% of responses, the sixth was "Inadequate training for action forces" with 5%, and the seventh was "Infrastructure in the forest" with 4%. The second least common challenges were "Not enough or inadequate vehicles" and "Other" with only 2% of Scientists opting for these options. The least common challenge for Scientists in this case was "Insufficient number of action forces", with only 1% of them agreeing on this option.

Across the three graphs, it can be seen that for the present forest fire fighting, one of the top challenges for all stakeholders was "High costs through large and/or long-lasting fires". Action forces and Authorities also considered "Missing/insufficient air support" as one of the top challenges. One of the least common challenges for all stakeholders was "Infrastructure in the forest". Authorities and Scientists also saw "Not enough or inadequate vehicles" as one of the least common challenges.

For future forest fire fighting, the top challenges for all three groups of stakeholders were "Water availability" and "High costs through large and/or long-lasting fires". Action forces and Scientists also considered "Several large fires at the same time" as one of the top challenges. Some of the least common challenges for all stakeholders were "Infrastructure in the forest" and "Other". Additionally, Action forces and Authorities saw "Inadequate equipment" as one of the least common challenges.

3.6.3. Action Forces

Figure 14 illustrates how Action forces perceived different challenges for the present and future of forest fire fighting.

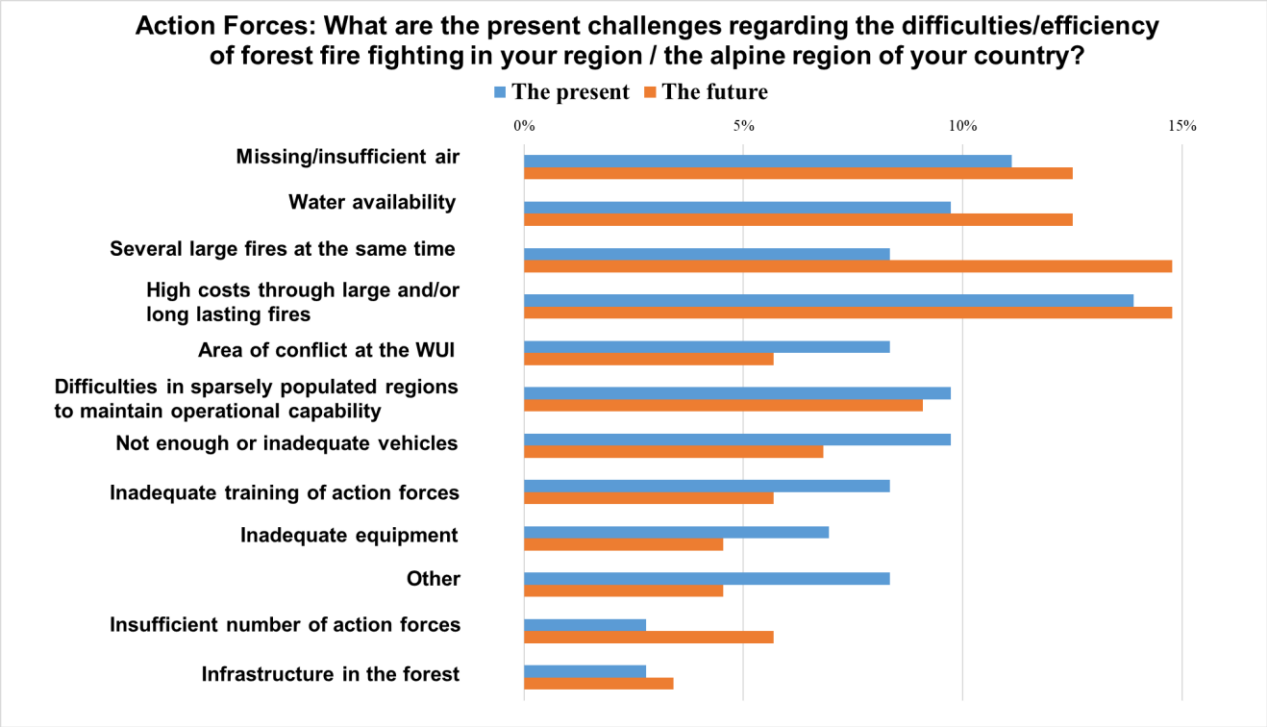

Figure 14. Action forces' perception about different challenges for the present and future of forest fire fighting (estimates in %). .

For the present forest fire fighting, "High costs through large and/or long-lasting fires" and "Missing/insufficient air support" were seen as the top two challenges, with 14% and 11% of Action forces choosing these options, respectively. In the third place were "Not enough or inadequate vehicles", "Water availability" and "Difficulties in sparsely populated regions to maintain operational capability" with 10% of Action Forces agreeing on each option. 8% of Action Forces chose "Inadequate training of action forces", "Several large fires at the same time", "Area of conflict at the wildland-urban-interface (WUI)" and "Other", putting them in the fourth place of the most popular challenges. "Inadequate equipment" came next with 7% of Action Forces choosing this option. The two challenges which were chosen by only 3% of Action forces were "Insufficient number of Action Forces" and "Infrastructure in the forest".

For the future of forest fire fighting, "Several large fires at the same time" and "High costs through large and/or long-lasting fires" were the two most common challenges with 15% of Action Forces choosing each option. The second most common challenges chosen by 13% of Action forces were "Missing/insufficient air support" and "Water availability". In the third and fourth place of the top challenges were "Difficulties in sparsely populated regions to maintain operational capability" and

"Not enough or inadequate vehicles" with 9% and 7% of responses, respectively. 6% of Action forces responded to "Insufficient number of action forces", "Inadequate training of action forces", and "Area of conflict at the wildland-urban-interface (WUI)", making them the fifth most common challenges. "Inadequate equipment" and "Other" are the second least common challenges, with only 5% of Action forces agreed on these two options. The least common challenge is "Infrastructure in the forest", with only 3% of Action Forces choosing this option.

To sum up, for the present and future forest fire fighting, "Missing/insufficient air support", "Water availability", "Several large fires at the same time" and "High costs through large and/or long-lasting fires" were the top challenges, whereas "Infrastructure in the forest" was one of the least common challenges for all stakeholders.

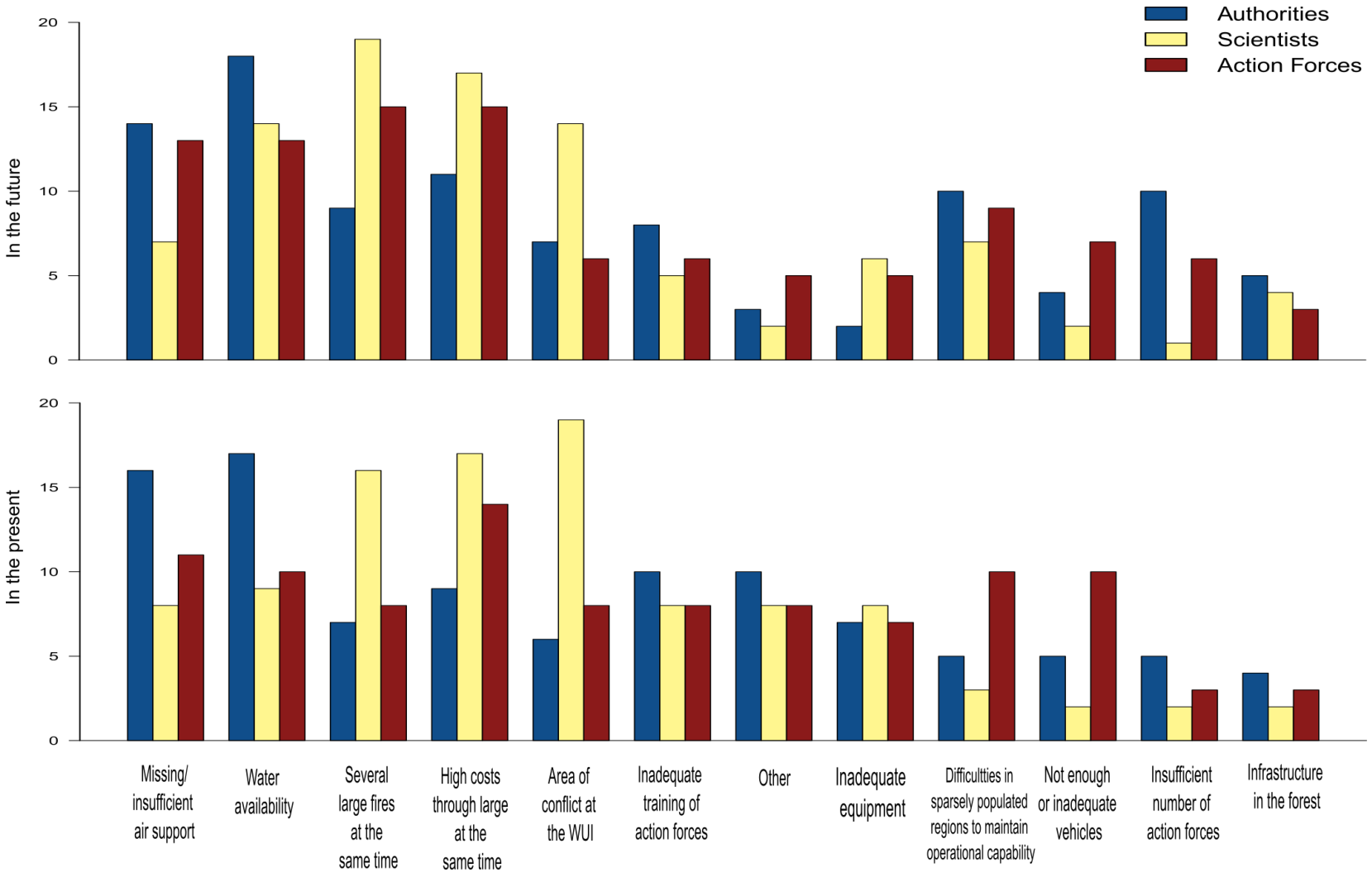

Figure 15. *All three group's perception about different challenges for the present and future of forest fire fighting (estimates in %)*

4. DISCUSSION

The respective results are discussed for each of the four hypotheses in combination with the additional comments from forest fire experts of the workshop and relevant literature research findings.

4.1 Differences between authorities, scientists, and action forces regarding the perception of the current and future forest fire regime

a. Stakeholder's perception about the number of forest fires

All stakeholders believed that there would be an increase in the number of fires for the next ten years, and there would not be a strong decrease in the number of fires in the Alpine region. The reasons for the increase in the number of forest fires in the Alpine region in the upcoming years are related to the increased intensity of drought periods and heat waves, as well as an increased fire hazard resulting from rural abandonment and recreational activities (Müller et al., 2020).

The views of different stakeholder groups related to the increased number of fires in the future might be partly explained by the fire statistics data shown in Figure 16. During the time between 2006 and 2017, the number of fires was observed tremendous, with a sharp increase occurring in the years 2011, 2012, 2015 and 2017 when extreme weather phenomena occurred.

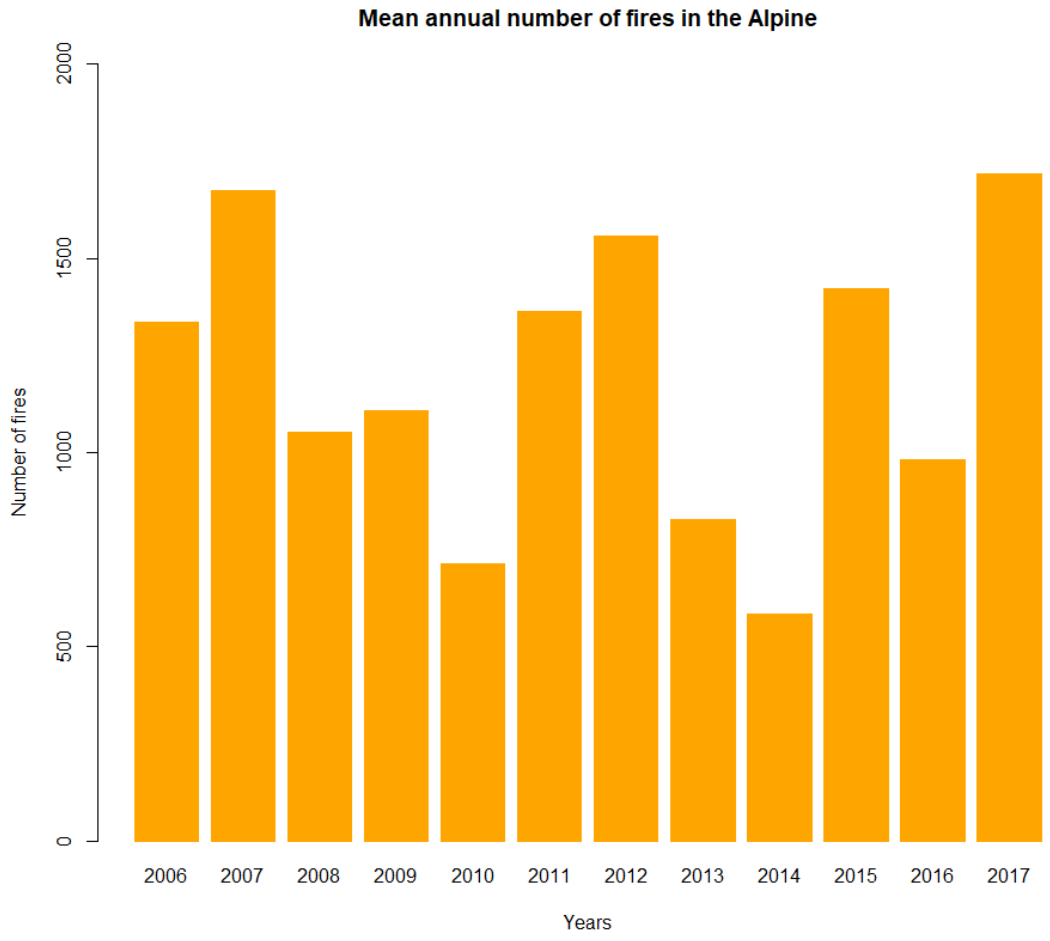

Figure 16. *The mean annual number of fires in the Alpine region from 2006 to 2017 (No data available for Germany and Liechtenstein. Source: National/regional databases)*

The Scientists group estimates the overall future trend for the number of fires significantly lower compared to the Action Forces groups in the Alpine region. While Scientists tend to make cautious forecasts by evaluating both scenarios of the increase and decrease in the number of forests fires, Action Forces tend to view that there will be an increase and strong increase in the number of forest fires. One of the reasons could originate from the fact that predicting forest fire trends is complex and its activities need to be considered based on different criteria as well as are often difficult to judge based on pure observations (Raftoyannis et al., 2014). For instance, in the discussion within the scope of the workshop of the forest fire experts in Vienna in June 2019, the participants pointed out that there are differences in the perception about the yearly number of forest fires and burnt areas between the groups of Action Forces and Fire managers. Specifically, Fire managers have a more accurate perception compared with the observed data because one of

their main duty is to work with these data directly in order to perform the yearly forest fire management activities. This difference also can be justified by the statistics of forest fires showing that there is a decrease in the number of forest fires in 2010 and 2014 beside an increase in the number of forest fires in other years. Perhaps, this could come from the distinct approaches to evidence on the field or scientific evidence of each group of stakeholders. In other words, the perceptions of each group of stakeholders are dependent on their own background and experiences in different regions and under various fire regimes. Moreover, there seems to be the fact that the ‘‘certainty bias’’ (Kahneman and Tversky, 1979) will appear in making fire management decisions (Maguire and Albright, 2005). Often when fire managers face complex choices in decision-making, they tend to consider more “safe” options that they assume to be less risky. In the context of the need to estimate the trend of forest fires in the future, stakeholder groups will also have biases in their options.

On the other hand, all three groups of stakeholders from six countries believed that there would be an increase and no strong decrease in the number of fires in the Alpine region. All countries of the northern Alps had a tendency to expect a higher number of fires than those of the southern Alps do. Results have shown that there is a statistically significant difference in perception between Austria, Switzerland, and Germany - countries of the northern Alps, and Slovenia - a country in the Southern Alps. This result is also shared by Dupire et al. (2019) in their study, it seems that there could be more fire occurrences not only in the North but also in southern forests in the French Alps in the next few decades, although there are variations in natural conditions. As well as from others shows that the leading cause of fires in the Italian Alps was negligence; however, there was also an increase in the rate of fires from lightning (Vacchiano et al., 2018). This could be due to the perception that natural, social, and economic factors that cause forest fires tend to be more dangerous and alarming in countries of southern Alps like Slovenia. Additionally, stakeholders could improve their understanding of different future scenarios through learning about past success stories of forest fire management. These success stories could also inspire and enhance the belief in the activities of forest fire suppression and management, thereby, resulting in the different responses in participants’ perception of the level of fire number in the next ten years.

b. Comparison of the stakeholder's perception of burnt area

Stakeholder's perception about the burnt area

All of the three groups of stakeholders expected that there would be no strong decrease in the burnt areas in the future. In fact, all of them believed that there would be an increase in the burnt areas in the next ten years. These findings agree with the findings of recent years showed that current fire seasons are shifting and expanding, or even new fire seasons are developing (Müller et al., 2015). This means that late autumn and winter fires may become more relevant in the future, as the years 2011 (Schunk et al., 2013), 2015 and 2018 have already shown.

Similar to the number of fires, the increase in stakeholder perception of burned areas in the Alpine region can be explained by the forest fire statistics. It completely agreed with the observations from the survey participants that responded that there was not a strong decrease related burnt area of the Alpine region.

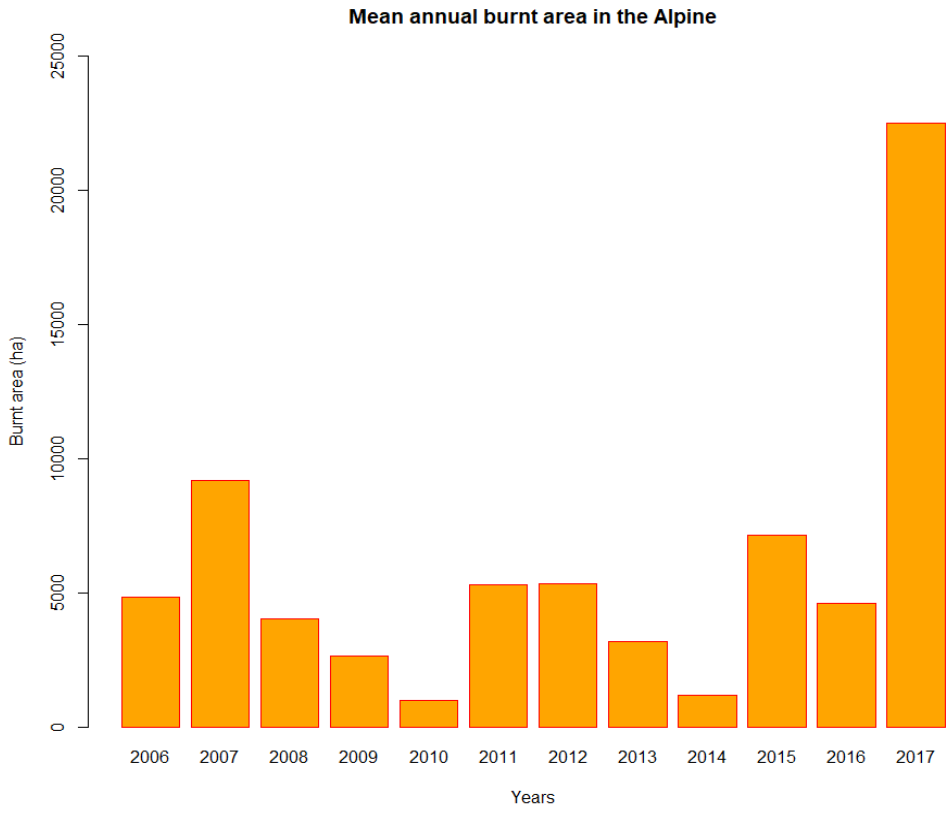

Figure 17. *The mean annual burnt area in the Alpine region from 2006 to 2017 (No data available for Germany and Liechtenstein. Source: National/regional databases)*

However, there are differences among the three groups of stakeholders such as experiences on the field, influence of the media on climate change, and news about consecutive forest fires in Brazil,

the U.S, and Australia. These factors could cause Action Forces to perceive a higher level of the burnt areas. Also, researchers might have more opportunities to gain access to information and to study experiences from other countries where there is a variety of fire situations. This could be a reason why the perceptions of researchers or Scientists are different from those of Authorities or Action Forces. Action forces often rely more on their own experiences in the field (Raftoyannis et al., 2014). Perception relating to natural, social, and economic factors, as well as the efficiency of techniques for forest fire forecast, measures of fuel management, based on evaluation in many consecutive years could be the evidence for the other two groups to share a different view with Action Forces. Besides, the forest fire statistics in this area reflecting the fluctuations in the burnt area shows that not only there is an increase in the burnt areas but also a decrease in some years. For instance, in the time periods from 2008 to 2010 and from 2013 to 2014, there is a decrease in the burnt area in the Alpine region.

All of the three groups of stakeholders in six countries of the Alpine region believed that there would be no strong decrease in the burnt areas in the near future. Countries of the northern Alps tended to perceive a higher level of burn areas than the southern Alps' countries. This is different from the result of the study by Dupire Curt and Bigot (2017), which indicated that in the case of the French Alps only, there is a difference in the level of the danger of forest fires between the South and the North, specifically, the danger of forest fires in the South is higher than it is in the North. The study of Conedera et al. (2018) should also be mentioned here. Their study showed that low terrains and higher population density in the areas of the northern Alps were expected to enhance fire ignition and spread. These findings could be explained by the differences in the perception of the nature of forest fires in different countries. Natural, economic, and social factors which cause forest fires in countries of the northern Alps like Austria and Switzerland tend to be more dangerous and alarming than those of the countries in the southern Alps like Slovenia. Along with South Tyrol and Aosta Valley with markedly mountainous character and continental climate which could have an impact on the occurrence of forest fires, this could also lead to differences in the perception of the three groups of stakeholders (Conedera et al., 2018a).

Besides, differences in measures of prevention and suppression, as well as fuel conditions could have different consequences on the level of burnt areas. Consequently, this could lead to the difference in the participants' perception of level of burnt areas in the next ten years. As a result,

collaboration among stakeholders, not only on scientific study of forest fire but also transnational training and specific forest fire scenarios for fire brigades and action forces should be enhanced.

4.2. Differences between three groups regarding natural factors and socio-economic characteristics driving forest fire ignitions

4.2.1. Natural factors

Based on the findings, it can be said that these groups of stakeholders shared the same view that the three most important natural factors as drivers of the present fire regime are precipitation, temperature, and wind. Our findings could explain by temperature can be expected to have an increase of +2 to +5 °C in the next decades. It is also likely that precipitation might increase in winter, and heat waves and droughts might be longer in the summer (Gobiet et al., 2014; IPCC 2014; Trnka et al., 2016). The consequence could be a higher tendency in the Alpine region.

Scientists had the tendency to rank wind, temperature, and precipitation the most important factors in the present than the other two groups of stakeholders (Authorities and Action Forces). By contrast, Authorities and Action Forces considered these factors more important in the future than Scientists. Except for the factor of wind, Scientists gave higher ranking for all the other factors both in the present and future than the other two groups of stakeholders did.

In addition, Action Forces had the tendency to give higher ranking to the remaining factors of fuel quality, fuel load, and atmospheric stability both in the present and future than Scientists and Authorities. Another reason for this difference could come from the practical experiences of directly conducting forest fire fighting on sites, while other groups of stakeholders only get access to forest fires fight via reported consolidation of data. As the study of Costanza and Moody (2011) indicated, those who have direct participation in firefighting and fire suppression on sites would have perceptions of the natural factors' impacts on people and property on burnt sites, while those who did not participate might not have these perceptions.

Moreover, respondents also suggested other natural factors affecting fire regime which were not mentioned in the survey. These factors are climate change, non-managed forest areas for biodiversity reasons, increased exposure to winter fires due to reduced snowpack and change in tree species composition and ground vegetation.

From another aspect, while most of the countries agreed upon the importance of precipitation. temperature, and wind factors for fire regime in Alpine region both in the present and future, some stakeholders from France perceived these factors of low and very low importance in this context.

Similarly, some stakeholders from Austria and Germany believed that temperature would be a less important factor in the future. Some stakeholders from Switzerland also considered wind as a less important factor. This can be explained by the differences in the reasons for forest fires occurring in France and in other countries. Similarly, reasons for forest fires in Switzerland are also different from those in the remaining countries.

The above findings have shown that a diversity in natural factors and differences in perception of these factors can impact the fire regime in the present and the future among the stakeholders in different regions and countries in the Alpine region. Identifying and understanding the similarities and differences in the stakeholders' perceptions of these natural factors might propose solutions for or support forest fire prevention better.

4.2. Socio-economic factors

Regarding the socio-economic factors, all groups of stakeholders shared the perception that recreational activities, rural abandonment, change in forest management, owner awareness, and traditional uses of fires were important drivers of the present fire regime. Meanwhile, when being asked about their perception of the impact of the socio-economic factors as drivers for the future, all of the three groups of stakeholders agreed upon three most important factors which are recreational activities, rural abandonment and owner awareness.

Regarding these three factors, Authorities perceived their level of importance not higher than other groups and lower than the average level in the perception of three groups. However, for recreational activities, Authorities considered this factor of higher importance than the other two groups of stakeholders did. Both rural abandonment and owner awareness factors were perceived important factors by Action forces and Scientists with the level of importance higher than the level perceived by Authorities and the average level of importance perceived by three groups. This finding aligns with the view that human activities have stronger and more serious impact than natural factors when those activities play as a source of ignition and directly cause an increasing number of forest fires (Goldammer and Crutzen, 1993, Silva et al., 2010).

In comparison with the study of Forest fire situation in Central Easter Europe (Jaspar, 2013), there are differences whereas rural abandonment was not considered as an important factor for fire regime in that region. The Administrative reforms factor was ranked highest in the level of

importance in Central-Eastern Europe in terms of social and economic aspects. However, considering the aftermath of the forest fire in Russia in 2010. the study of Goldammer and Director (2010) found out that negligence and irresponsibility in fuel management as well as rural abandonment were the main causes of the forest fire. The root cause of this was the consequences of the administrative reforms and change in forest management in this region.

On the other hand, when considering the perception of the social and economic factors affecting forest fires among six countries in the Alpine region, there is a clear difference in recreational activities, rural abandonment and owner awareness in the six countries.

Although the general perception of the countries was that recreational activities are of high importance in the future, however, a majority of respondents from every country considered this factor of low and very low importance, whereas none of the respondents from Austria perceived it to have very low level of importance. This may be due to a large number of forest fires associated with tourism and recreational activities in the history of Austrian mountainous areas, which could cause respondents from Austria to have a cautious perception of this factor.

Rural abandonment was perceived to be a factor of high and even very high importance by all countries (for instance, Switzerland, France, Italy, and Slovenia perceived it as highly important). The reason for this perception could come from the fact that land in rural areas is being increasingly abandoned, when young people tend to seek jobs and live-in big cities. By contrast, a large number of respondents in Germany considered this factor to have a very low level of importance, which could be explained by the fact that the population density in Germany is higher than that in other remaining countries in the Alpine region.

Regarding Owner awareness, all countries in the southern parts of the Alpine region perceived it to have a high level of importance, and northern countries (e.g., Switzerland and Germany) considered it of very high importance. This seemingly indicates that although forest fire prevention measures have been taken, the importance of raising awareness of private forest owners and the board of forest management in protected areas still needs to be improved in the future.

4.3. Differences in the stakeholders' priorities for fire management options

The results have shown that there were no differences in the perceptions about the priorities for fire management options between the groups of stakeholders. It is apparent that the top three priorities for Authorities, Scientists, and Action Forces are setting a temporal limited legal ban to ignite fires, cooperation between responsible agencies, and other instruments related to the legislation. The two lowest priorities for the three groups of stakeholders are economic incentives and information for private forest owners. This could be explained by the causes of forest fires currently in the Alpine region. There is a need for more appropriate policies suitable for the changing importance of natural, economic, and social factors, which have been driving forest fires. In order to implement the appropriate policies, it is important to focus on the ability of different stakeholders in understanding the interests of the others in the decision-making process (Wondolleck and Yaffee, 2000). This is the reason why most responses perceived cooperation between responsible agencies as very effective among many stakeholders. Also, Costanza (2011) indicated in her study that an increase in the understanding of different stakeholder perspectives is a key success factor.

Considering the efficiency of fire management options, most of the suggested options, except Economic incentives, were perceived as very effective in France. Meanwhile, in Austria, Cooperation between responsible agencies, Information for the public and Information for qualified personnel were considered the most effective options for fire management. The responses from Italy showed that this country had different views compared to Austria. Stakeholders in Italy perceived information for the public as less efficient, but options of temporal limited legal ban to ignite fires and Legislation as very effective. However, Italy's stakeholders also shared the same view with those in Austria that information for qualified personnel was an effective option. On the other hand, stakeholders in all of the three countries shared the same view that the option of Economic incentives was less efficient. Additionally, both France and Italy perceived legislation and temporal limited legal ban to ignite fires as effective, whereas Austria did not think that these were effective options.

4.4, Differences in the stakeholders' perceptions about challenges for forest fire management

Presently the high costs for fighting forest fires through large and/or long-lasting fires was one of the top challenges, whereas lack of infrastructure in the forests was one of the least common challenges for all stakeholders. Groups of Action forces and Authorities perceived missing/insufficient air support to be one of the top challenges. By contrast, Scientists believed that area of conflict at the wildland-urban-interface (WUI) was the top challenge. The results could be explained by the fact that there is scientific evidence showing that the Alps will be seriously affected by climate change. Müller et al. (2017) have found that records of drought like the driest July in 2013 in Austria and of temperature like the extremely hot summer in 2015 have happened in the Alpine region. In addition, the mortality rate of trees may be higher in the presence of drought, which could lead to more forest fires (Allen et al., 2010; Anderegg et al., 2015; Choat et al., 2018). Furthermore, the increase in combustible fuel associated with deadwood management can be a factor in increasing the intensity of the fire and causing them to become out of control (Agee et al., 2000). These things will likely lead to major challenges in terms of substantial damages as well as tremendous financial losses in dealing with forest fire in the future.

Scientists also pointed out a major challenge coming from area of conflict at the wildland-urban-interface. This was also presented in Müller et al. (2020) 's study that "Most Alpine villages used to be cultivated or grazed in their surroundings. Especially in the Southern Alps most of these fields and pastures have been abandoned. Flammable vegetation encroached this area, leading to an increased fire hazard. In countries like France, USA or Australia, the problem of this phenomenon is well known. Many forest fire catastrophes with numerous deaths, also in southern Europe, resulted from the flames spreading to populated areas or hitting traffic routes." Especially in the Alpine region the challenges for the WUI are still hardly discussed (Müller et al., 2020). For example, two Austrian forest fires Absam (2014) and Lurnfeld (2015) showed that there is a huge risk related to the impact of strong winds affecting the safety of people and property.

For the future forest fire fighting, water availability and high costs through large and/or long-lasting fires were perceived to be the top challenges, whereas lacking infrastructure in the forest was perceived to be the least common challenge by all of the three stakeholder groups.

Action forces and Scientists shared the view that Several large fires at the same time was one of the most major challenges. Meanwhile, Authorities also perceived Missing/insufficient air support

to be a major challenge in the future. Thus, the differences in perceptions of stakeholders regarding their preferences for forest fire management may be explained by the imbalance between actions on fire prevention, fire suppression, and post-fire management, with too much focus and money spent on fire suppression but a lack of measures for forest fire prevention in the Alpine region (Müller et al., 2020).

Water availability was perceived as the most major challenge for the future by all stakeholders. This can be explained by the limitation in the distribution of water tanks, natural and artificial ponds in the Alpine region. This is in turn caused by the lack of risk maps in regions with high risk of forest fire alert in order to build water tanks in good preparation of pre-suppression activities (Müller et al., 2020). Another reason considering the challenges of water availability is the rise of rural abandonment in the Alpine region. For instance: Rural abandonment makes it very difficult to access, preserve and maintain the infrastructure used for purposes of forest fire prevention and fighting like water tanks.

Regarding the lack of infrastructure in the forest, interestingly, all three groups of stakeholders perceived it to be least challenging in the present and future. However, the maintenance of the forest and its infrastructure (e.g., water availability, forest accessibility, road maintenance) is one key challenge in the future (Müller et al. 2020). These maintenance services are also needed for harvesting purposes, tourists, and infrastructure. Tourism and recreational activities are the most important social factors for igniting forest fires in Austria, Germany, Liechtenstein, and Switzerland. This difference could be explained by the perception of the survey respondents that maintenance relating to tourism and recreational activities belongs to another topic which is governed by other authorities. Therefore, additional research with the participation of stakeholders are needed to make more detailed recommendations for infrastructure in the forest in the future.

5. CONCLUSION

The goal of this present study was to analyze and compare the differences in the perceptions of the authorities, scientists and action forces, regarding the trends and driving factors of forest fires, as well as the priorities and challenges for present and future forest fire management in the Alpine region. The data for the analysis were collected from the stakeholders in the six countries of the Alpine region and analyzed according to four main hypotheses. The findings indicate a significant difference in the perceptions of the three stakeholder groups about the number of forest fires and burnt areas. Besides, “Precipitation”, “Temperature” and “Wind” were agreed by all of the stakeholders to be the most important natural factors as drivers of the present and future fire regime, whereas “Recreational activities”, “Rural abandonment” and “Owner awareness” are the most important socio-economic factors. In addition, there were no differences in the stakeholders’ perceptions about the priority measures for fire management. Last but not least, the top challenges for the stakeholders for both present and future of forest fire fighting were identified as “Missing/insufficient air support”, “Water availability”, “Several large fires at the same time” and “High costs through large and/or long-lasting fires”.

In light of the above findings, it is obvious that the differences in the perceptions of the three stakeholder groups will significantly affect the present and future situation of the Alpine forests. Therefore, the collaboration, support, and mutual understanding among the diverse group of stakeholders are of ultimate importance. Thus, the following recommendations can be made based on the findings of the present study to tackle these issues:

- Establish a fire awareness culture in the Alpine region by promoting the perceptions of forest fire management among the six countries through related campaigns and joint activities.
- Promote the shared understandings and up-to-date knowledge of integrated fire management by establishing a joint database which stakeholders from all Alpine countries can access.
- Promote the best practices in each country by frequently exchanging information.
- Sharpen common knowledge and skills of the stakeholders by organizing transnational trainings and workshops in all countries of the Alpine region.

- Improve mutual understanding and mutual agreements on the most important drivers and measures among the stakeholder through open discussions, identification of the similarities and differences in their perceptions, and (transnational) collaborative projects.
- Raise and improve the awareness of private forest owners and managers in protected areas by organizing campaigns or orientation programs.
- Raise and improve the awareness of the public towards the importance of forest fire management by organizing campaigns or disseminating related information on different digital channels such as social media.
- Prepare both financial and human resources for forest fire management for all Alpine countries by setting up joint funds upon agreement of the six governments.
- Focus on doing research on forest fire management, not only on a national but also on a regional level.

There are many more other steps towards a sustainable and healthy forest situation in the Alpine region. Thus, more research is needed to develop a more holistic understanding of forest ecosystems and the influence of fires in the Alpine region.

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Austria:

Institute of Silviculture, University of Natural Resources and Life Sciences Vienna (BOKU), Fire database Austria (http://fire.boku.ac.at/firedb)

France:

Ministry of Agriculture and Food, French Forest Fire Database, BDIFF (http://bdiff.ifn.fr/)

Germany:

Bundesanstalt für Landwirtschaft und Ernährung, Forest fire statistics of the federal republic of Germany (https://www.ble.de/DE/BZL/Daten-Berichte/Wald/wald_node.html)

Italy:

Civil Protection Departments of Regione Piemonte, Regione Liguria, Regione Lombardia, Regione Valle d'Aosta, Regione Friuli Venezia Giulia, Regione Veneto, Provincia Autonoma di Trento, and Provincia Autonoma di Bolzano.

Slovenia:

Slovenian Forest Service (http://www.zgs.si/index.html)

Switzerland:

Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Swissfire (https://www.wsl.ch/en/services-and-products/data-monitoring-and-inventories/swissfire.html)

7. APPENDICES

Appendix A

Demographic characteristics of respondents

Table A.1: Number of answers obtained per target group

	Action forces	Authorities	Scientists	Total
AT	8	11	4	23
CH	2	17	3	22
DE	2	3	2	7
FR	2	2	6	10
IT	3	3	5	11
LI	-	1	-	1
SL	-	5	1	6
Total	17	42	21	80

Table A.2: List of regions from where answers were provided.

Country	Regions
AT	Burgenland, Kärnten, Oberösterreich, Salzburg, Steiermark, Tirol, Vorarlberg
CH	Appenzell Ausserrhoden, Appenzell Innerrhoden, Bern, Fribourg, Graubünden, Jura, Lucerne, St. Gallen, Schwyz, Solothurn, Ticino, Vaud, Zug, Zürich
DE	Bavaria
FR	Provence-Alpes-Côte d'Azur
IT	Bozen, Friuli-Venezia Giulia, Liguria, Piemonte, Trento, Veneto
LI	-
SL	-

Appendix B

The questionnaire used to conduct the online survey:

(a) Choose your language

(b) Choose the target group you are representing (Authorities, Scientists, Action forces)

1. CONTACT INFORMATION

a) **Country Name**

b) Do you reply to this questionnaire from the perspective of a country or a region?

c) Which region do you represent? Answers according to the list of the 48 regions: (Slovenia and Liechtenstein are one region each)

d) **Please enter your personal details**

Name: Organization: Position:

2. FIRE SITUATION

a) **How many forest fires occur in your country on average every year?**

< 100
100-250
250-500
500-1000
> 1000

b) **How much percent of these fires occur in the alpine region of your country?**

< 20 %
20-40 %
40-60 %
60-80 %
> 80 %

c) **What is the most characteristic size of an alpine forest fire in your region/country?**

< 0,1 ha
0,1-1 ha
1-10 ha
> 10 ha
Remarks

d) **What is the share of unknown, human and natural (lightning) induced forest fires in your region / the alpine region of your country?**

- Unknown caused fires %
- Human caused fires %
- Natural caused fires %

e) **Rank the following anthropogenic causes of forest fires in your region / the alpine region of your country according to their relevance**

- Carelessness (e.g., cigarettes, bonfire, hot ashes)
- Accidental ignition (e.g., by trains, cars, power lines)
- Burning activities (e.g., brush piles, prescribed burning)
- Traditional uses of fires (e.g., Easter fires, solstice bonfires, strokeburning)
- Intentional fires (arson)

f) **What is the economical/social damage of forest fires for different stakeholder groups in your region / the alpine region of your country?** (no damage, low damage, medium damage, high damage, cannot judge)

General public living in urban areas	Fire brigades
Communities in rural landscape	Industries
Landowners / Forest owners	Insurances

g) Are there other relevant stakeholder groups not mentioned in the previous question that may experience high economical/social damage through forest fires?

h) **What are the financial resource requirements regarding preventing and suppressing forest fires for different stakeholder groups in your region / the alpine region of your country?** (none, low, medium, high, cannot judge)

General public living in urban areas	Fire brigades
Communities in rural landscape	Forest industries
Landowners / Forest owners	Insurances
Forest authorities	

i) Are there other relevant stakeholder groups not mentioned in the previous question that may require significant financial resources to prevent and suppress forest fires?

j) **What are the technical/personnel resource requirements regarding preventing and suppressing forest fires for different stakeholder groups in your region / the alpine region of your country?** (none, low, medium, high, cannot judge)

General public living in urban areas	Fire brigades
Communities in rural landscape	Forest industries
Landowners / Forest owners	Insurances
Forest authorities	

k) Are there other relevant stakeholder groups not mentioned in the previous question that may require significant technical/personnel resources to prevent and suppress forest fires?

3. NATURAL PRECONDITIONS AND TRENDS

a) **In comparison to the present situation, how would you estimate the overall future trend for the <u>burnt area</u> ("intensity") in approx. 10 years for your region / the alpine region of your country?**

strong increase
increase
constant progression
decrease
strong decrease

b) **In comparison to the present situation, how would you estimate the overall future trend for the <u>number of fires</u> ("ignitions") in approx. 10 years for your region / the alpine region of your country?**

strong increase
increase
constant progression
decrease
strong decrease

c) **Please rank the following <u>natural factors</u> by their importance as drivers for the present fire regime and the future trend in your region / the alpine region of your country.** (first column: importance at present (from 1 – very low to 5 – very high); second column: importance in approx. 10 years (from 1 – very low to 5 – very high))

- Precipitation (low humidity, dry winter or summer seasons)
- Temperature (higher summer temperatures, more heatwaves)
- Wind (dry (foehn) wind, wind speed, evaporation)
- Atmospheric stability (lightnings)
- Fuel quality in forests (moisture, structure, compactness)
- Fuel load in forests (biomass, deadwood content)

d) **Please rank the following <u>socio-economic factors</u> by their importance as drivers for the present fire regime and the future trend in your region / the alpine region of your country.** (first column: importance at present (from 1 – very low to 5 – very high); second column: importance in approx. 10 years (from 1 – very low to 5 – very high))

- Recreational activities (e.g., cigarettes, campfires)

- Traditional uses of fires (e.g., Easter fires, solstice bonfires, strokeburning)
- Change in forest management (e.g., thinning intensity, management type)
- Rural abandonment (e.g., unmanaged forests)
- Owner awareness (e.g., missing relation to forest, no awareness of fire)
- Administrative reforms (e.g., reduction of workforce)
- Change of infrastructure (e.g., number of railways, roads, power lines)
- Intentional fires (arson)

l) Are there other natural or socio-economic factors relevant now or in the future not mentioned in the last two questions?

4. FIRE DANGER ASSESSMENT

a) **How long is the record of a central/decentral and almost complete documentation of forest fires in your region/country?**

< 10 years	30 to 40 years
10 to 20 years	> 40 years
20 to 30 years	

b) **Is there an official and nationwide forest fire danger assessment system used?**

- Yes
- No
- if yes, which? (Please provide a web-address of the system if available)

c) **If yes, which parameters and methods are used to predict fire danger**

Recent meteorological data	Topography
Historical meteorological / fire data	Human impacts
Interpolations of the fuel moisture (e.g., high resolution weather models, satellite data)	Lightning (fire) patterns
In situ measurements of the fuel moisture	Others (please specify)
Vegetation type and structure	I cannot answer

d) **Is the current used fire danger assessment system in your region/country adequate under most climatic and seasonal conditions?**

- Yes
- No
- Remarks

e) **Are the differences between danger of ignition and danger of propagation/severity considered in the communication from/to authorities, fire brigades or other stakeholders?**

- Yes
- No
- Remarks

5. FOREST MANAGEMENT

a) **What kind of influence will the future trend of forest fires have on the protection function of forests (regarding rockfall, mudslides, erosion and avalanches) in your region / the alpine region of your country?**

very positive
positive
no influence
negative
very negative
Remarks

b) **What kind of influence will the future trend of forest fires have on the species diversity in your region / the alpine region of your country?**

very positive
positive
no influence
negative
very negative

c) **What kind of influence will the future trend of forest fires have on the structural/habitat diversity in your region / the alpine region of your country?**

very positive
positive
no influence
negative
very negative

d) **How would you describe the integration of forest fire danger and forest fire prevention measures in forest management and planning?** (e.g., choice of tree species, fuel management, harvesting techniques, fire prevention measures)

very strong
strong
weak
very weak
no integration or consideration at all
Remarks

e) **Which of the following forest fire prevention measures in forest management and planning are performed in your region/country?**

Choice of tree species	Fire prevention measures (protective strips, fire breaks)
Fuel management: thinning, deadwood content	Others (please specify)
Fuel management: prescribed burning	No integration or consideration at all
Harvesting techniques	Fire prevention measures (protective strips, fire breaks)

f) **How would you describe the consideration of predictions of climate change in long-term forest / fire management and planning?** (e.g., temperature rise, more heatwaves, dryness)

very strong	very weak
strong	no integration or consideration at all
weak	Remarks

g) **How would you describe the transnational exchange on forest fire prevention measures in forest management and planning?**

very strong	very weak
strong	no integration or consideration at all
weak	Remarks

h) **To what extend does prescribed burning support the prevention of forest fires in your region / the alpine region of your country?**

- high supportive
- moderate supportive
- less supportive
- not supportive
- prescribed burns not executed
- Remarks

i) **Will conservation measures (e.g., deadwood, extensive management) in forest management increase the intensity of forest fires?**

- Yes - No
- Remarks

j) **Arrange the following post-fire difficulties according to their importance**

- Expensive restoration of forest cover
- High costs of protective measures

- Risk of following natural hazards (e.g. mudslides, rockfall, new avalanche-prone slopes)
- Risk of complete erosion of the soil

k) Are there other post-fire difficulties not mentioned in the last question?

l) Your opinion concerning the current situation of forest fire management in your region / the alpine region of your country. (e.g., current gaps of knowledge, needs for research, ideas for improvement)

6. POLITICAL AND LEGAL FRAMEWORKS

a) **How would you describe the integration of forest fire management in forest policy making?** (e.g., awareness-rising, setting of priorities, early warning, funding)

very strong	very weak
strong	no integration or consideration at all
weak	Remarks

b) **How would you assess the farsightedness of forest fire policies in your region/country?**

long-term (> 10 years)	do not exist at all
short-term	Remarks

c) **Are decision-making processes in forest fire management open for the participation of multiple stakeholders in your region/country?**

yes	no
partly	Remarks

d) **How would you describe the transnational exchange of knowledge, technology and resources to facilitate rapid suppression of fires in your country?**

very strong	very weak
strong	no exchange or consideration at all
weak	Remarks

e) **Are the knowledge, leadership and expertise of forest authorities recognized and used in forest fire management activities in your region/country?**

yes	no
partly	Remarks

f) **Are any international guidelines for (forest) fire management** (e.g., FAO, UNEP, ITTO) **used to develop and implement national or local legislation?**

yes	cannot judge
partly	If yes, which?
no	

g) **At which levels do forest fire management plans exist in your country?**

national	do not exist at all
province	Remarks
local (forest) district	

h) **How widespread are forest fire management plans used in your country?**

nationwide	do not exist at all
local	Remarks
isolated	

i) **Are there differences between the implementation or execution of forest fire management plans for public owned and privately owned forests?**

- stronger implementation/execution in public owned forests
- stronger implementation/execution in privately owned forests
- no difference
- do not exist at all
- I cannot answer
- Remarks

j) **If forest fire management plans exist, do they include fire prevention measures?** (e.g., road infrastructure, fire trails, fuel reduction, prescribed burning) Q043

yes	do not exist at all
partly	Remarks
no	

k) **Are subsidies or any other support provided for fire prevention measures in private forests or for other ownership types?**

yes	do not exist at all
no	If yes, how?

l) **Are there awareness-building activities conducted for the population?**

- Bottom-up approach (e.g., visiting schools)
- Information material (e.g., forest fire book, online brochures)
- Guidelines for the behavior in the forest at high fire risk days
- Governmental information events
- Forest fire education film
- online available forest fire database
- social media presence (e.g., facebook, twitter, forest fire blog)
- Others (please specify)

m) **How efficient are the measures in place to control the forest fire situation in your region/country?** (very efficient, efficient, less efficient, not efficient, not applicable)

- Legislation (e.g., environmental or forest law)
- Temporal limited legal ban to ignite fires
- Information for the public (e.g., public awareness, press releases)
- Information for qualified personnel (e.g., translated or accessible technical materials)
- Information for private forest owners (e.g., property rights, risk assessment, possible measures and implementation)
- Economic incentives (e.g., funding, subsidies, lower insurance costs)
- Cooperation between responsible agencies (e.g., during firefighting, risk precaution)

n) Are there other efficient measures to control the forest fire situation in your region/country not mentioned in the previous question?

7. RISK GOVERNANCE & MANAGEMENT

a) **Is risk governance / management part of fire management plans and forest policy making in your region / the alpine parts of your country?**

yes	do not exist at all
no	Remarks

b) **Are there danger/risk maps on forest fires for your region / the alpine region of your country?**

- Yes - No
- Remarks

c) **If yes, are these danger/risk maps available for the general public?**

- Yes - No
- Remarks

d) **Are there evaluation processes regarding fire management activities?**

- Yes - No
- Remarks

e) **Are there transnational activities concerning forest fires to improve risk governance and fire management in your country?**

- Yes - No
- Remarks

f) **Do national standards exist for quantifying positive and negative fire effects and assessing fire damage?**

yes partly
no Remarks

g) **Was the European disaster relief already used in your region/country in case of a forest fire?**

yes I cannot answer
no Remarks

8. FOREST FIRE FIGHTING

a) **What are the present challenges regarding the difficulties / efficiency of forest fire fighting in your region / the alpine region of your country?**

Insufficient number of actions forces	Several large fires at the same time
Inadequate equipment	High costs through large and/or long-lasting fires
Not enough or inadequate vehicles	Difficulties in sparsely populated regions to maintain operational capability (e.g., retirements, insufficient equipment, few members of fire brigades)
Inadequate training of action forces	Area of conflict at the wildland-urban-interface (WUI)
Missing/insufficient air support	Infrastructure in the forest (e.g., cell towers)

Water availability	Others (please specify)

b) **What are the assumed challenges in the future regarding the difficulties / efficiency of forest fire fighting in your region / the alpine region of your country?**

Insufficient number of actions forces	Several large fires at the same time
Inadequate equipment	High costs through large and/or long-lasting fires
Not enough or inadequate vehicles	Difficulties in sparsely populated regions to maintain operational capability (e.g., retirements, insufficient equipment, few members of fire brigades)
Inadequate training of action forces	Area of conflict at the wildland-urban-interface (WUI)
Missing/insufficient air support	Infrastructure in the forest (e.g., cell towers)
Water availability	Others (please specify)

9. EXPERT PANEL MEETING

a) "Do you want to participate in a two-day expert panel meeting in Vienna (Austria) on the forest fire issue?"
[Yes / No]
b) If yes: "I can participate on:"

[27. June 2019 / 28. June 2019 / I can not participate]

e) **Are the knowledge, leadership and expertise of scientists recognized and used in forest fire management activities in your region/country?**

yes	partly
no	Remarks

f) **Are the knowledge, leadership and expertise of action forces recognized and used in forest fire management activities in your region/country?**

yes	partly
no	Remarks

c) **Are the legal basis, operation structure, requirements and possibilities of the European disaster relief generally known amongst decision makers in your region/ country?**

yes partly
no Remarks

d) **Was the European disaster relief already used in your region/country in case of a forest fire?**

yes I cannot answer
no Remarks

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Declaration in lieu of oath

I herewith declare in lieu of oath that this thesis has been composed by myself without any inadmissible help and I did not use any other not permitted help.

I further declare that I did not submit this thesis nationally or internationally as an examination paper in any form.

25.01.2021	
Date	Signature