A systemic approach to fire prevention:
A case study of rural fires in Portugal

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"Fire is a bad master but a good servant."

(Finnish proverb)

Abstract

Society is confronted with enormous obstacles in addressing complex and interconnected socio-ecological issues, such as climate change. Over time, climate change has been manifested in several weather-related events, particularly fires and natural ecosystems' degeneration. As fires become more intense and faster spreading, national and local governments, civil protection, and fire-fighting forces become less effective in protecting society. Future policies should promote a more preventive, less reactive attitude in this new era of severe conditions. Therefore, a holistic understanding is needed: living in the age in which fires are rising as a global concern, it is crucial to study, analyse, and propose interventions to tackle the problem through an integral approach.

This thesis addresses the issue by exploring how a systemic approach can contribute to an understanding of the prevention of rural fires by investigating the rural fire management system in Portugal. The study provides an overview of natural hazards, disasters, and disaster management, focusing on rural fires. Furthermore, it presents the case study adopting a systemic approach bridging the knowledge from strategic design and actor-network theory literature, considering the role of the non-human actors in the Portuguese rural fire management system.

The thesis complements the knowledge gain from the literature with a qualitative research approach. The research process includes conversational and semi-structured interviews and the study of existing policy documents. These methods provide an in-depth view of the system and the institutional structure by identifying the actors, their relationships, and unpacking the current issues. The findings, categorised in five themes, expose the main factors that can influence rural fire prevention: 1) The roles and responsibilities of actors, 2) The institutional structure, mindset and attitude, 3) The heterogeneity of the rural areas, 4) The phenomenon of fires, and 5) The forest as an agent.

Supported by the leverage points, this study identifies intervention areas and suggests a series of recommendations to address the challenges identified in the findings. The thesis concludes that with more involvement and collaboration between the different actors, the fire management system can prevent and mitigate the risks of rural fires in a more efficient and organised manner. This thesis demonstrates how a systemic approach can provide a holistic overview of rural fire prevention. It contributes with insights to the academic community, providing a deeper understanding of how to address complex societal challenges.

Keywords

Rural fires, Portugal, systemic approach, strategic design, systems thinking, non-human actor

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Obrigado!
Thank you!
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Table of Contents

Glossary

Actor
Both human beings and non-human actors such as technological and natural entities part of a network or system (adapted from Gonzalez et al, 2012).

Disaster
A dangerous event that results in an unacceptably large number of casualties and extensive physical and natural damage.

Non-Human Actor
Non-human actors such as technological and natural entities part of a network or system.

Prevention
Activities and actions taken to prevent a natural phenomenon or potential hazard from having harmful effects on either people, natural environments, or economic assets.

Rural Fires
Fires that have a strong physical impact on society, destroy structures and goods, and harm natural ecosystems.

Strategic Design
The application of conventional design concepts to "big picture" systemic challenges. It is the use of design methodology and attitude to reframe how challenges are solved, to recognise possibilities for action, and to contribute to the delivery of more comprehensive and resilient solutions (Boyer et al., 2013).

Systemic Approach
an approach that enables a comprehensive understanding of complex, multi-actor infrastructure systems. It adapts design competencies to define, map, suggest and reconfigure complex systems and processes.

Systems Thinking
The process of comprehending a phenomenon concerning a greater whole (Buchanan, 2019).

Abbreviations

AGIF - Agency for Integrated Rural Fire Management
ANEPC - National Authority for Emergency and Civil Protection
ANT - Actor-Netowrk Theory
CRED - Centre for Research on the Epidemiology of Disasters
GHG - GreenHouse Gases
GNR - Portuguese National Guard
ICNF - Institute for Nature Conservation and Forests
IPCC - Intergovernmental Panel on Climate Change
ITC - Independent Technical Committee
NGO - Non-Governmental Organisation
ITO - Independent Technical Observatory
PNGIFR - National Plan for Integrated Rural Fire Management
RFM - Rural Fire Management
RFP - Rural Fire Protection
SGIFR - Integrated Rural Fire Management System
SGT - Sustainable Global Technologies
UNDRR - United Nations Office for the Disaster Risk Reduction
UNISDR - Former United Nations Office for the Disaster Risk Reduction

List of Figures

List of Tables

List of Images

Chapter 1.
Introduction

1.1. Motivation

The interest in disasters started in January 2019, when the author participated in the Sustainable Global Technologies (SGT) Studio course at Aalto University. In this course, the author joined a multidisciplinary team of students from various backgrounds, including design, architecture, engineering and business. As part of this course, the author worked on a project focused on the sustainable reconstruction of communities after the 2015 Nepal earthquake. The 2015 earthquake resulted in almost 9000 casualties and left hundreds of thousands of people homeless. The objective was to research the current situation of a rural settlement north of Kathmandu, Dhungentar, regarding community cohesion and how that could improve disaster resilience. During the two-week field research (Image 1), different social cohesion factors present in the community were identified and analysed, resulting in two future scenarios: 1) the network scenario and 2) the committees' scenario (Santos et al., 2019). The future scenarios aimed to address social cohesion issues from different perspectives through collaboration and knowledge-sharing.

The first scenario was developed around four well-acknowledged actors in the Dhungentar settlement: the schools, multipurpose community centre, social mobilisers, and the model house. The scenario mainly focuses on enhancing collaboration and knowledge-sharing activities, which can affect the different aspects of social cohesion; strength and size of social networks, neighbourhood socialising, sense of community identity, and community-based livelihood. Scenario number two focused on addressing the social cohesion of the Dhungentar settlement through improving coordination and collaboration between the independent committees in the village. The aim is to support the committees' inclusiveness and help them work more efficiently for the community's development (Santos et al., 2019).

Before the disaster in 2015, there was a lack of community-focused disaster preparedness or planning, and national policies were not always relevant and not thoroughly implemented (Hall & Lee, 2017). The community could have responded and dealt with the earthquake's consequences in a more efficient and organised manner with more engagement, involvement and collaboration between the community, local governments, and national authorities in disaster preparedness and planning at a regional and national level. Better community involvement would also need disaster response coordination and aid distribution to achieve a rapid and more appropriate local response to all affected communities (Hall & Lee, 2017).

The role of design research in the resolution of wicked problems is fundamental to understand the importance of collaboration between local communities and national authorities as complex and dynamic entities in disaster prevention. For this reason, there is a need for a holistic understanding: living in an era in which disasters are rising as a global concern, it is crucial to create a strategy to tackle the problem in a collaborative approach. Only by collaborating through systems and organisations, such as emergency responders, government and non-governmental entities, companies, and municipalities, can disaster prevention be accomplished. Instead of utilising the effort on a project where the author was a stranger, he realised that it would be more beneficial to take such an approach in Portugal, where he is more familiar with the cultural, social, economic, and environmental aspects.

The author was born and raised in Portugal, a country that suffers from one of the most frequent natural disasters in Europe: rural fires. Every summer, the rural areas in Portugal experience fires from low to high-intensity levels, resulting in extreme rural fires. These events significantly impact society - the local communities need the land and forest to survive and generate income to support themselves and the natural environment. As a Portuguese, the author cannot disregard this fact, thus deciding to address and explore this complex issue through this master thesis.
As a designer, the author investigates ways to enhance collaboration in disaster prevention through systems thinking and a strategic design approach.

On a more personal level, this opportunity also presented a way to evolve as an individual. This research has increased the author's breadth of knowledge about systems and strategic thinking, which will ultimately explain the role of design as a systemic tool in complex challenges. Besides, there is a hope that this thesis will acknowledge human and non-human actors as a part of the system to promote holistic environmental, social and economic changes that can improve the rural fire prevention system.

Image 1. *Field research in Dunghentar settlement in Nepal (Santos et al., 2019). Photo by: Carles Martinez*

1.2. Research Scope

Today, in a world where design has evolved and is now seen as a transversal discipline, it is imperative to acknowledge that different people, backgrounds, cultures and most importantly, empathy and understanding are integral to society's development. These aspects are not limited to technological advancement or social discourse but include the breadth of developing solutions to further all people's well-being (Figure 1). By participating more effectively in social and environmental development, designers can offer solutions with the highest impact on society and minimal damage to our planet.

The growing number of people living on our planet leads to more consumption, production, energy, and resources, which has a significant impact on our planet and, consequently, on climate change. With the current pace of climate change, we get fewer disasters, but the ones we have are of a higher category. For this reason, a holistic understanding is needed: living in the age in which natural hazards are rising as a global concern, it is crucial to understand, learn, and create strategies to tackle the problem in a systemic approach.

This thesis focuses on the study of rural fire management in Portugal. More particularly, this thesis analyses the current status of rural fire prevention, the actors involved in the system, their interconnections and current strategies to mitigate the social, economic, and environmental consequences of rural fires in Portugal. Furthermore, it aims to raise awareness and enable collaboration between the national government, local governments, nature and communities that live in precarious places with a high risk of rural fires.

When fires get more frequent and grow further, the effectiveness of civil defence fire fighting forces deteriorates. Future investments should encourage a more strategic, less reactive approach in this current age of extreme burning conditions (Beighley & Hyde, 2018). With more involvement and collaboration between government, local governments, the private sector and citizens in rural fire prevention at a local and national level, the communities can respond and deal with the consequences of rural fire in a more efficient and organised manner. A better understanding of the relevance of preventive activities involving national and local governments would be needed concerning rural fire prevention coordination and the fair distribution of resources to achieve a rapid and more appropriate local preparedness to all communities in high-risk areas.

Figure 1. Scales of design (adapted from Hill & Candy, 2019)
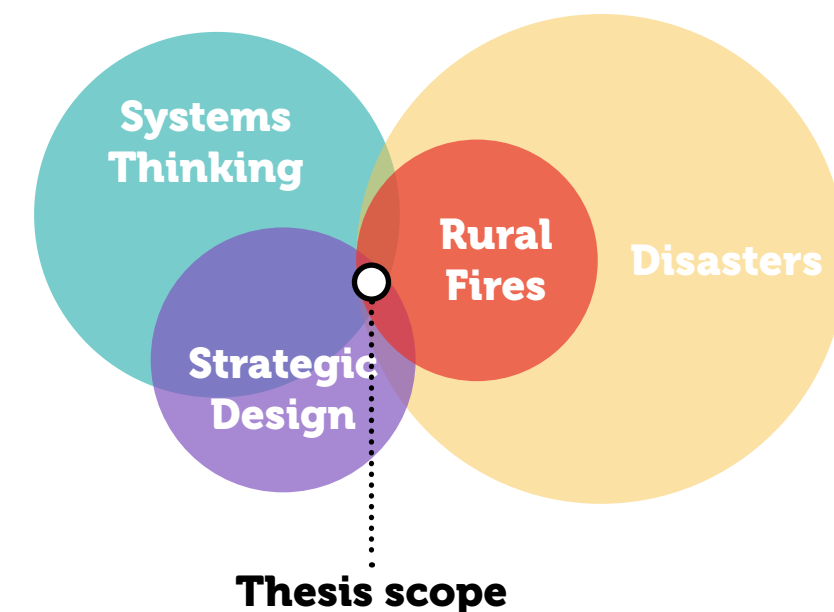
Figure 2. Research scope.

1.2.1. Research Objectives

Despite the critical need for increased awareness of governments and communities towards disaster prevention, there is a poor understanding of how rural fire prevention works on a systemic level. Additionally, this topic is deeply rooted in its specific geographic and socio-financial context - it is unknown what impact and role the different actors have on developing strategies for rural fire prevention. The aim of this thesis is to overcome the above knowledge gap by addressing the following research objectives:

→ *Provide a systemic understanding of the rural fire prevention system in Portugal*

→ *Identify and examine the role of the different actors within the rural fire prevention system*

→ *Analyse, synthesise and reflect on the challenges towards rural fire prevention*

→ *Formulate strategic recommendations while working within the constraints of national and local needs in rural fire prevention in Portugal*

→ *Explore the potential of non-human actors in the prevention of rural fires in Portugal*

1.2.2. Research Questions

Taking into account that the main aim of this research is to explore how a systemic approach can contribute to the understanding of rural fire prevention, its main research question is:

→ ***How can a systemic approach contribute to the understanding of rural fire prevention in Portugal?***

The following sub-questions aim to support the main research question:

→ *Who are the actors in the rural fire prevention system in Portugal?*

→ *What is the role of the actors in developing strategies and actions for rural fire prevention in Portugal?*

→ *What are the challenges of rural fire prevention in Portugal?*

→ *What are the strategic opportunities in rural fire prevention in Portugal?*

1.3. Research Methods

Qualitative research was selected as the primary research method to understand the rural fire prevention system and identify and analyse the role of the different actors within the system. The study of how individuals perceive and communicate with their social world and the meaning they put on it is critical for developing a qualitative approach. (Merriam & Grenier, 2019). Therefore, Creswell (2007) argues that qualitative research should be conducted when a detailed understanding of the issue is necessary. This method is essential when a group or demographic must be analysed to determine factors that can be evaluated or to enable members of neglected groups or entities to have a chance to be heard (Creswell, 2007). In the rural fire management system, there was a need to listen to a diversity of actors and understand their views towards the same issue. In this same context, Muratovski (2015) claims that qualitative research can be applied when it is necessary to understand the nature of certain situations, processes, relationships, interactions, systems, or people (Muratovski, 2015).
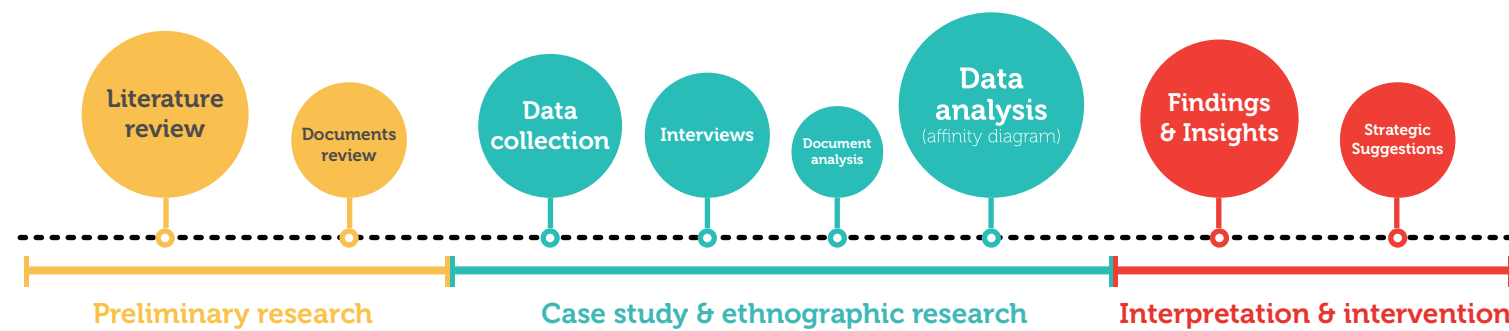
Figure 3. *Research process.*

Case study approach
Exploring a specific case study in the context of this thesis will provide the necessary tools to study a complex phenomenon by using various data from observations to interviews, documents, newspaper articles and official records. (Baxter & Jack, 2008; Muratovski, 2015). This method can help narrow down a broad topic that might be difficult to research (Yin, 2009). To narrow down the topic's scope, defining a specific case study is necessary, mainly due to the complexity of rural fire management. By setting a clear focus and parameters for the project, the research's objectives will be more explicit and less broad (Muratovski, 2015). For a better application of the case study approach, this thesis relies on interviews and analysis of relevant documentation to learn more about the policies, strategies and actors engaged in rural fire management in Portugal.

Ethnographic Approach
Ethnographic research is a fundamental method in understanding people and their behaviours (Muratovski, 2015). The ethnographic research method provides a holistic perspective of cultures and environments into a specific context. This way, it can help understand local governments' role in rural fire management and the level of collaboration and dynamics with higher entities, such as national agencies, national governments, or other organisations in the private and non-profit sectors. This method will contribute to the analysis, synthesis, and reflection on the challenges that the actors face towards rural fire prevention through in-depth interviews.

The research methods had initially combined participatory processes and ethnographic approaches, but the study's scope was limited due to COVID-19 restrictions. For that reason, the primary method of collecting data was through interviews, either presential, online or via email.

Systemic Approach
The systemic approach emerged as a natural method to provide a deeper understanding of Portugal's rural fire prevention system. This approach is intended for problems that are dynamic, unique, involve conflict, or have ambiguous goals (Ryan, 2014). Furthermore, it enables different teams to gain a holistic view of the problem and quickly transform new ideas into actions (Ryan, 2014).

1.4. Thesis Structure

This thesis is divided into eight chapters, starting with the Introduction chapter. This chapter introduces the motivation, the research scope, objectives and questions, and methods.

The second chapter presents the main topics of the literature study and the academic setting for this thesis. It provides an overview of natural disasters and disaster management, with a particular focus on rural fires. Further, it presents research on design and its role in addressing complex problems through a systems approach, based on strategic design and systems thinking literature. This chapter closes with research on Actor-Network Theory (ANT), a framework that addresses the agency of non-human elements that are part of systems. Chapter two concludes with a summary of the literature review.

The third chapter introduces the case study of rural fire management in Portugal. It looks into the system, and the institutional structure, identifies the actors and their relationships and unpacks the current issues with rural fire prevention in Portugal.

Chapter four presents the research methodology. It describes the research process in detail based on the qualitative research strategies such as the case study, the ethnographic and systemic approaches. Additionally, it provides information on data collection, the types of interviews and how they were performed, and the data analysis through affinity diagramming.

The fifth chapter offers an overview of the findings and main insights that resulted from the data collected through empirical research. The findings unpack five main themes by explaining each theme and building on the interviews. In addition, this chapter illustrates the systemic overview of the rural fire prevention system, identifying their roles and interconnections.

Chapter six presents a series of recommendations based on the results from the findings. The objective of these recommendations is to propose new interventions at a strategic level of the whole (eco)system. The strategic recommendations are formed and explained using Meadows' list of leverage points (1999).

The final chapters of this thesis (chapter seven and eight) reflect on the thesis's findings and their application regarding the research questions and objectives. The final chapter discusses the thesis's limitations and provides guidance for further study on the topic.

1.4. Thesis Structure
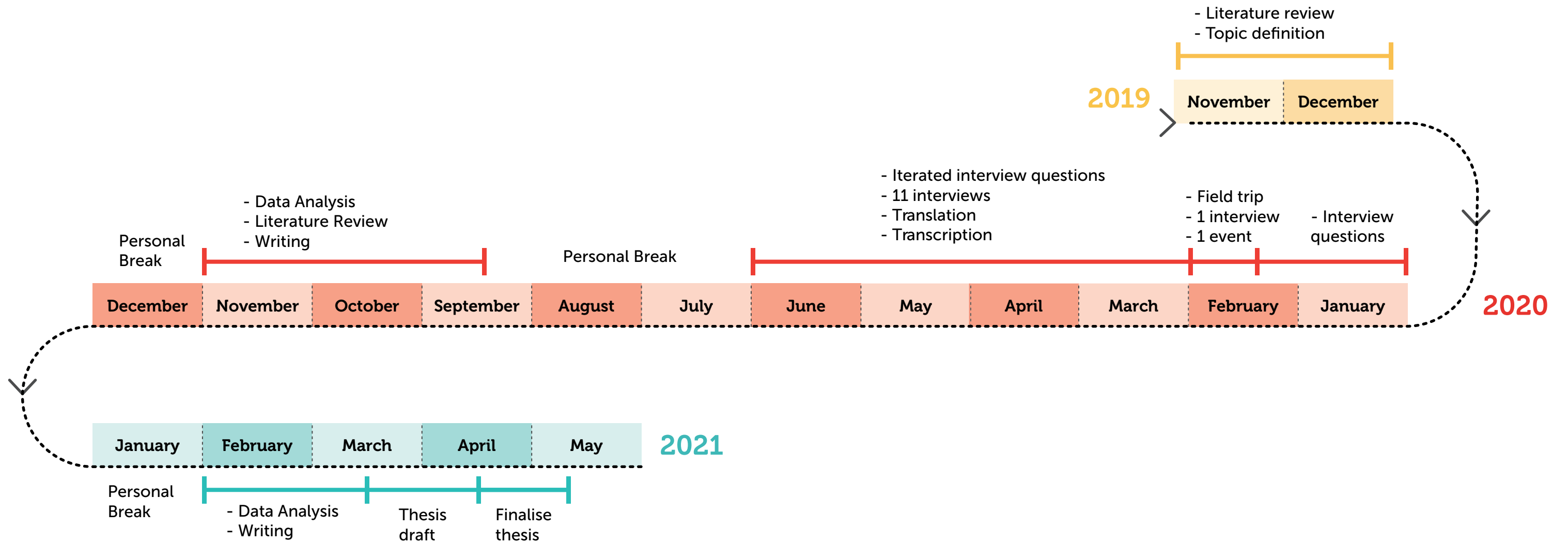
Figure 4. *Thesis timeline.*

Chapter 2.
Theoretical Background

This chapter introduces an overview of natural hazards, disasters, and disaster management, focusing on rural fires. Furthermore, it examines the role of design in addressing complex challenges such as disasters through a systemic approach. The chapter then discusses the ANT framework and the value of ANT as a complement to systems thinking. Finally, the chapter ends with a summary of the literature.

2.1. From Climate Change to (Natural) Hazards

Society is confronted with enormous obstacles in addressing complex and interconnected socio-ecological issues, such as climate change (Rockström et al., 2009). Over time, climate change has been manifested in several weather-related events, namely natural hazards and the deterioration of the ecosystems (Tanjeela, 2015). These events have had implications for socio-economic sectors. The impacts and effects of climate change vary significantly across social and political bodies and geographic regions. Unstable economies will gradually fall behind those that are more stable, particularly regions and countries that depend on natural resources (Tanjeela, 2015).

Although climate changes have been occurring throughout time, only recently society has been taking actions towards global warming and climate change (IPCC, 2018). Despite widespread awareness, attempts to mitigate climate change have been restricted, and greenhouse gas emissions have steadily increased over the last decades (IPCC, 2018). The study on climate change presupposes forecasting how human-caused greenhouse gas emissions will grow in the future (Hallegatte, 2014). However, this progression is contingent on many unpredictable factors, including demographic trends, economic development, technological advancements, and cultural preferences. Climate change and its consequences cannot be anticipated in the conventional sense (Hallegatte, 2014). Projections of large-scale changes in temperature, precipitation, and other meteorological variables indicate that all extreme events (droughts, heatwaves, wildfires, floods and cold spells) will be affected (Hallegatte, 2014).

According to a report by UNDRR and CRED (2020), over the last two decades, 7348 extreme events have been reported worldwide (Figure 5). As illustrated in Figure 5, disasters related to natural hazards took approximately 1.23 million lives, an average of 60,000 each year, and impacted a total population of more than 4 billion, resulting in economic losses reaching approximately US$ 2.97 trillion (UNDRR/CRED, 2020). The number of people impacted by disasters, including injuries and disruption of livelihoods, especially in agriculture and the economic harm associated with them, is increasing in direct proportion to mortality decline. There is strong evidence that the consequences of global warming are being felt by an increased occurrence of severe weather events such as heat waves, droughts, flooding, winter storms, hurricanes, and wildfires.

	Reported disasters	Total casualties	Total affected	Economic losses (USD)
1980-1999	4 212	1.19 million	3.25 billion	1.63 trillion
2000-2019	7 348	1.23 million	4.03 billion	2.97 trillion
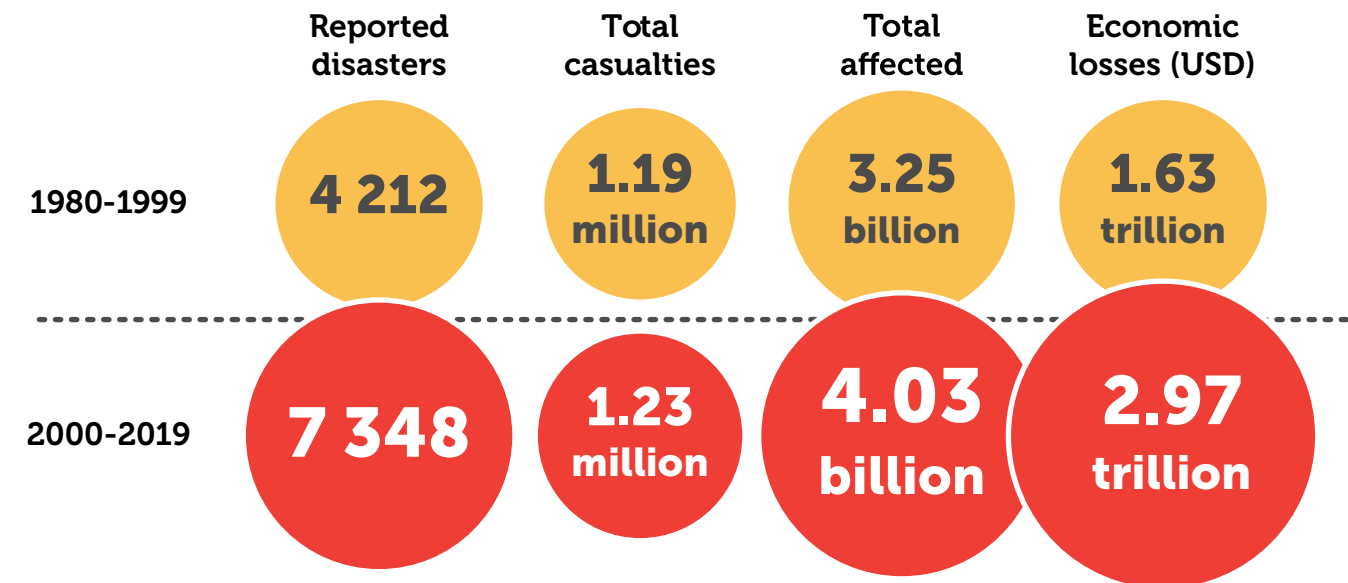
Figure 5. *Disaster Impacts: 1980-1999 vs 2000-2019 (adapted from UNDRR/CRED, 2020).*

The reported focus on extreme weather-related events highlights the concerning connection between natural hazards and climate change, driven by significant changes in average weather conditions and patterns (Thomas, 2017). Natural hazards affecting heavily populated areas have a greater chance of escalating into disasters due to the sheer number of people exposed. By 2050, two-thirds of the global population is expected to live in cities (Ritchie & Roser, 2018; Thomas, 2017).

Climate change hampers the issue of natural disasters. The relationship between human-caused greenhouse gas (GHG) emissions and global temperatures establishes a connection between climate change and human activities. Climate change, whether anthropogenic or human-driven, changes the nature of natural hazards, shifting them from those inherent in the physical environment and outside human control to phenomena influenced and induced by human activities (Thomas, 2017). People are no longer passive victims, and human activity plays a role in the development of disasters.

2.1.1. The Nature of Disasters

As stated in the previous section, a natural hazard involves humans, regardless of the word "natural". A physical occurrence, such as a volcanic eruption that has no impact on humans, is a natural phenomenon, not a natural hazard. A hazardous incident is a natural event that occurs in a populated area. A natural disaster is a dangerous event that results in an unacceptably large number of deaths and extensive property damage (Blanchard, 2020; Chmutina & von Meding, 2019; Hallegatte, 2014; World Bank & United Nations, 2010). Natural events do not constitute threats or cause disasters in places devoid of human interests. Thus, this idea contradicts common perceptions of natural hazards as inevitable devastation inflicted by nature's unbridled forces. It moves the presumption of evidence away from solely natural processes and toward the coexistence of human activities and natural events (OAS, 1990).

While humans have little or no control over most natural phenomena' frequency or intensity, they have a critical role in ensuring that natural events do not become disasters due to their behaviour. It is essential to recognise that human activity can exacerbate the frequency and magnitude of natural hazards. For instance, when the tipping point of a landslide is removed to allow construction, the land will return and cover it (OAS, 1990). Additionally, human intervention can create natural hazards where none previously existed. Volcanoes regularly erupt, but they are not considered dangerous until they affect farms and human settlements (OAS, 1990). Eventually, human activity diminishes natural habitats' mitigating impact. Coral reef degradation, which disempowers coastal ecosystems from floods and waves, is an example of a disturbance. Desertification is an extreme example of human interference in an environment that is, by definition, a human-induced "natural" threat (OAS, 1990; Thomas, 2017). Despite this, a wide variety of scientific disciplines refer to disasters as "natural". Several scholars have concentrated on the disaster's "natural hazard" aspect; however, in many social science disciplines, the term is unsettling at best, particularly in light of current awareness of the role of vulnerability in disaster impacts on society. (Chmutina & von Meding, 2019). Not all persons and infrastructure can be impacted in the same manner by threats such as flooding, cyclones and wildfires. Physical, mental, and economic attributes can impact individuals' proclivity and properties to be harmed and their capacity to cope and adapt. Therefore, vulnerability to climate change is a multidimensional concept determined by non-climatic factors such as income and other demographic and socioeconomic aspects (Thomas, 2017).

Ultimately, if an event damages a human system with sufficiently severe adverse effects, the incident is classified as a natural disaster. However, a catastrophe happens because a natural occurrence collides with a human system, resulting in harmful effects (Hallegatte, 2014). A natural disaster is mainly a social and human phenomenon (World Bank & United Nations, 2010).

Types of Disasters

As previously stated, disasters strike when a society is inadequately resourced or prepared to endure the consequences and whose population is vulnerable due to poverty, isolation, or some other form of social disadvantage. Thus, disasters can and should be avoided. Society may attempt to avert disasters by mitigating risks and fostering resilience (IFRC, 2020). However, it is fundamental to understand and identify the different types of disasters to mitigate those risks. UNDRR/CRED (2020) reports that hazards could be classified into six categories: geophysical, hydrological, meteorological, climatological, biological, and extra-terrestrial (Figure 6). Climate-related events include floods, hurricanes and temperature fluctuations, droughts and wildfires, but not earthquakes and volcanic eruptions (Thomas, 2017).

Geophysical	Hydrological	Meteorological	Climatological	Biological	Extra-terrestrial
Earthquake	Flood	Storm	Drought	Animal accident	Impact
Mass movement (dry)	Landslide	Extreme temperature	Glacial lake outburst	Epidemic	Space weather
Volcanic activity	Wave action	Fog	Wildfire	Insect infestation	
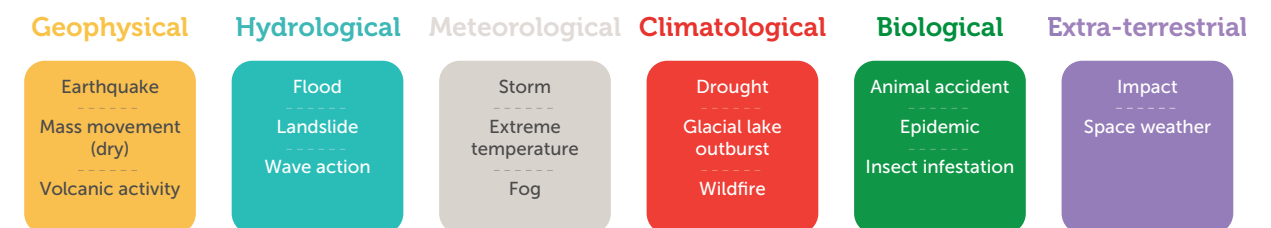
Figure 6. Classification of natural hazards by disasters type (adapted from UNDRR/CRED, 2020).

Floods are the most prevalent form of disaster worldwide, accounting for 44% of all events examined in this study (Figure 7). Floods are hydrological occurrences, a subcategory of disasters that also encompasses landslides, which account for 5% of overall events (Figure 7). Storms are the second most frequent form of disaster globally, accounting for 28% of all incidents. Storms are the most common form of meteorological hazard that impacts coastal areas near the world's oceans (Figure 7).

Climatological events are a less common form of disaster, accounting for 5% and 3% of total incidents, respectively. Finally, geophysical phenomena such as earthquakes and seismic activity account for 9% of all events, with earthquakes accounting for the bulk of these (including tsunamis). Between 2000 and 2019, the annual number of disaster incidents and the distribution of disaster sub-groups remained broadly constant, with an average of 367 reported events per year (Figure 7).
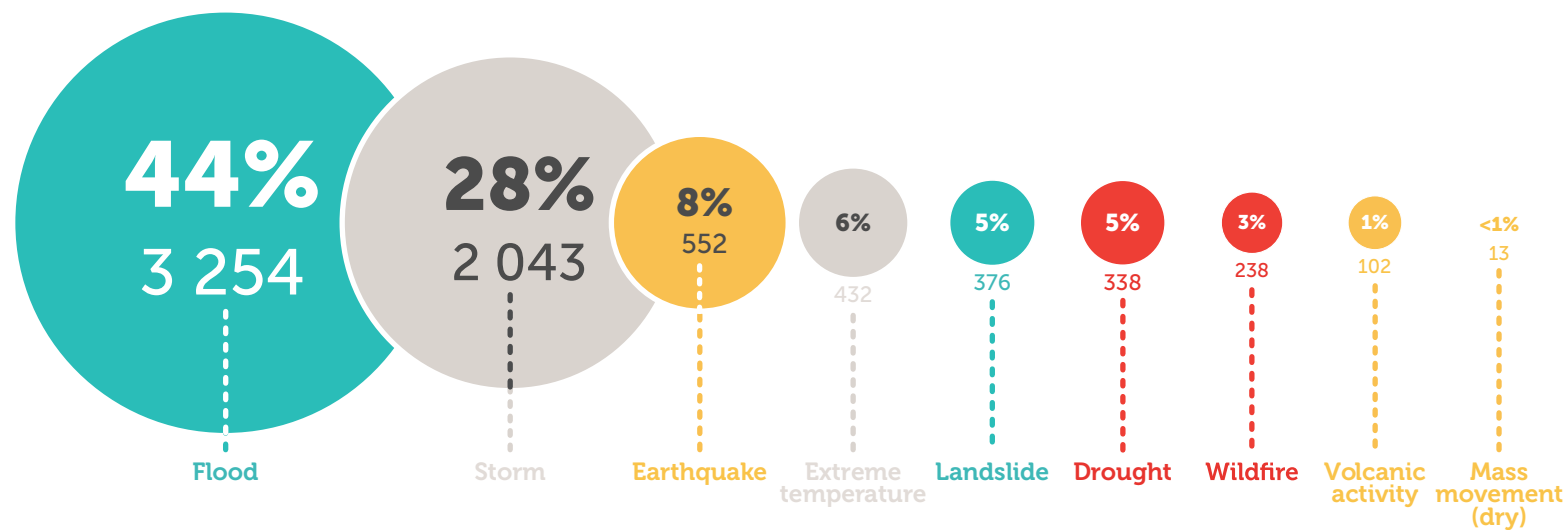
Figure 7. *Percentage of occurrences of disasters by disaster type (2000-2019) (adapted from UNDRR/CRED, 2020).*

Disasters may harm the climate and ecosystems, with immediate to long-term implications for the populations whose lives, health, livelihoods, and well-being are dependent on a particular environment or ecosystem (Rieux, 2013).

2.1.2. Disaster Management

As mentioned in the previous section, public authorities have traditionally regarded disasters as a set of isolated extreme incidents, prompting top-down government initiatives and actions by local and foreign aid organisations that failed to consider the social and economic consequences and causes of these events (Yodmani, 2001). With substantial advancements in understanding the natural forces behind dangerous events, a more technical model emerged, recognising that the best way to deal with disasters was to implement geophysical and technical expertise and related interventions in public policy. These perspectives viewed disasters as singular occurrences unrelated to ongoing social and developmental cycles. As it became clear that disasters are related to social systems and their complexities (Hallegatte, 2014; OAS, 1990; World Bank & United Nations, 2010), the technocratic approach changed to a focus on preparedness initiatives, developing prevention strategies, and expanding aid organisations' position (Yodmani, 2001). This shift in public policy from "relief and response" to "risk control" affected disaster management systems' planning and financing, emphasising social, economic, and environmental vulnerability reduction and long-term prevention activities (Tiefenbacher, 2013).

Disaster response aims to limit or minimise the potential damage caused by hazards, provide disaster victims with prompt and sufficient assistance, and enable a rapid and complete recovery. The disaster management cycle (Figure 8) illustrates the ongoing process by which governments and civil society plan for and alleviate the impacts of disasters, respond and recover from disasters, and take action to rebuild after a disaster. Appropriate actions at each point of the cycle result in improved preparedness, enhanced warnings, reduced vulnerability, and the prevention of hazards in the next iteration of the cycle. The complete cycle of disaster management entails developing national policy and strategies that aim to either prevent disasters or minimise their impact on persons, facilities, and the environment (Alexander, 2002; Warfield, 2005).

Prevention and preparedness processes emerge as disaster management changes are implemented in advance of a disaster incident (Thomas, 2017). Developmental factors are critical in assisting communities in mitigating disasters and preparing them to deal with them efficiently. When a catastrophe strikes, disaster management actors, especially governmental agencies and aid organisations, are drawn into the rapid response and long-term recovery processes. The four stages of disaster management (Figure 8) do not always

happen in isolation or this particular order. Frequently, the cycle's stages intersect, and the duration of each process varies significantly according to the magnitude of the catastrophe. Each action impacts the management and efficacy of the following phase, and each needs equal consideration (Thomas, 2017).

Local authorities and humanitarian organisations are often tasked with emergency response and rehabilitation after a disaster. These organisations must have experienced managers, qualified professionals, proper transportation and logistical assistance, reliable communications, and policies governing emergency response to respond efficiently. Without the appropriate arrangements, local authorities and humanitarian organisations will not address the urgent needs of the people affected by disasters (Warfield, 2005).
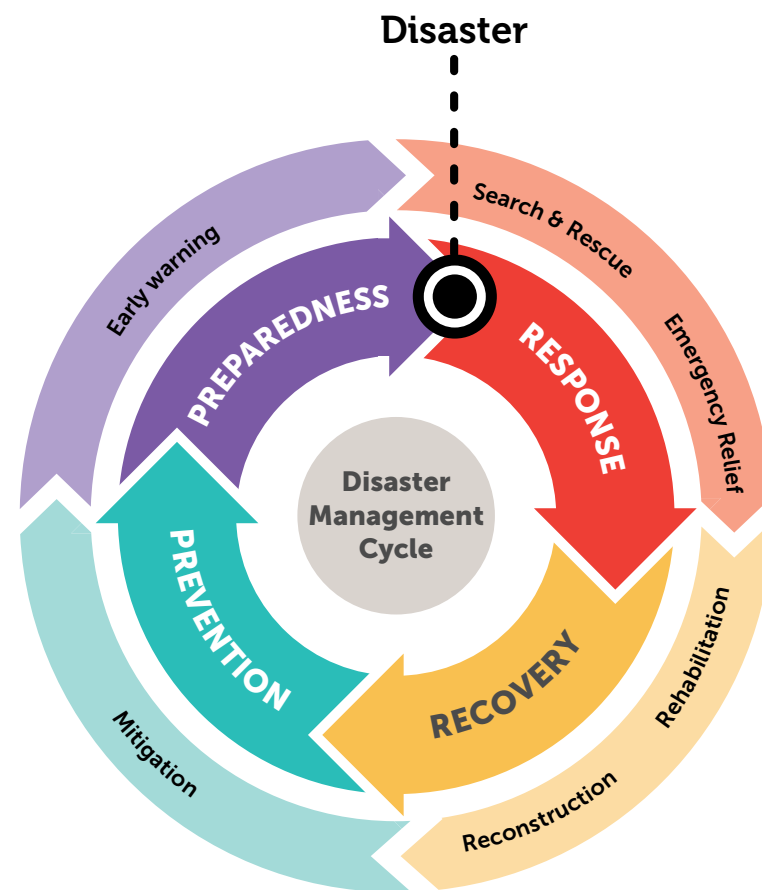
In 2009, the United Nations International Strategy for Disaster Reduction (UNISDR), currently known as United Nations Disaster Risk Reduction (UNDRR), published a report on disaster terminology (UNISDR, 2009). This report sought to foster shared awareness and application of disaster management cycle principles and support policymakers, professionals, and the general public in their attempts to reduce disaster risk.

The study was commissioned in response to a proposal from the "Hyogo Framework for Action 2005-2015" to update and broadly disseminate standard world vocabulary on disaster risk mitigation for use in the creation, implementation, and research of programmes and organisations, as well as in training curricula and public awareness programmes. The UNISDR report (2009) provides the following definitions for each phase of the disaster management cycle:

Prevention
"The outright avoidance of adverse impacts of hazards and related disasters."

Prevention refers to the idea and goal of entirely avoiding future negative consequences by proactive measures taken in advance. Examples include flood-control barriers or embankments, land-use laws that prohibit settlement in high-risk areas, and seismic infrastructure designs that guarantee the survival and operation of a vital building in the event of an earthquake (UNISDR, 2009). Sometimes, total loss prevention is not possible. The challenge becomes reducing the impact of such disasters and their negative consequences (UNISDR, 2009).

Preparedness
"The knowledge and capacities developed by governments, professional response and recovery organisations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions."

Preparedness policy occurs within the framework of disaster risk management. It seeks to develop the capabilities necessary to effectively handle all forms of crises and ensure an orderly transition from response to sustainable recovery (Twigg et al., 2004). Preparedness is based on a thorough review of hazard threats and strong connections to early warning services. It entails strategic

Figure 8. *Disaster management cycle (adapted from Alexander, 2002)*

preparation, stockpiling resources and resources, developing plans for coordination, rescue, public information, and related training and field exercises. These require structured administrative, legislative, and economic capacities (UNISDR, 2009; Warfield, 2005).

Response

"The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected."

Disaster response is often referred to as "disaster relief" because it is mainly concerned with urgent and short-term needs. The distinction between this level of reaction and the following stage of recovery is not apparent. Certain response activities, such as providing temporary accommodation and water, continue well into the recovery stage (Warfield, 2005).

Recovery

"The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors."

The rehabilitation and reconstruction phase of recovery should begin immediately after the emergency phase. It should be guided by pre-existing plans and policies that provide specific administrative responsibilities for recovery action and encourage public involvement. In conjunction with increased civic recognition and participation after a crisis, recovery programmes provide an invaluable incentive to formulate and enforce disaster risk prevention strategies and incorporate the "build back better" concept.

According to (Van Niekerk, 2007), one major limitation of the disaster management cycle is that it preserves a disaster-focused approach. This approach implies that all activities and services are oriented towards the possibility of a catastrophic occurrence. The root causes of these disasters are often overlooked or result from bureaucratic inefficiency (Van Niekerk, 2007). When these causes are analysed objectively, it becomes clear that most of them can be attributed to some weakness caused by human activities. Many efforts have shown the significance and singularity of hazard and risk reduction for the future (Forino, 2015; Rieux, 2013). Compared to earlier disaster management principles, hazard risk and mitigation strategies include considerably broader specialised supporters and depend on a much more complex set of knowledge criteria (Van Niekerk, 2007).

The evolution of the debate around disaster management has had profound implications for the underprivileged world, especially in reducing casualties. National governments, non-governmental organisations (NGOs), and local communities have taken various steps to alleviate natural disasters' effects on society, the economy, and the environment (Tiefenbacher, 2013).

2.1.3. Prevention of Disasters

One of the primary objectives of disaster management and one of the most direct ties to sustainability is promoting safe livelihoods, protecting and restoring them during disaster situations. By meeting this objective, people have a greater capacity to cope with crises, and their recovery is more expeditious and better sustained. A development-oriented approach to disaster management aims to minimise risks, avoid crises, and plan for emergencies. As a result, developmental factors are prominent in the disaster management cycle's mitigation and prevention phase (Thomas, 2017; Warfield, 2005).

Mitigation refers to any measures taken to lessen the effects of future disasters (Alexander, 2002). Although hazards cannot be avoided entirely, their magnitude or severity can also be significantly reduced by different strategies and activities. Mitigation initiatives include advanced building practices and hazard-resistant architecture, more stringent environmental policies, and increased public awareness (Huang & Anderson, 2011). It is worth noting that in climate change policy, the word "mitigation" is interpreted differently; it refers to the process of reducing greenhouse gas emissions that cause climate change (UNISDR, 2009).

Prevention refers to the concept and purpose of entirely avoiding potential adverse effects by taking proactive measures in advance. Examples include flood-control barriers or embankments, land-use laws that prohibit settlement in high-risk areas, and seismic infrastructure designs that guarantee the survival and operation of a vital building in the event of an earthquake (UNISDR, 2009). Sometimes, it is not possible to eliminate casualties, and the problem becomes part of mitigation. To some extent, this is why the terms mitigation and prevention are often used interchangeably in everyday use (UNISDR, 2009). Mitigation entails reducing the impact of the disaster's human and material damages (Alexander, 2002; Huang & Anderson, 2011; Twigg et al., 2004), while prevention ensures that human activity or natural events do not cause a disaster or emergency (UNISDR, 2009).

In this thesis, particular attention is given to the prevention of rural fires in Portugal.

2.1.4. Fires as Disasters

In recent years, weather conditions have become the warmest on record, impacting European Mediterranean countries such as Greece, Italy, Portugal, Spain, and Central and Northern European countries (UNDRR, 2019). Historically, increased temperatures have been associated with severe weather conditions such as extended droughts, heat waves, and flash flooding. Flash flooding is often caused by a short-term precipitation cycle that is spatially intensive and thus happens more often in drier climates (Allan & Soden, 2008). Under such conditions, fire outbreaks in arid climate zones can quickly become extreme fires, as demonstrated by the fires in Portugal in 2017 (Mira & Lourenço, 2019), and more recently, in Australia (Maas et al., 2020) and California (National Academies of Sciences, Engineering, and Medicine, 2020).

There appears to be a pervasive problem with the definition of fires. The European Union (EU) has used forest fires to define fires that have a strong physical impact on society, destroy structures and goods, and harm livestock and wildlife. The increased frequency of fires has resulted in an extended definition of fire, its causes and impacts. A rural fire is an uncontrolled burn. This rule does not apply to fires started for legitimate purposes such as crop burning but does apply to the same fires if they spread outside the intended location (UNDRR, 2019). In general, a fire may be sparked by natural (e.g. lightning strikes) or human-caused causes (e.g. campfires or arson). If it expands, it can ingest fuel from various flammable sources, grow in size and effect, and, under some circumstances, can become an extreme fire (Figure 9). Extreme fires close to populated areas can pose significant threats to populations, vital infrastructure, and the environment. Fires that spread rapidly and uncontrollably typically result in human fatalities and property losses, as was the case in Portugal (ITC, 2017, 2018).

Apart from the effects of fire expansion, smoke generated by fire presents significant health hazards due to the chemical combination of some contaminants such as particles or gaseous toxins. Massive amounts of smoke along with the excessive thermal radiation released will result in suffocation and death for those who are immediately exposed, even long after the fire has been extinguished (Karma et al., 2019).
If climate change impacts continue to warm the world, fires will increase and occur in previously non-fire prone regions. One major shift would imply a more profound observation and study of communities and organisations' activities and their interaction with the natural ecosystems to mitigate risks of extreme fires.

In 2017, the most destructive fires in Europe (in June and October) occurred outside of the conventional fire season (July to September). Fire seasons are getting longer and affecting a larger region each year (UNDRR, 2019).

On a global scale, the increased frequency of severe heat waves and fires has raised grave concerns in recent years. Future changes in the climate will have a direct impact on such phenomena. Each year, fires cause a large number of fatalities and property losses. These fires impact millions of people and have a devastating effect on habitats and ecosystems (UNDRR, 2019). Although international policies and fire protection regulations have resulted in successful preventive measures, technological and environmental fire hazards continue to jeopardise local communities' sustainability, biodiversity and the natural ecosystems of affected areas (Karma et al., 2019).

Rural fires may significantly affect public health due to the fine particle air pollutants they produce, which irritates the eyes and lungs, exacerbating chronic problems and causing new ones. They may also harm mental health when they cause severe trauma. They continue to affect nature by destroying forest-based habitats and polluting others, such as rivers, wetlands, and even coral reefs (IFRC, 2020).

During the past decade, many extreme fires happened, with the most occurring in the Americas, Europe and Oceania (Figure 10). The United States of America was the worst-affected region, with major fire-related disasters losing approximately 200 people and affecting over 300 thousand. In Asia, Indonesia was only struck by one rural fire, which lost 19 people and displaced over 400 thousand people (IFRC, 2020).

The condition is expected to deteriorate as time progresses. Scientists predict that the probability of fires of the same severity will be at least four times greater than it was in the early 1900s, though this claim is undoubtedly an estimation (IFRC, 2020). Several regions, including the Americas, Europe (particularly across the Mediterranean), southern Africa, and Central Asia, are predicted to become increasingly vulnerable and affected by rural fires (IPCC, 2019).
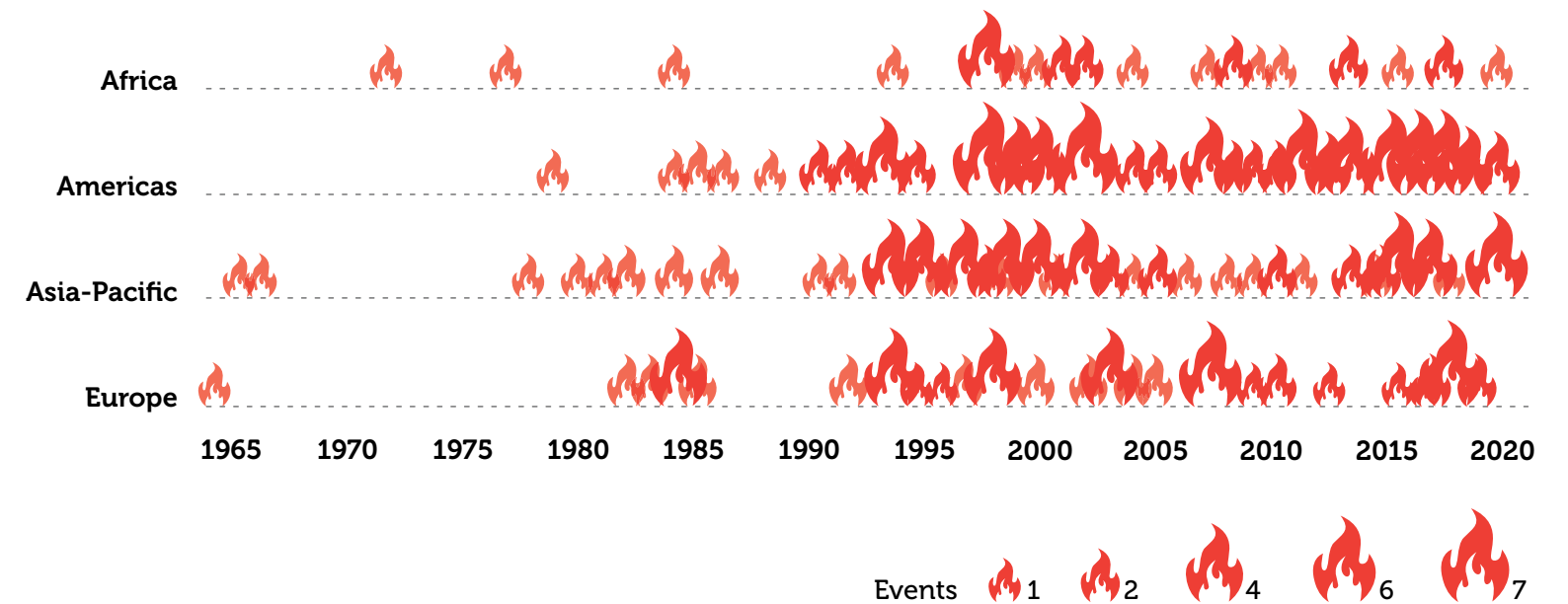

Figure 9. Visual representation of extreme fires (adapted from Tedim et al., 2019).

Figure 10. Frequency of rural fires by region since the 1960s (adapted from IFRC, 2020).

2.2. Designing for Systemic Transformation

Today, the new types of challenges that society is confronted require a new way of thinking. Society is currently facing the ethical shortcomings of accumulated environmental mismanagement over the years (Sepers, 2017). Although the present challenges are distinct, they are characterised by the fact that they are increased by human behaviour, affecting the whole planet, ecosystems, communities and individuals. This complexity compels an investigation of what it is in human nature that creates so much confusion and inquires whether it is possible to develop a culture that encourages society to be anything more than individuals exploiting the planet (Sepers, 2017). For designers, this entails dealing with dynamic processes, emphasising the individual, social, and environmental connections while also delving into the human behavioural aspects of the current issues. Only with a move from a materialistic understanding of processes to grasping the deeper patterns underlying how existential human problems arise is it possible to explain, comprehend, and holistic design solutions that address social, environmental, and economic challenges (Sepers, 2017).

Hazards are rapidly recognised as one of the most critical and pressing issues of our time, requiring a national and coordinated approach. Only in this interconnected manner will the impacts of hazards be mitigated and disasters avoided (Hallegatte, 2014; Thomas, 2017; World Economic Forum, 2020). Although it is generally accepted that disasters are a global challenge, there are still many uncertainties on how to address them, with various disciplines offering many suggestions. Design can play an essential role in addressing dynamic, intertwined, conflicting issues situated in an unpredictable setting and embedded in rapidly evolving environments (Sun & Yang, 2016). Additionally, the interconnected social, political, and cultural gaps between countries complicate efforts to solve disaster management and prevention on a global and regional scale (Sun & Yang, 2016).

Historically, responsibility for protection against such hazards has been transferred to the government and its institutions because it is preferable to have well trained and resourced organisations act and protect society. However, this delegation of accountability has reached a limit. Individuals are no longer adequately responsible for their risk management (Thornton, 2015). Although fire seasons are prolonging and severe fire weather is becoming more prevalent, it is not the entire picture. Most of the public commentary suggests that there are a variety of straightforward solutions to this hazard. Natural hazard management, which includes rural fires, is a profoundly dynamic concern that

spans many governments, private, and community levels (Thornton, 2015). The issue of disasters has increasingly been referred to as a 'wicked problem' (Head, 2008; Stang & Ujvari, 2015; Sun & Yang, 2016). Introduced by Rittel and Webber (1973), the term 'wicked problem' has been used to describe multidimensional challenges that arise due to insufficient or conflicting information, divergent views on the problem's existence, or complex relationships with other issues (Rittel & Webber, 1973). Wicked problems arise at the intersection of human-environmental activity and are defined by solutions that generate an abundance of new problems (Sun & Yang, 2016). From this point of view, extreme fires are such an issue: a long-term crisis for which the importance of urgent intervention is becoming increasingly evident. Increased air heat and cooler ocean surface temperatures can cause wind speeds to rise during tropical storms and rural fires. Although mitigation measures contribute to the increase of rural fires in many countries, it is not clear how society will coexist with this disruption.

Rava (2016) claims that there are no solutions to complex, wicked problems by definition. The concept continues to evolve through implementation, and the only criterion for completion is determining whether the design output is satisfactory — and agreeing to further redesign in the subsequent stage (Rava, 2016). The strategic and analytical concept of "wicked problems" encompasses a variety of interpretations. For instance, hazards such as rural fires occur as a natural part of the environment, and the occurrence affects everything we value: our lives, homes, livelihoods, or services. The fires we have seen — burning hotter, quicker, with increased complexity and expense, and posing increased risk to habitats and communities — require a systemic analysis (Steffens, 2016).

Disasters are one of the most complex challenges society has ever encountered. The consequences of human actions are becoming more severe, and the causes of these actions are profoundly ingrained in many of the systems on which we depend. These conditions imply that solutions to the problem cannot be conceived as one-off concepts but require a strategic and systematic change of the current systems. Since human-made systems must be redesigned, it has been argued that complex issues such as rural fires and other disasters must be tackled with a systemic approach to understand and address the problem.

2.2.1. Strategic Design

In the 20th century, the role of design shifted away from aesthetics and toward intentionality and human-centred processes to create products that people found functional, accessible, and attractive (Kimbell, 2012). Early adopter organisations invested much time and resources into combining human-centred design with innovative practices and technologies to generate new value. Now, the focus has shifted again, as well as the perception of design's capacity to support change; it has grown beyond the creation of concrete objects to the construction of complex systems, transforming designers into facilitators and co-creators of systems, services, and even policies (Buchanan, 1992; Meroni, 2008). This change supports the idea that the traditional design principles and practices alone are no longer sufficient to address significant systemic challenges. This shift reinforces the notion that conventional design practices and methods alone are insufficient to solve systemic challenges on a large scale. The role of design has progressed from the operational to the strategic level, which, according to Meroni (2008), is about granting a set of values, ideals, principles, and tools to assist leaders in dealing with the external environment rather than social and business actors.

The principle of approaching complex challenges, characterising them, and resolving them demonstrates the fundamental nature of the value that strategic design delivers. It is a complex relationship, an organically evolving system of related components in continuous motion (Scaletsky & Da Costa, 2019). According to several studies, strategic design can be defined as a practice concerned with uncertainty and transformation (Boyer et al., 2013; Hill, 2012). It determines strategic orientations across scenarios, taking common goals and principles into account, and provides resources for external environment learning (Buehring & Bishop, 2020). Manzini (2009) argues that if designers want to be agents of change, it is fundamental to go outside their comfort zone and constantly develop new skills (Manzini, 2009). This mindset entails having broader strategic goals and collaborating from new perspectives, bridging disciplines to carry out tasks and address new challenges (Meroni, 2008). Calabretta et al. reinforce the idea that working from unfamiliar perspectives requires recognising how organisations see the issues, using design as a way of thinking to understand and connect diverging perspectives (Calabretta et al., 2016).

In an increasingly interdependent, dynamic, and regulated environment, the efficacy of project-level innovations is declining (Boyer et al., 2013). For example, in disaster management, creating effective solutions by focusing on response alone is insufficient due to the variety and characteristics of the events and the environment.
As strategic design's contributions increase, the role of design can shift from problem-solving to the catalyst of progressive change that includes economic, social, and environmental values (Lam, 2017). By applying a strategic mindset, designers can strengthen society's capacity to deal with challenging problems, such as disasters - designing methods that assist organisations in conceptualising and reacting to 'wicked' problems (Boyer et al., 2013).

After presenting the fundamentals of design as a strategic tool, it is possible to conclude that strategic design offers the lenses to articulate novel ideas about systems, relationships, and interconnections, making design decisions in complex and unpredictable environments, from businesses to associations, institutions and governments (Boyer et al., 2013; Hill, 2012; Meroni, 2008). This position presents excellent opportunities for design to contribute to new fields and broaden the influence.

The following section will explore the role of design in addressing challenges from a systems perspective. It will serve as a foundation for further investigation into the rural fire management system in Portugal.

2.2.2. Thinking in Systems

The concept of using design as a tool to address systemic issues is not new. In 1984, Papanek explored how design could tackle complex challenges and social concerns, such as design for people with disabilities (Papanek, 1984). However, it is only recently that the number of studies investigating the strategic role of design has increased substantially (Cross, 2014; Lam, 2017; Tietjen & Jørgensen, 2016).

An approach for addressing the rise of today's diverse and intertwined problems, such as rural fires, is investigating the issue on a systemic level. According to Buchanan (1992), design cannot be limited to products or services (Figure 11). Design must consider the organisations that provide those products and services (Buchanan, 1992). In his work, Buchanan indicates that design professions have progressed from designing symbols and artefacts to interactions, and finally to the design of systems, environments, and organisations (Buchanan, 1992). This idea is similar to that found in Manzini's introduction in 'Design for Services' by Meroni and Sangiorni (2011), who claims that addressing complex issues involves a systemic approach that benefits the social economy and compels social innovation to discover the ideal solution (Manzini, 2011). These design solutions must bring together various actors and resources to diagnose a problem and create an actionable solution; they, therefore, involve logic and judgment in determining how to proceed (Forlizzi, 2013). The systemic approach is a crucial
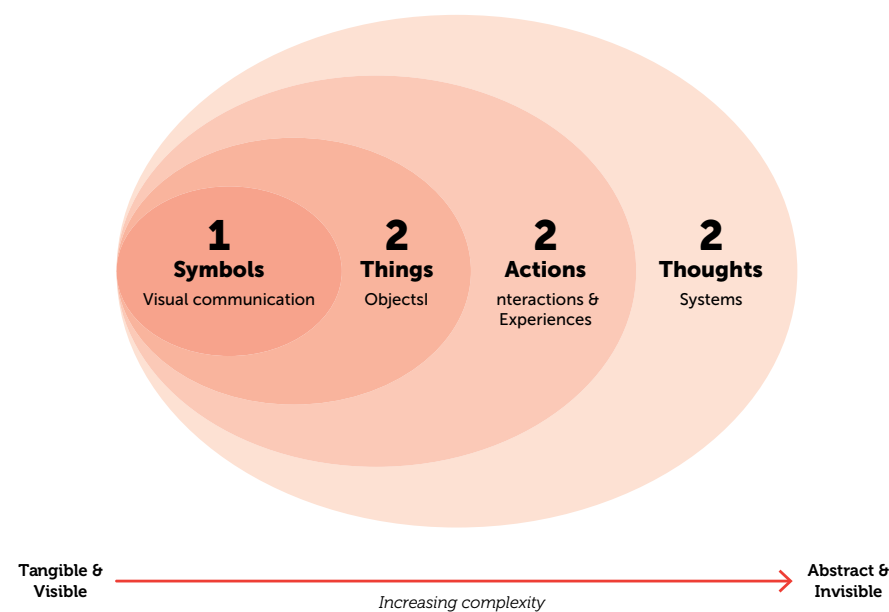
skill set in design, given the predisposition for systemic change (Hill, 2012). Hill (2012) argues that many designers who are more experienced with systems may be the best suited to think strategically and systemically (Hill, 2012). This ability to address and understand complex challenges at a systemic level is intrinsically linked to the field of systems thinking. Systems thinking is a holistic approach to research that emphasises the interdependence of a system's parts and how systems work over time (Meadows, 2008). For instance, the human body as a whole emerges from the relationships between body parts, and the body's emergent property is existence. Similarly, in the context of this thesis, the fire management system in Portugal emerges from the relationships between the actors, policies, resources and context, and its emergent property is the prevention and response of rural fires.

Systems thinking is the process of comprehending a phenomenon concerning a greater whole. Compared to traditional research, which studies systems by dismantling them into their constituent parts, systems thinking examines systems holistically (Buchanan, 2019). Systems thinking applies to every area of research and has been applied to examining environmental, political, economic, social services, and educational systems.

Boundaries in Systems
Since everything in the world is intertwined, a system hardly has an actual boundary. As a result, it is vital to keep in mind that the knowledge society has about the world is a model (Meadows, 2008). While the models closely resemble the real world, society tends to underestimate the natural world's complexity. Nonetheless, to comprehend and analyse systems, researchers must simplify them and provide some boundaries (Meadows, 2008). The boundaries of this study are limited to rural fire prevention as a system composed of actors (governmental agencies, private institutions, local governments, and citizens) and influencing factors (such as policies, legislation, forests, lands, and fire), their interconnections, and their role.

1	2	2	2
Symbols	**Things**	**Actions**	**Thoughts**
Visual communication	Objectsl	nteractions & Experiences	Systems

Tangible & Visible ──────────────→ Abstract & Invisible

Increasing complexity

Figure 11. The four orders of design (adapted from Buchanan, 1992).

Intervention in Systems

Many approaches recognise the shortcomings of forecasting and designing complex societal systems, thus fostering system change toward more sustainable societies. The leverage points by Meadows (1999) are an excellent example of this type of systemic change approach (Figure 13). These are strategic points of intervention within a complex system where a minor change in one area will significantly change the system (Meadows, 1999). The interventions aim to alter the system to produce significant change and improve the processes with a small action. Figure X lists the twelve leverage points and summarises their level of intervention.

Meadows (1999) claims that society is intensely concerned with parameters and numbers due to their short-term significance (Meadows, 1999). Nevertheless, leverage points that aim to alter the system's goal, mindset, or paradigm are more powerful. Moreover, those leverage points face more significant systemic opposition and need a long-term commitment to effect improvement (Meadows, 1999). The disaster prevention system is a potent leverage point that can catalyse social and global changes toward disaster management by shaping the thinking and, ultimately, the behaviour of society and governments.

This thesis will use the leverage points to analyse the rural fire prevention activities and identify intervention areas to incorporate prevention strategies.

System

12 Constants, parameters, numbers

11 Buffer sizes

10 Material stocks and flows

9 Relative delays

8 Negative feedback loops

7 Positive feedback loops

6 Information flows

5 Rules of the system

4 Structure of the system

3 Goal of the system

2 Mindset/ paradigm

1 Power to see paradigms as such

Most interventions are designed around these leverage points.

Deep leverage points have higher transformative impact, but harder to design for.
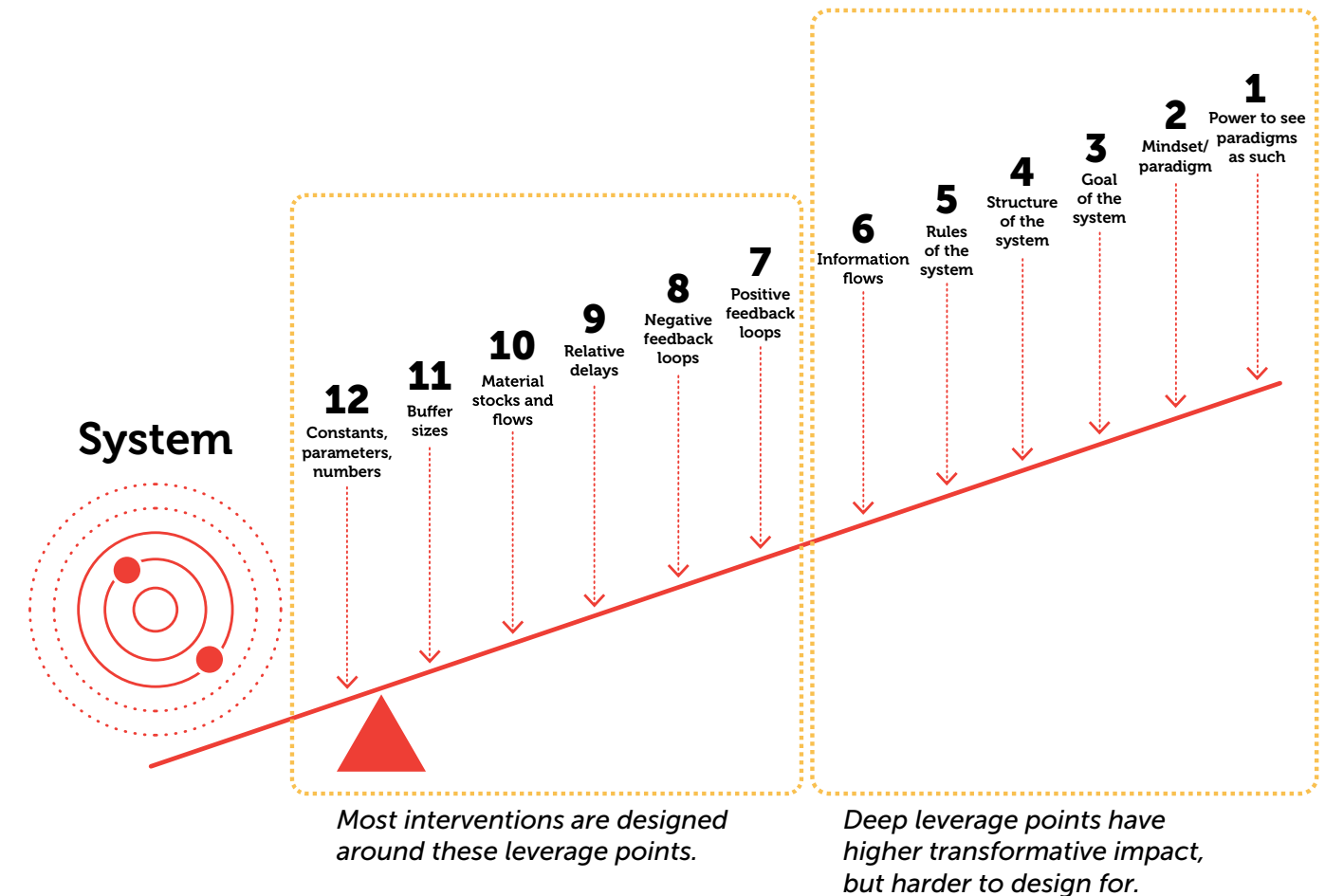
Figure 12. *Leverage points in increasing order of effectiveness by Donella Meadows (1999)*

2.2.3. Systemic Approach in Design

Although there is a long tradition of association between systems thinking and design, the approaches and implementations in the field have diverged (Jones, 2014). However, in recent years, the system complexity and the emphasis on societal impact has reignited the interest in using a broader range of design practices to draw on the theoretical skills of systems thinking (Buchanan, 2019). Buchanan (2019) states that systems thinking brings to light the complexity, interconnections, and many interdependencies in current settings. However, it does not result in action until the discipline of design mediates it. Design is more than the set of strategies and methods often condensed in system thinking approaches (Buchanan, 2019). Design is a discipline concerned with transforming surroundings into environments helpful to human experience. Such environments are products that can be thought of as processes and systems inside systems. In the most challenging work of fourth-order design (Buchanan, 1992), designers often seek to build structures on the scale of social, economic, and political systems, with varying degrees of success.

Ryan (2014) claims that a single variant of systems and design thinking can simplify the challenge of creating a coherent and concise language for practitioners. For a systemic design approach to be practical beyond a few specialised implementations, practitioners must choose the variants of systems thinking and design that are most appropriate for their specific task (Ryan, 2014). According to Ryan (2014), a systemic design approach is intended for problems that are dynamic, unique, involve conflict, or have ambiguous goals. He continues affirming that systemic design enables different teams to gain a holistic view of the problem and quickly transform new ideas into actions (Ryan, 2014). In an iterative cycle of framing, formulating, creating, reflecting, inquiring, and encouraging, action is taken to change the situation often accelerates organisational learning in proposed processes for systemic design (Ryan, 2014). The framework proposed by Ryan (2014) views systemic design as a three-tiered process that is mutually reinforcing: mindset, methodology, and method (Figure 13). The term "method" refers to a set of procedures for initiating group processes that specify how group members can collaborate to produce and externalise ideas. Methodology refers to a rationale for choosing and integrating methods in a logical sequence to progress from gaining a better view of the problem to producing behaviour to change the situation. Mindset refers to the principles and practises brought to the task by the system designer, which drives judgement during methodology implementation and method selection (Ryan, 2014).

Ryan (2014) outlined that these three processes offer a versatile and realistic basis for combining processes and design thinking to assist organisations and communities in meaningfully confronting their most complex challenges.
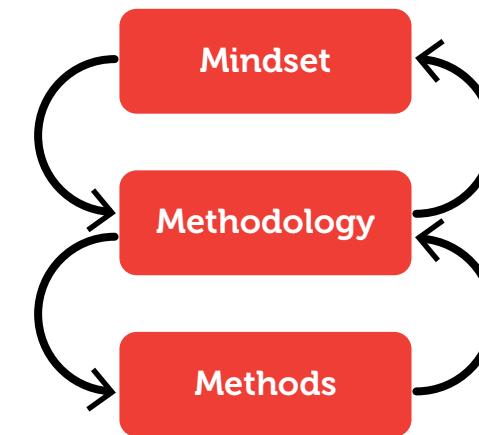
Figure 13. *Three levels of systemic design (adapted from Ryan, 2014).*

The work of Costa Junior et al. also contributes to the discussion of a systemic approach in design by bringing the compatibility of systems thinking and design to the attention of designers, highlighting the importance of incorporating systems thinking into design and offering an overview of the field of systems-oriented design approaches (Costa Junior et al., 2019). Costa Junior et al. (2019) presents a philosophical paradigm organised around five clusters: mindset, methodology, knowledge, skill, and tool (Figure 14). Mindset refers to an awareness of the beliefs that drive systems thinking. It encourages designers to consider the importance of supplementing conventional design methods with a system-oriented viewpoint while confronted with complex societal issues. The methodology collection focuses on defining the prevalent way of thinking used by a systems methodology and aligning it with the designer's approach to problem-solving. The skillset encompasses the ancillary skills to design's core competencies needed to facilitate the development of information necessary for problem or system resolution. Finally, the tool collection encompasses methods and approaches for examining competencies to mediate and promote logic, visualisation, modelling, sense-making, and sense-sharing (Costa Junior et al., 2019). This framework is intended to assist designers in incorporating systems thinking into their practice, allowing them to address challenging societal problems more effectively (Costa Junior et al., 2019).
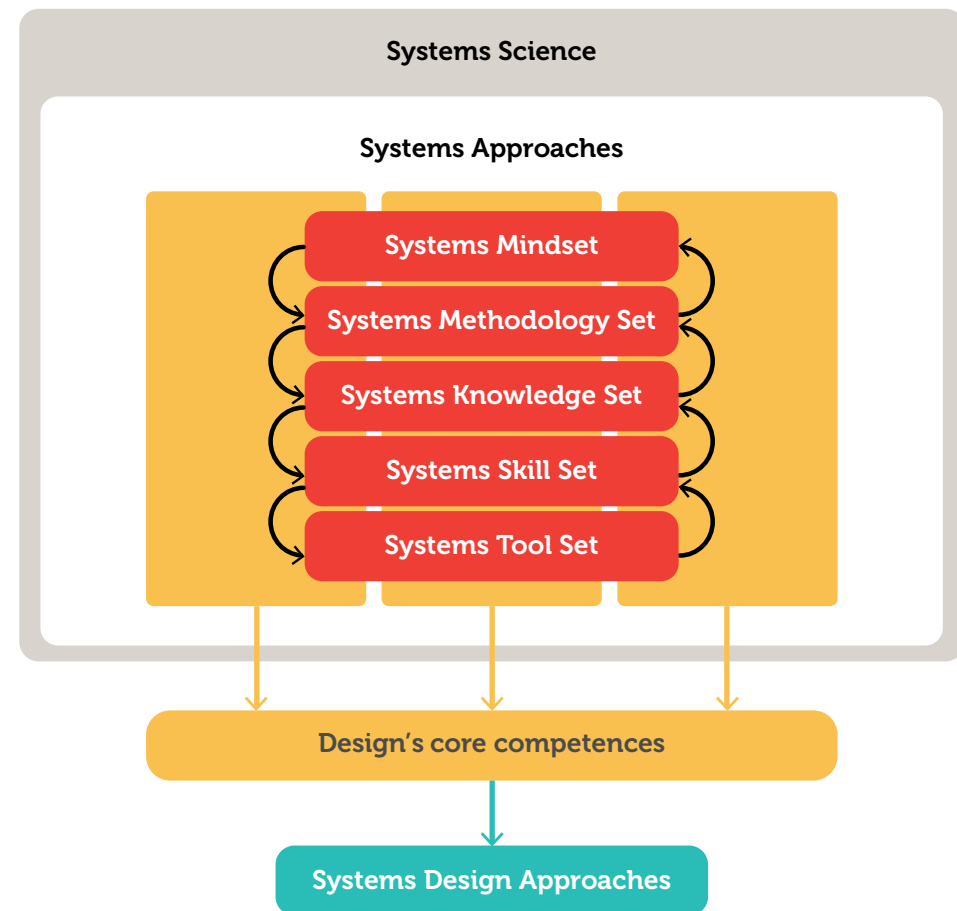
Figure 14. *Conceptual framework for systems design approaches (adapted from Costa Junior et al., 2019).*

The Design Council's framework (2021) provides increased awareness and legitimacy of the growing practice of systemic design and a platform that enables designers from diverse disciplines to collaborate with non-design professionals and societies to accomplish this work. Furthermore, it exerts control on legislation, law, requirements, and the design commissioning system to make it possible for designers to operate in this manner. The framework provides designers with the knowledge to help them make more rational decisions and related use of systems thinking to help them improve their competency and efficacy while tackling complex societal issues. In reality, implementing systems design approaches presents many difficulties. Simultaneously, this knowledge can be used as a foundation to address some of the complex issues and advance emerging studies on incorporating system thinking into design.

Although Costa Junior et al. 's framework (Figure 14) aids in identifying the approaches needed for the application of systems thinking to design, those resources must also be created by designers or outsourced before being used in design practices. One example that supports this argument is the systemic design framework by Design Council (2021). Guided by a series of six principles, the framework is intended to serve as a roadmap for action by assisting designers and practitioners interested in working more sustainably and systemically (Figure 15). By recognising the intertwined, diverse existence of problems and prioritising both the planet and its inhabitants, the systemic design approach builds on the current framework for creativity. Moreover, the framework defines the methods of work required for each stage of the design process, outlining critical work practices that designers should adhere to throughout the process (Design Council, 2021).

The systemic approach is distinct from user-centred, and service design approaches in many critical ways. For example, it involves the extension and negotiation of system limits to frame the design situation, the deliberate adoption of sociotechnical complexity, and strategies of systemic convergence rather than market distinction (Jones, 2014). In policy, operational, or product-service settings, a systems approach is concerned with the higher-order, social-organised, hierarchical, or product-service environments (Jones, 2014). Incorporating a systemic approach in the design process enables a comprehensive understanding of complex, multi-stakeholder infrastructure systems such as transportation, healthcare, and disasters. It adapts well-established design competencies to define, map, suggest and reconfigure complex systems and processes.

2.3. Actor-Network Theory

Several studies have recognised the presence of an intriguing dimension at the intersection of design and Actor-Network Theory (ANT), particularly as design research confronts increasingly complex issues such as climate change, sustainability, inclusion, and democracy. As mentioned in previous sections (2.2), design has evolved from a discipline focusing on products and manufacturing to a discipline focusing on society and their needs (Buchanan, 1992). This human-centricity includes broader concerns about the relationship between humans and technology. However, being concerned about humans' fate entails being concerned about the nature of all living creatures on our planet, as knowledge about all life's crucial interdependence expands (Akama et al., 2020). Recognising these interdependencies and how they undermine hierarchies with human control over others is visible in various areas, including political ecology (Donnelly, 2008) and environmental humanities (Boerboom & Ferretti, 2014). These discussions rethink relationships, broadening the understanding of the world's agencies, dependencies, entanglements, and ties (Forlano, 2017).

ANT is a theoretical framework for conducting sociological research. ANT derives from sociology, known as Science and Technology Studies (STS), which has historically been concerned with how science is conducted and how society affects science (Latour, 1999). Michael Callon, Bruno Latour, and John Law established ANT to understand better how science and technology are made (Callon, 1986; Latour, 1999, 2005). Its fundamental premise is that every individual is the product of the relationships and assembly of heterogeneous actors and their networks. It makes no inferences about cause and effect; instead, it asserts that actors have their desires and agendas. The symmetrical attention influences the distinctiveness of ANT it pays to human and non-human beings by elevating the critical perspective on intermediary artefacts and inscriptions (Law, 1992).

ANT has argued for a better understanding of the relationships between human and non-human networks and "assemblages"—"actors'' that share equal agency in shaping problems. In ANT, actors include both humans and non-humans; there is no distinction between people and objects (Law, 1992). The word 'actors' refers to entities capable of associating documents, humans, non-humans, and money (Callon, 1986). The core tenet of the theory is that human and non-human entities are linked in a network that seeks to accomplish specific goals by translating disparate interests. The actors, the networks of which they interact, and the concepts they promote are constantly interpreted within this framework

to maintain network continuity. When the network reaches a state of equilibrium and the actors can be viewed as a single, unified participant, the network is referred to as an actor-network (Latour, 2005). According to ANT, both events are the product of or are caused by heterogeneous networks (Law, 1992).

In this research context, forests, lands, fire and legislation are examples of non-human actors. The agency of these actors is intrinsically linked to their role in the system. The government defines policies and implements legislation, and society has to follow and respect those rules.

2.3.1. Actor-Network Theory and Systems Thinking

The ANT has been applied to the study of the interactions between a variety of social processes and technology, including scallops and fishers (Callon, 1984), electric cars (Callon, 1986), and alternate public transportation systems (Latour, 1996). ANT has gained interest amongst designers and the design field (Akama et al., 2020; Johnson & McHattie, 2014; Kraal, 2007; Storni, 2015; Yaneva, 2009). These diverse analyses have in common the ANT vocabulary, which is oriented toward explaining the processes that go into constructing and using socio-technical and environmental structures.

When confronted with complex challenges, ANT offers a systematic framework for defining the issue, highlighting the causal interactions that contribute to the problem, proposing solutions based on this analysis, and identifying the primary autonomous and institutionalising actors. While systems thinking enables analysing a problem and determines the actions required to solve it more efficiently, ANT requires stepping beyond the focal systems and breaking internal and external borders to identify and engage the heterogeneous actants.

The nature of ANT is to provide a framework for moving beyond systems thinking and determining how to negotiate necessary change and compromise. However, ANT is not a forecasting tool; although it can assist in identifying areas for improvement, it cannot forecast outcomes (Young et al., 2012). According to Latour (2005), the actor-network evolves and works together to generate innovation. This fusion of human and non-human agency through heterogeneous networks that can endure by continuing translation and reproduction distinguishes ANT and contributes significantly to a systemic understanding. (Young et al., 2012).

The interest in ANT arose from the recognition that it is a society with the capacity to act and communicate with one another who initiate, activate, form, and obstruct a change process. It is a self-evident belief of daily life that ANT wants to embrace. Additionally, the ANT is particular because it is based on the premise that each entity or actor (human or non-human) has its wishes.

2.4. Literature Summary

This section summarises the key findings from the literature review that influenced this thesis.

Climate change, whether anthropogenic or human-driven, changes the nature of natural hazards, shifting them from those inherent in the physical environment and outside human control to phenomena influenced and induced by human activities (Thomas, 2017). People are no longer passive victims, and human activity plays a role in developing disasters such as rural fires. However, the magnitude or severity of rural fires can be significantly reduced by different strategies and activities.
One of the primary objectives of disaster management and one of the most direct ties to sustainability is promoting safe livelihoods, protecting and restoring them during disaster situations. By implementing prevention strategies, people have a greater capacity to cope with crises, and their recovery is more expeditious and better sustained.

The complexity of the current societal issues requires an investigation of what it is in human nature that creates so much confusion and inquires whether it is possible to develop a culture that encourages society to be anything more than individuals exploiting the planet (Sepers, 2017). For designers, this entails dealing with complex processes, emphasising the individual, social, and environmental connections while also delving into the human behavioural aspects of the current issues. The systemic approach is a crucial skill set in design, given the predisposition for systemic change (Hill, 2012). This ability to address and understand complex challenges at a systemic level is intrinsically linked to the field of systems thinking. Ryan (2014) claims that a single variant of systems thinking and design can simplify the challenge of creating a coherent and concise language for practitioners. Incorporating a systemic approach in the design process enables a comprehensive understanding of complex, multi-stakeholder infrastructure systems such as rural fires.

The fundamental premise of ANT is that every entity is the product of the relationships and assembly of heterogeneous actors and their networks. ANT has argued for a better understanding of the relationships between human and non-human networks and "assemblages"—"actors'' that share equal agency in shaping problems. In ANT, actors include both humans and non-humans; there is no distinction between people and objects (Law, 1992). While systems thinking enables analysing a problem and determines the actions required to solve it more efficiently, ANT requires stepping beyond the focal systems and breaking internal and external borders to identify and engage the heterogeneous actants. The nature of ANT is to provide a framework for moving beyond systems thinking and determining how to negotiate necessary change and compromise.

Chapter 3.

Case Study: Understanding the Rural Fires in Portugal

The author used a case study approach to contextualise the theoretical investigation of the complexity of fire prevention in the Portuguese fire management system. This approach was applied to facilitate exploration through the intertwined works of literature of disaster management, systemic thinking, strategic design and actor-network theory by constructing a narrative of the literature and exposing its levels of complexity and networks. The case study led approach focuses on identifying the role of the different actors, their responsibilities, agency, and the existing challenges.

In this chapter, rural fires are considered more broadly, including fires in scrubland, unplanted land, and natural grasslands. They refer to fires that occur in areas suitable for forestry, even though they are not forested at the burn time.

This thesis intends to create a comprehensive overview and explain a few aspects of rural fires and Portugal's rural fire management system.

3.1. The European Context

In general, it is suspected that Europe's high proportion of heatwave deaths is a product of improved reporting mechanisms. Heatwaves occur regularly throughout the world, especially in areas with vulnerable populations and inadequate infrastructure; however, the difficulties associated with recognising heatwave-related deaths may result in an underestimate. Heatwaves are expected to become much more frequent over a large portion of the globe due to climate change (IPCC, 2018). In the coming decades, more prolonged and more intense heatwaves may intensify demand on productivity and electricity grids and, if not treated properly, could create factors that escalate existing impacts.

Between 2000 and 2019, high temperatures were responsible for 13% of all disaster deaths worldwide, with heatwaves accounting for the majority (91%) of those deaths. Almost all deaths from high temperatures occurred in the global north, with Europe responsible for the largest share of casualties at 88 per cent (UNDRR/CRED, 2020).

In Europe, the Mediterranean and eastern temperate-boreal forests are most prone to rural fires. Recent temperature anomalies and conventional socioeconomic and land-use shifts have favoured increased rural fires' frequency and intensity in previously unaffected areas (San-Miguel-Ayanz et al., 2018). Technological solutions alone will not be sufficient to mitigate natural, economic, and human losses. Potential solutions, such as adaptive fire control, will need to be identified to improve socioeconomic and ecological resilience in the face of extreme climate and rural fires (Hernández, 2019). Not only do rural fires pose an immediate danger to the population, but they may also have significant implications in terms of increased risks of landslides, mudflows, and flooding – especially in mountainous areas.

Based on a recent study from Lourenço (2018), this thesis presents a table (Table 1) that compares the number of rural fires in the last decades in Portugal, Spain, France, Italy and Greece. In the previous four countries, the pattern in the average burnt area from the first five years to the subsequent five years is strongly positive. There is an emphasis on Spain and Italy, but also on France and Greece, where the trend, although less pronounced, is still positive. On the contrary, the trend in Portugal is negative, as shown by the continuous increase of burnt area over the first three five-year periods and, most significantly, by the value seen at the turn of the century, which was particularly expressive because

it was twice the value of the previous periods (Table 1). The last five-year period reveals a significant increase compared to the last period due to the rural fires in 2017.

The results demonstrate that the measures implemented have been insufficient to revert the general pattern. It could prompt governing authorities to view rural fires less politically and focus more on the areas appropriate for forestry to make them lucrative in the medium term. Since political cycles are relatively brief, lasting a little more than four years, there is a strong dichotomy between these intervals that have proven challenging to transcend and clarify why forest spaces might seem unattractive for political investment (Lourenço, 2018).

	Portugal	Spain	France	Italy	Greece
1981-1985	75 227	241 777	44 231	170 408	53 501
1986-1990	92 342	235 802	44 172	136 764	52 457
1991-1995	107 279	207 203	17 484	106 033	44 723
1995-2000	101 598	112 553	18 195	95 614	64 781
2001-2005	223 408	123 619	31 742	61 611	9 282
2006-2010	68 942	87 265	9 874	90 779	62 371
2011-2015	84 234	100 650	8 098	61 906	33 737
2016-2019	197 204	88 294	17 768	70 751	16 138

Table 1. *Average burnt area (hectares) per five-year period in southern European countries (adapted from Lourenço, 2018).*

3.2. Rural Fires in Portugal

Portugal is the European country that suffers most from rural fires, both in the number of fires and burnt areas in comparison to countries such as Spain or Greece (Lourenço, 2018). Summers in the country have become warmer, drier, and longer because of climate change, which increases the risk of rural fires. In addition to the weather conditions, fire analysts also point to other factors such as rural abandonment, shifts in land use with farmland and forested areas left unmaintained, and land ownership division trends that discourage investment in forest management and fire planning (Mateus & Fernandes, 2014; Meira Castro et al., 2020; Mira & Lourenço, 2019).

The occurrence of fire in Portuguese rural areas grew naturally until the industrial revolution began in the nineteenth century. From this point on, the conventional use of fire in Portuguese forests began to change, owing primarily to increased agricultural mechanisation and improvements in people's everyday lives and organisational structures (Meira Castro et al., 2020; Mira & Lourenço, 2013; Nunes et al., 2016).

As a result of these phenomena, the everyday use of the Portuguese territories shifted, increasingly abandoning vast areas of cultivated land favouring woodland and large areas of scrubland (Nunes et al., 2014; Nunes et al., 2016). Livestock grazing slowed dramatically under these circumstances, leaving scrublands and wood abandoned in the forest. The abandonment of rural areas gained momentum in the twentieth century, owing mainly to the country's severe economic downturn (Meira Castro et al., 2020). This shift in the socioeconomic trend has also resulted in changes in the conventional causes of fire ignition in recent decades, with the origins increasingly being anthropogenic, not only in Portugal but also in other Mediterranean European countries (Catry et al., 2010; Meira Castro et al., 2020; Nunes et al., 2016). The

3.2.1. History of Rural Fires in Portugal

idea of massive rural fires in Portugal has evolved throughout time (Lourenço, 2018). In the 1970s, significant rural fires were described as those with a burned area of at least ten hectares. Later, only major fires with an area equal to or greater than 100 hectares were considered, and this was increased to 500 hectares where fires with an area of one hundred or more hectares were highly abundant (Lourenço, 2018).

In 1986, the first fire more prominent than 10,000 hectares occurred in the centre of Portugal (Nunes et al., 2016). This event was considered a genuinely extraordinary circumstance. Over time, the Portuguese society became used to the situation, with fires covering more than ten thousand hectares (Mateus & Fernandes, 2014), as was the case in 2003, indicating that this year was the most extreme in terms of burned area (Mateus & Fernandes, 2014; Nunes et al., 2014). Additionally, for the first time in 2003, larger fires with an area of over 20,000 hectares were registered.

The year 2017 marked a shift in the history of rural fires in Portugal. Five significant fires with dimensions never before seen lead to the start of a new generation of rural fires (Mira & Lourenço, 2019; Parente et al., 2018). According to Lourenço (2018), the history of the rural fires in Portugal can be divided into four different generations:

First generation - 1974 to 1985
The first generation resulted from the dramatic social and economic changes in Portuguese society after the April 1974 revolution, with ramifications for forests and rural fires. This first generation lasted until the end of 1985, and it was marked by few and comparatively limited outbreaks, with the larger fires covering areas less than 10,000 hectares in size. As a result, big fires were described as those that consumed at least ten hectares (Lourenço, 2018).

Second generation - 1986 to 2002
The second generation of fires began in 1986 and lasted until 2002, 17 years over which incidents became more frequent and more prominent in scale than in the previous decade (Meira Castro et al., 2020; Nunes et al., 2016). This phenomenon of more frequent and prominent incidents is why big fires are now described as those with an area of at least 100 hectares. The larger fires consumed areas that two major fires had ravaged in the previous century. On the other hand, while the most significant fires could have burned over 10,000 hectares, they were all less than 20,000 hectares in size (Lourenço, 2018).

Third generation - 2003 to 2016
2003 brought a new era of large fires, which continued in 2004 and, most recently, in 2012 and 2016 (Nunes et al., 2014). Thus, the frequency of significant fires remained high, while their burned area rose as well. As such, significant fires grew in scale and began to impact areas that two or three large fires had destroyed in previous years (Lourenço, 2018). 2005 was also a challenging year for rural fires, as it was the year with the most incidents and, except 2017, the second-worst year in terms of burnt area (Parente et al., 2018). Once again, atmospheric patterns played a significant role in understanding why there were such frequent and massive fires (Lourenço, 2018).
Before 2017, this generation was the most difficult of the three generations. This difficulty was due to the geographic spread of the primary rural fires being different than expected or further from the usual areas of the North and Center, which had the greatest concentration of firefighting equipment (Lourenço, 2018).

Fourth generation - 2017 to present
In 2017 the burning area matched all standards and broke all existing levels (Mira & Lourenço, 2019). Without a doubt, 2017 year marked the start of a new generation of fires, the fourth, which correlates to fires with burn areas exceeding 30 000 hectares (Lourenço, 2018).

3.2.2. Causes of Rural Fires

The study by Mateus and Fernandes in 2014 revealed that rural fires have various causes, but they are primarily anthropogenic in Portugal. According to the study, false alarms and rekindles account for almost 10% of all ignitions investigated successfully between 2001 and 2012 (Mateus & Fernandes, 2014). Negligence (including accidents), vandalism, and lighting accounted for the remaining ignitions; about half of negligent fires are associated with land-management activities (Mateus & Fernandes, 2014). However, ignition is only one of many switches involved in fire activity; the others are biomass (potential fuel), availability to burn, and the risk of fire spreading in response to changing weather conditions (Nunes et al., 2014). The apparent causes of burning and the subsequent fire action and effects are the product of deeper causes. Human-caused ignitions are seen as the effect of rural vegetation triggers or technological issues, manifested in conventional fire uses in the modern sense of a highly flammable landscape.

Weather and Climate
Weather conditions have a strong correlation with fire activity. As fire weather gets severe, the burning landscape, the representativeness of significant fires, and the scale of fires increase (Mateus & Fernandes, 2014), resulting in soil water deficits, soil erosion and habitat destruction (WWF, 2020). Climate change will alter the distribution patterns of forest ecosystems. Extended dry and warm summers in the Mediterranean Basin imply longer fire seasons, which are associated with more intense and extreme weather conditions, which result in higher-intensity, larger, and more destructive rural fires (Bedia et al., 2015; Costa et al., 2020).

Territory
Although seasonal temperature changes and the frequency of extreme weather conditions are significant factors in creating catastrophic rural fires, they are not the only ones. Portugal is especially vulnerable to rural fires due to a unique combination of systemic environmental conditions. Marginally viable farm fields formerly turned to timber plantations are gradually being left unmanaged due to their high maintenance costs (Lourenço, 2018; Mira & Lourenço, 2019). The neglected areas are gradually taken over by shrubs and woody plants, resulting in an increasingly uniform landscape with burning characteristics. The regions that once served as a barrier to fires now serve as a fuel source for increased fire severity. In several areas in Portugal, the conditions for more catastrophic significant fires are still in place, waiting for the next extreme fire weather occurrence (Beighley & Hyde, 2018).

Socio-economy
Socioeconomic and landscape variables also contribute significantly to fire activity in Portugal. Between the 1950s and 1970s, changes in Portuguese culture resulted in a half-century of inefficient forest resource management. Rural abandonment and a decline in biomass usage resulted in unmanaged or undermanaged ecosystems that conflicted with society (Mateus & Fernandes, 2014). The reckless use of fire for multiple land control purposes continues, and the peri-urban population's lack of knowledge of the fire danger is widespread. Mainly precarious conditions occur as wildlands collide with developing urban perimeters or remote small settlements, posing a civil protection challenge (Mira & Lourenço, 2019).
Approximately 95% of Portugal is privately owned (Mateus & Fernandes, 2014). Forest properties are inherited in most cases. About one-third of proprietors own more than 5 hectares of land (indicating an obstacle to successful forest management), and 25% of the land is neglected or unmanaged (Mateus & Fernandes, 2014). The apparent abandonment may be classified as passive management, a prudent choice given the limited probability of achieving an economic return on investment. In this sense, legal retaliation against forest owners and widespread fuel-hazard elimination is neither feasible nor desirable from an economic or ecological standpoint (Mateus & Fernandes, 2014).

Human activity
One last factor that cannot be overlooked is that 98% of all fires in Portugal are sparked by human activity (Beighley & Hyde, 2018; Meira Castro et al., 2020). Compared to other southern European countries with comparable fuel and environmental conditions, Portugal has a relatively high number of human-caused ignitions per capita (Beighley & Hyde, 2018). For example, Spain is five times bigger and four times more populous than Portugal and has fewer overall human-caused ignitions. When combining the effects of climate change and related weather, fuel and plant environments through large ecosystems and the likelihood for human combustion, a nearly incomprehensible array of fire years from harmless to catastrophic is possible. Without long-term and permanent action, the possibility of an intense fire year is increasing over the next decade. (Beighley & Hyde, 2018).

As described in this section, humans trigger the vast majority of these fires, whether by mistake, neglect, or arson, which is why it is critical to understand the rural fire management system.

3.3. Rural Fire Management System in Portugal

The rural fire crisis has become worse due to periodic structural reforms by the government and its diminished capacity to intervene in the absence of a private-sector counterpart. Before the 2003 and 2005 rural fire disasters, fire prevention practices were notoriously reactive, contradictory, and short-sighted (Mateus & Fernandes, 2014; Nunes et al., 2014). Fire management has consistently strengthened fire control capabilities rather than tackling underlying factors, including property ownership structure, timber and land conservation, state authority, social stability, and agriculture, energy, and soil sector regulation (Mateus & Fernandes, 2014).

Portugal's political approach to fires has been interventionist. Over the years, a variety of management and control tools (legislation, policy, and planning) have been implemented, as well as financial instruments. These instruments are continually tweaked and revised, often with potentially conflicting results. As a result, there is inconsistency, inadequate understanding of applicable rules, and, perhaps most importantly, a failure to take a clear direction toward successful performance. Fire-related functions and competencies are spread through several government ministries and departments, which exacerbates the crisis.

The uncertainty implicit in the system's constant revisions to legal and organic structures is regarded as a liability (Mateus & Fernandes, 2014). The quantity of national-level strategic documents issued is indicative of uncertainty in the system (Table 2).

National forestry policies and proposals for a broader perspective (Table 2) summarise the latest Portuguese fire protection strategy. Increased fire frequency is a significant potential risk, and its prevention is critical to the national forest strategy. In 2006, Portugal chose to pursue a national strategy that concentrated on growing firefighting capabilities rather than considering significant fire prevention improvements. Despite all efforts to alter this, the annual rise in the region gradually increased, resulting in the devastating rural fires of 2017. These rural fires impacted people and natural heritage, causing chaos on a scale never seen in Portugal or any other nation in western Europe or the Mediterranean (Mira & Lourenço, 2019).

Year	Plan
1996	Forest Policy Bases Law
1999	Portuguese Forest Sustainable Development Plan
2003	Action Plan for the Forest Sector
2003	Forest Sector Structural Reform
2005	Operational Plan of Forest Fires Prevention and Suppression
2006	Naitonal Plan of Forest Defence Against Fires (2006-2018)
2006	National Forest Strategy
2020	National Plan for Integrated Fire Management

Table 2. *National-level Portuguese forest strategies and plans (1996-2020) (adapted from Mateus & Fernandes, 2014).*

3.3.1. National Plan for Integrated Rural Fire Management

In the aftermath of the rural fires in 2017, discussions resulted in consensus on the structural vulnerabilities found by the Independent Technical Committees (ITC) (ITC, 2017, 2018), such as a lack of deterrence or an inability to incorporate information into management processes. The magnitude of the disaster forced a strong response that drew on all existing national capabilities and the best available foreign expertise to minimise the severity of rural fires and the associated disruption to environmentally, socially and economically sustainable standards (AGIF, 2020). Due to the complexity of engaging and committing all stakeholders (public entities and private entities that own the majority of Portuguese territory), it was critical to develop a comprehensive plan that included all actors, to make severe rural fires in Portugal a thing of the past (AGIF, 2020).

In the first quarter of 2018, the Task Force for the Installation of the Integrated Rural Fire Management System conducted a study on the model in use until 2017 on the new Integrated Rural Fire Management System (SGIFR) and its organisation. Given this alignment, the 2018 fire campaign policy and processes were created. As a result, the Agency for Integrated Rural Fire Management (AGIF) emerged as the main actor in integrated analysis, planning, evaluation and strategic coordination of the SGIFR, in collaboration with the National Authority for Emergency and Civil Protection (ANEPC) and the Institute for Nature Conservation and Forests (ICNF) (AGIF, 2020). The SGIFR is built on two action pillars that the ITC believed were critical to mitigating the effects of rural fires (ITC, 2017, 2018). These two pillars, Rural Fire Management (RFM) and Rural Fire Protection (RFP), represent a significant shift from the previous plan, which was in effect from 2006 to 2018.

The political responsibility for protecting rural spaces by adequate fire control falls to the government responsible for the environment. In contrast, the government member responsible for home affairs is responsible for protecting citizens and property (AGIF, 2020). This distinction clarifies the roles of the two primary public authorities (ICNF and ANEPC) in preventing and mitigating fire danger in rural spaces (RFM) and the adjacent urban areas (RFP), respectively. In addition, state governments, fire departments, the National Guard (GNR), and the Armed Forces, as well as other civil society organisations, such as farm and forest producer organisations, are responsible for providing cross-cutting assistance to these two agencies at all procedural levels, from preparation to reconstruction, including deterrence, monitoring, and containment (AGIF, 2020).

Figure 16 illustrates the current structure of the fire prevention system and identifies the different levels of stakeholder and actor engagement, from national to local and their general roles.
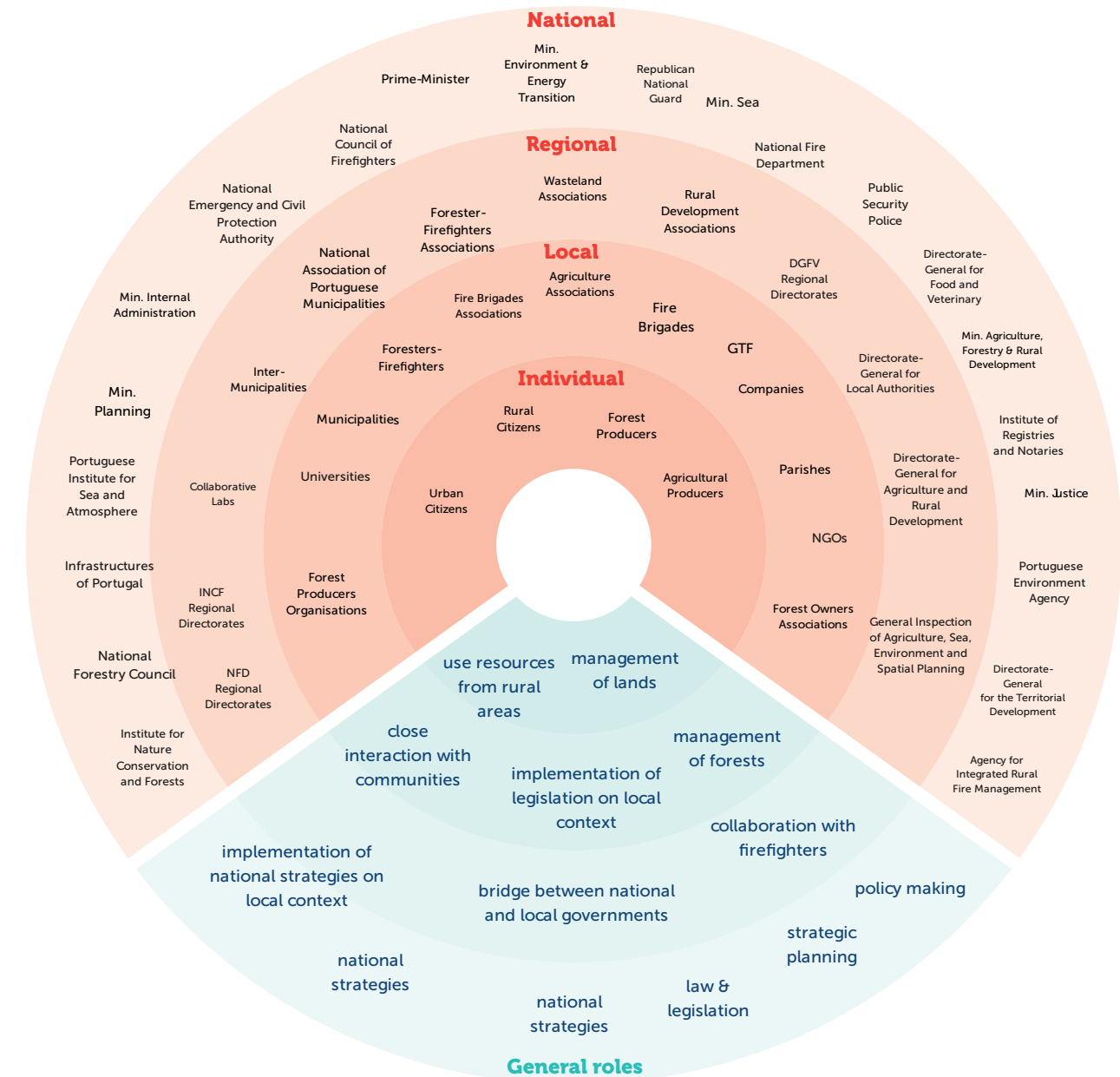
Figure 16. *Map of actor's level of action and general roles in rural fire prevention.*

Strategy 20-30

AGIF's National Plan for Integrated Rural Fire Management (PNGFR) is an ambitious government plan aimed at implementing strategies that assist in resolving a portion of the issue and the associated repercussions of the Portuguese structural fire risks. The PNGFR established four strategic guidelines to address perceived gaps and capitalise on opportunities: 1) value and 2) active management of rural areas, 3) change behaviours, and 4) efficient risk management (Figure 17). These strategic guidelines could create positive reinforcement cycles, as depicted in figure X. However, despite its broad policy objectives, the PNGFR is very unclear on specifics, especially on the role of local governments and farm and forest owners. Greater awareness of the relevant actors in the system could aid in fire prevention, the control of fire risks, fire protection planning, and firefighting. With these factors, it is evident that a new era of rural fire demands a more comprehensive and strategic approach.
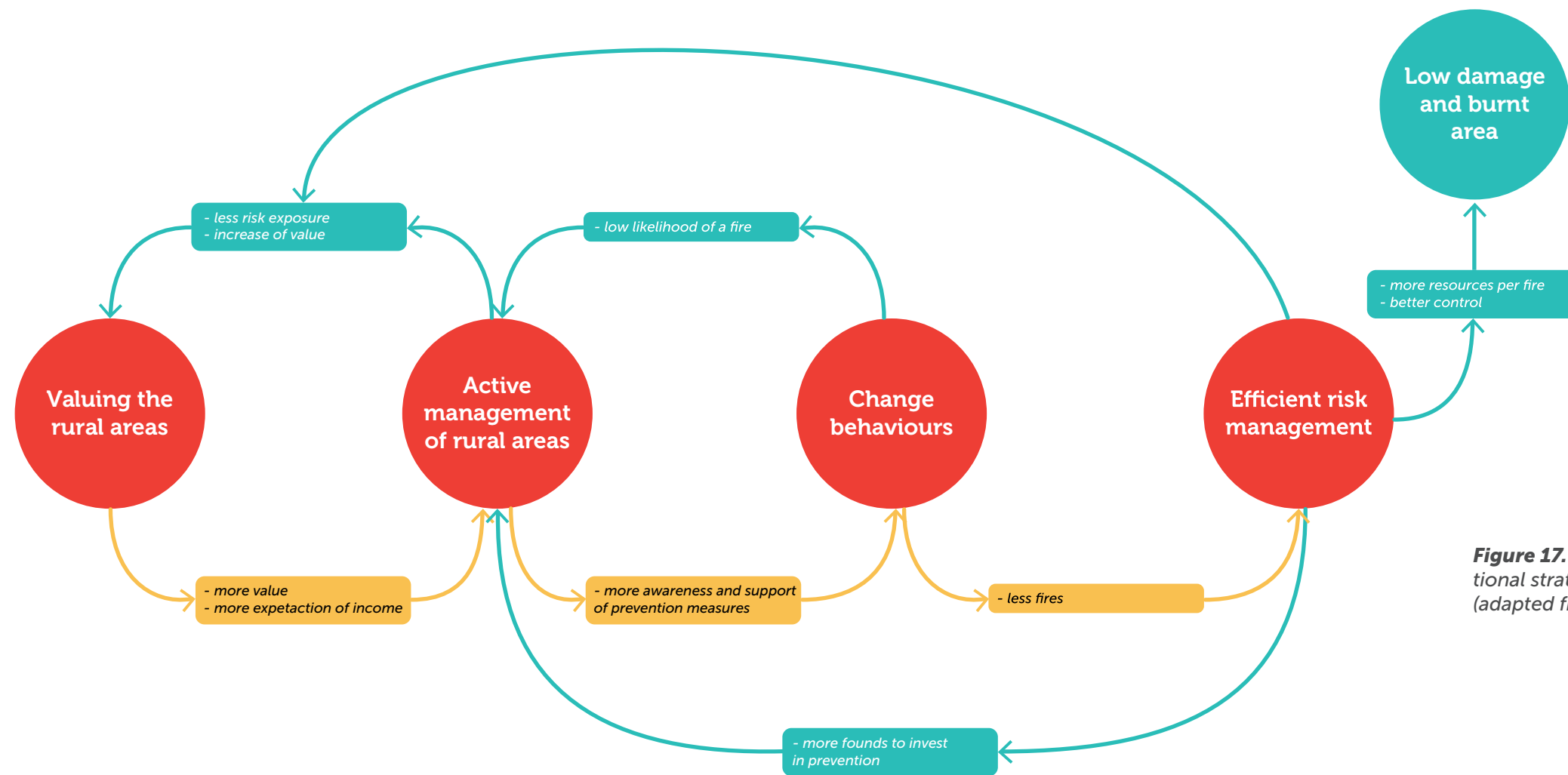
Figure 17. *Strategic guidelines of the national strategy 20-30 for fire management (adapted from AGIF, 2020).*

Chapter 4.
Methodology

The research methodology for this thesis was primarily a qualitative research approach. Initially, it had combined participatory processes and ethnographic approaches; however, the study's scope was limited due to COVID-19 restrictions. The initial plan was to travel to Portugal, have the first round of interviews with experts, analyse the data, then the second round of interviews, and organise a collaborative workshop for co-creation with the relevant actors within the system. Instead, given most participants' role in responding to the COVID-19 crisis, the workshop was removed from the research process, and only one round of interviews (conversational and semi-structured) took place. This phase was spread out over an extensive period to enable different cycles of feedback and further exploration.

This chapter will present the systemic and ethnographic approaches, the choices of the methods for the thesis's scope, and explain how each method was applied. Furthermore, it will explain the process of data collection and the types of interviews, followed by a discussion on the results of such interviews and their implications. Moreover, it will justify the adoption of affinity diagramming to analyse the data collected. Five themes resulted from the analysis. Naturally, two of those topics were about the role of non-human actors in the system, such as the phenomenon of fire and the forest.

4.1. Data Collection

To complement the knowledge gained from the literature review and to understand the rural fire management system, the study process began collecting and analysing documentary information from the national government and national agencies, such as legislation, decrees, and national strategies. According to Creswell, data collection is "a series of interrelated activities aimed at gathering good information to answer emerging research questions" (Creswell, 2007). In January 2020, at the beginning of the collection process, the Portuguese government had published a new strategy for the new National Plan for the Integrated Rural Fire Management (PNGFR). The national strategy document served as a support for this thesis throughout the research project. Moreover, the attendance at the Closing Seminar of the Public Discussion on the National Plan for Integrated Management of Rural Fires in Portugal provided valuable information on how the actors look at the issue (Image 2). After analysing the documentation and learning more about the rural fire management system structure in Portugal, participants were selected and contacted for interviews. As mentioned at the beginning of this chapter, due to time constraints and travel restrictions imposed by the pandemic in Finland, it was impossible to visit Portugal; therefore, the ethnographic methods to understand and gain knowledge were limited.

The main goal of the study of the documentary information was to provide an overview of the organisations and the actors involved in the rural fire management system and provide more analysis guidance for the interviews. Furthermore, the interviews contextualised this thesis concerning institutional structure, relationships, perspectives, and collaborative activities between the various actors within the system, which presented the foundation for the findings and insights of this project.

4.2. Document Analysis

The topic of rural fires in Portugal is a complex issue; therefore, it was critical to investigate policies and publications on the subject that could offer a general picture of the legislation and regulations related to the rural fire management system. Bowen (2009) claims that documentation analysis can be an effective means of gathering data when events cannot be observed (Bowen, 2009). Additionally, Bowen suggests that "documents provide background and context, additional questions to be asked, supplementary data, a means of tracking change and development, and verification of findings from other data sources." (Bowen, 2009, p. 30). Considering Bowen's view, four documents were studied (Table 3). These documents provided valuable information on the causes of wildfires, the deficient coordination between the actors, and the lack of appropriate knowledge at all system levels. The data extracted from the documents offered new perspectives, contributing to the data analysis's final results.

The document analysis method was used as the primary source of information, followed by the interview research method. The table below (Table 3) shows the studied documents based on the relevance of the content to the research project.

Document	Year	Type	Summary
National Plan for Integrated Rural Fire Management	2020	National Strategy	Strategic goals: Valuing the rural areas, Active management of rural areas, Change behaviours, and Efficient risk management
Analysis and determination of the facts surrounding the Pedrógão Grande, Castanheira de Pera, Ansião, Alvaiázere, Figueiró dos Vinhos, Arganil, Góis, Penela, Pampilhosa da Serra, Oleiros and Sertã fires, between 17 and 24 June 2017	2017	Report	The main reasons for that dramatic event originate from three levels of problems: knowledge, qualification, and governance. Recommendation of the creation of a new Agency with the responsibility of coordinating all actors
Assessment of the fires that occurred between 14 and 16 October 2017 on Continental Portugal	2018	Report	Rural fires resulted from two main problems: Planning, planning and management of the territory; and Information and communication.
Assessment of the national civil protection system in the context of rural fires	2018	Report	Recommends focus on six aspects: Territorial coherence; Regional coordination; Training and qualification; Requalifying and consolidating the Foresters Program; Structural reorganisation of the firefighters' operational sector; Global system coordination

Table 3. *Overview of documents studied.*

4.3. Event Observation

At the beginning of the research, it was possible to attend and observe participants at the Closing Seminar of the National Public Debate on the National Plan for Integrated Management of Rural Fires in Portugal (Image 2).

According to Creswell (2007), observation seems to be one of the most fundamental analysis methods because it does not necessitate specialised instruments or facilities (Creswell, 2007). Observation approaches are beneficial for tracing non-verbal signals and determining how participants interact with one another in a given social environment (Creswell, 2007). This method was incorporated into this project to account for the event mentioned above. Even though it aided this thesis in comprehending the different points of view from the attendees, the specificity and format of the event limited the collection of more relevant data.

Image 2. *Closing seminar of the national public debate on the National Plan for Integrated Management of Rural Fires.*

The event was attended by the Prime Minister of Portugal, the Minister of Internal Administration, the Minister for the Environment and Energy Transition. and other entities involved in the system such as fire brigades associations, forest owners associations, forest producers associations, civil servants, forester associations, researchers and civil society. Members from the Portuguese government coordinated the seminar.

The event included conversations about the national plan and the strategic goals. Several topics were explored, including the collaboration between organisations, the current conditions of the fire-fighting forces, the support to the landowners, and new approaches for land management. To understand

4.4. Interviews

and support the information gained from the documents, the interviews were selected as the primary method of gathering data. The choice of conversational and semi-structured interview formats was decided based on the possibility of allowing for questions to be revised based on what the interviewees revealed by speaking with a broad and representative range of actors. This degree of flexibility was needed to identify the research scope and people's roles, activities, procedures, and perspectives on the topic. The participants were chosen from organisations that can directly or indirectly affect the rural fire management system.

In total, thirteen in-depth interviews were conducted with participants in three different formats and were spread out over four months, from February to June of 2020. Each interview participant was informed that their identity would remain anonymous. Table 4 presents an overview of the participants according to the type of their organisation and level of activity. The number and profiles of interviews were based on three factors: time limitations given the extensive required resources to transcribe and analyse the interviews, the capacity to reach out to potential participants, and their availability. Considering this thesis was conducted by the author, these time and resources limitations had to be considered. With more extensive resources, there would have been significantly more reliable data; however, the relevance and accuracy of the results were assessed as sufficient to proceed with the research confidently.

Conversational Interviews
The first phase of interviews was the conversational interviewing format. These interviews were characterised by an informal talk and flexibility in the interviewees' topics and questions. The data collected through the conversational interviews contributed to a better understanding of the topic, which helped narrow this thesis's scope and iterated on questions for the semi-structured interviews. Roulston (2008) stated that the conversational method facilitates a research environment where participants feel free to discuss the topics more openly than those in a more structured setting (Roulston, 2008). The author undertook the five conversational interviews by phone, video call, and in-person and ranged from 45 to 60 minutes.

Semi-Structured Interviews

The next step after the first phase of the interviews was the semi-structured interview format. There was more control over the interview topics in semi-structured interviews than in conversational interviews, but there was no predefined set of responses to each question (Ayres, 2008). The interview questions were based on the research questions and the concept of the rural fire management system that is under study. The questions were tailored according to the competence and role of the interviewee. These interviews provided a better understanding of the rural fire prevention practices and helped identify the system's connections and relationships.

They contributed to getting multiple perspectives on how national agencies, NGOs, and private sector organisations collaborate and how collaboration activities should be executed. The six semi-structured interviews were conducted in-person (one interview) and via video call (Zoom, Teams and Jitsi) with an average length of 60 minutes each.

Email Interviews

The last format of interviews was via email. This method allows access to difficult or impossible participants to reach or interview in-person or via phone and video call (Meho, 2006). Since two participants were not available for an interview by video call, the interviews had to be conducted over email. As an interview method, email interviews can focus on the questions and more thorough responses. However, the answers can lack some in-depth information easily obtainable through live interactions between the interviewer and the participant (Meho, 2006).

All interviews were recorded with the permission of the interviewees. However, due to time resources, the transcriptions of the interviews were not transcribed verbatim. As an alternative, the main points and statements were extracted from the original recording.

Interview	Participant Role	Type of Organisation	Level of Action	Interview Method
I01	President	Governmental Agency	National	Semi-Structured (in person)
I02-A	Researcher	Collaborative Lab (CoLab)	National	Conversational (online)
I02-B	Project Manager	Collaborative Lab (CoLab)	National	Conversational (online)
I03-A	Director	Governmental Agency	National	Conversational (phone)
I03-B	Civil Servant	Governmental Agency	National	Conversational (phone)
I04	Director	Forest Producer	Local/National	Semi-Structured (online)
I05	Assitant Director	International Organisation	Global	Conversational (in person)
I06	Association Member	Environmental NGO	National	Semi-Structured (online)
I07	Vice-President	Environmental NGO	Local	Semi-Structured (online)
I08	President	Forest Association	Local/National	Semi-Structured (online)
I09	Head of Forestry Technical Office (GTF)	Municipality	Local	Structured (email)
I10	Researcher	University	National	Semi-Structured (online)
I11	Head of Foresters	Municipality	Local	Structured (email)

Table 4. *Generic description of interviewees.*

4.5. ANT Mindset

ANT emphasises how an actor's views, emotions, and actions are determined by the interactions that any actor will shape with other actors, including human and non-human (Sage et al., 2011). This analysis required an in-depth engagement with the research participants. However, due to the distance and unavailability of the participants, it was impossible to engage on a deeper level. These challenges prevented the author from collecting data on the role and agency of all actors, both human and non-human.

ANT emerged in the research process after the interviews exposed the role of non-human actors in the prevention of rural fires. Even though the interviews did not include any questions related to non-human actors, the topic spontaneously emerged from the conversations with the participants. Therefore, the author decided to pay particular attention to the role of non-human actors. Although ANT was not utilised as a method, this decision proved to be a comprehensive basis for interpreting and comprehending the role of the forest and fire as non-human actors in the rural fire prevention system.

4.6. Data Analysis

Through the data analysis, it was possible to deconstruct the current system's perception and unpack existing collaboration principles and activities of rural fire prevention. First, the interviewee's opinions were analysed and then compared to others to find possible contradictions. However, this strategy was abandoned due to the difficulty in finding new understandings and connections. Instead, the author selected the affinity diagram method for the analysis of the data. Through this method, it was possible to organise the statements into groups of overlapping or identical perspectives and categorise them into broader themes. According to Hanington & Martin (2012), affinity diagramming is a method to help to make sense of information by externalising and meaningfully clustering observations and insights from research.

Five themes resulted from the data. The first three are related to the responsibilities of actors, the institutional structure and the heterogeneity of the rural areas in Portugal. The last two themes related to non-human actors' role, such as the phenomenon of fire and the forest, in the system. In the last part of the analysis, the ANT framework compares the results to the translation moments (Callon, 1986).

Mapping the data
The affinity diagram method contributed to a more effective and flexible way of grouping the statements from the interviews. Through this method, the interview statements were grouped and clustered into five main themes: 1) Roles & Responsibilities of Actors, 2) Institutional Structure, Mindset and Attitude, 3) Heterogeneity of the Rural Areas, 4) Phenomenon of Fires, and 5) Forest as an Agent.

The analysis process was done in 2 rounds. First, the 351 statements were grouped into 35 sub-categories. Since there was a large amount of unstructured data, the first round aimed to organise and filter the relevant data for this thesis. Therefore, the 351 statements were clustered according to their subject, resulting in 35 sub-categories spanning across different topics. After mapping the statements, the sub-categories were structured and iterated, establishing a map with five distinct themes identified with different colours (Figure 18).

RESPONSIBILITIES & ROLES OF ACTORS IN THE SYSTEM

What is the understanding of the role of stakeholders and their responsibility in the system?

INSTITUTIONAL STRUCTURE, MINDSET & BEHAVIOUR

How the system is structured. How the organisations collaborate with each other?

FOREST AS AN AGENT IN THE SYSTEM

The role of the forest and its elements in the system.

THE PHENOMENON OF FIRES

What is the role of fires, and its impact.

PORTUGAL TERRITORY & MANAGEMENT OF RURAL AREAS

The context (social, economic, environmental) where fires happen.

Figure 18. Results of the first round of affinity diagramming.

The second round of analysis aimed to unpack each theme. The reason for such an approach was the high number of sub-categories that resulted from the first round. This approach helped to delve deeper into each theme and extract the main findings. All five themes were carefully analysed, resulting in 16 categories in total.

The reiteration of the first theme resulted in four categories mainly focused on the different levels of action: National, Regional, local, and individual levels (Figure 19).
This theme illustrates the role of the actors and their responsibility in the rural fire prevention system.

Figure 19. Result of the second round of affinity diagramming in theme 1

In theme 2, four categories emerged from the clustering: Unsuitable National policies, Lack of collaboration, Knowledge transfer, and Internal and external communication (Figure 20). This theme reveals how the system is structured and how the actors and organisations collaborate (or not) with each other.

Figure 20. Result of the second round of affinity diagramming in theme 2

The analysis of theme 3 resulted in three categories: Climate and characteristics, Economic value, and Management of rural areas (Figure 21). This theme highlights the context (social, economic, environmental) where rural fires happen.

PORTUGAL TERRITORY & MANAGEMENT OF RURAL AREAS

The context (social, economic, environmental) where fires happen.
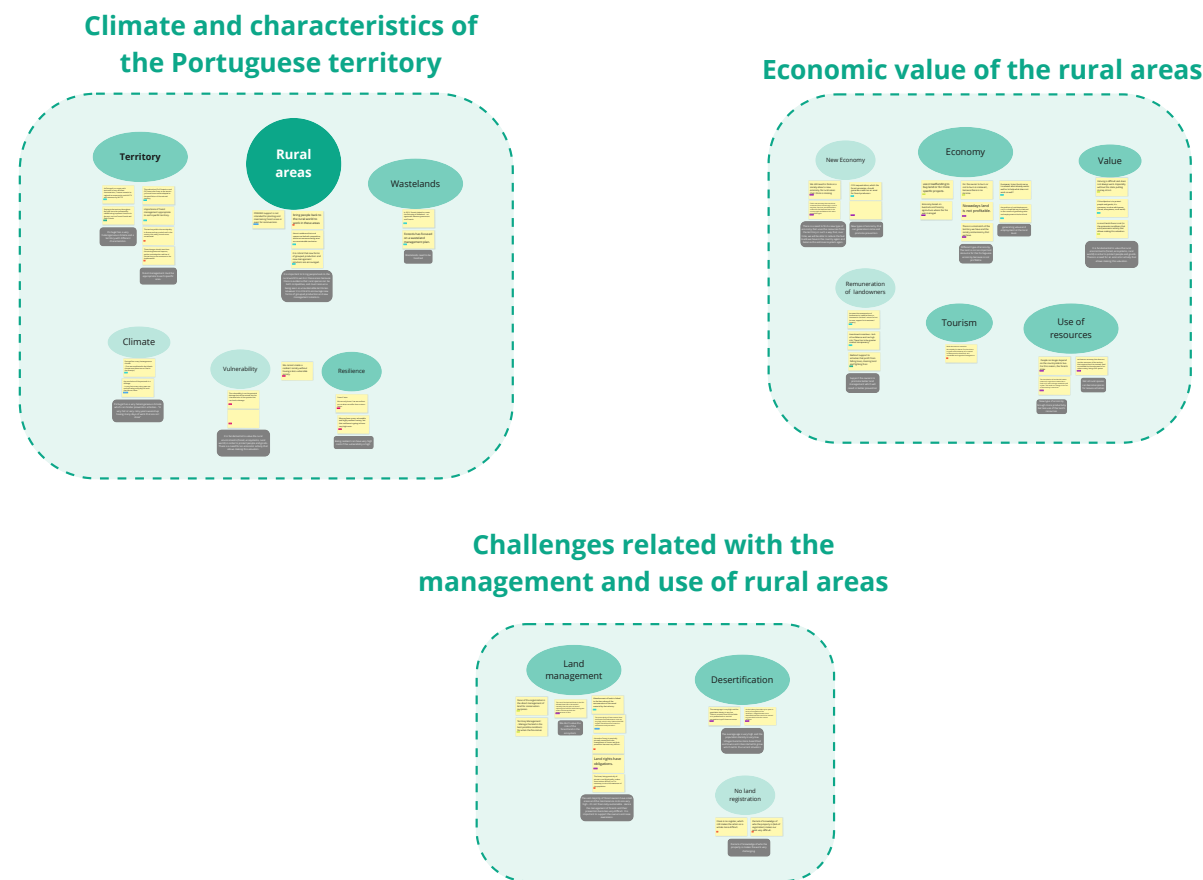
Figure 21. *Result of the second round of affinity diagramming in theme3*

In theme 4, three categories emerged from the analysis: Cultural perception of fires, Causes and aftermath, and Attitude towards prevention (Figure 22). The fourth theme includes findings of the role of fires in the ecosystem, their cultural perception and its impact.

THE PHENOMENON OF FIRES

What is the role of fires, and its impact.
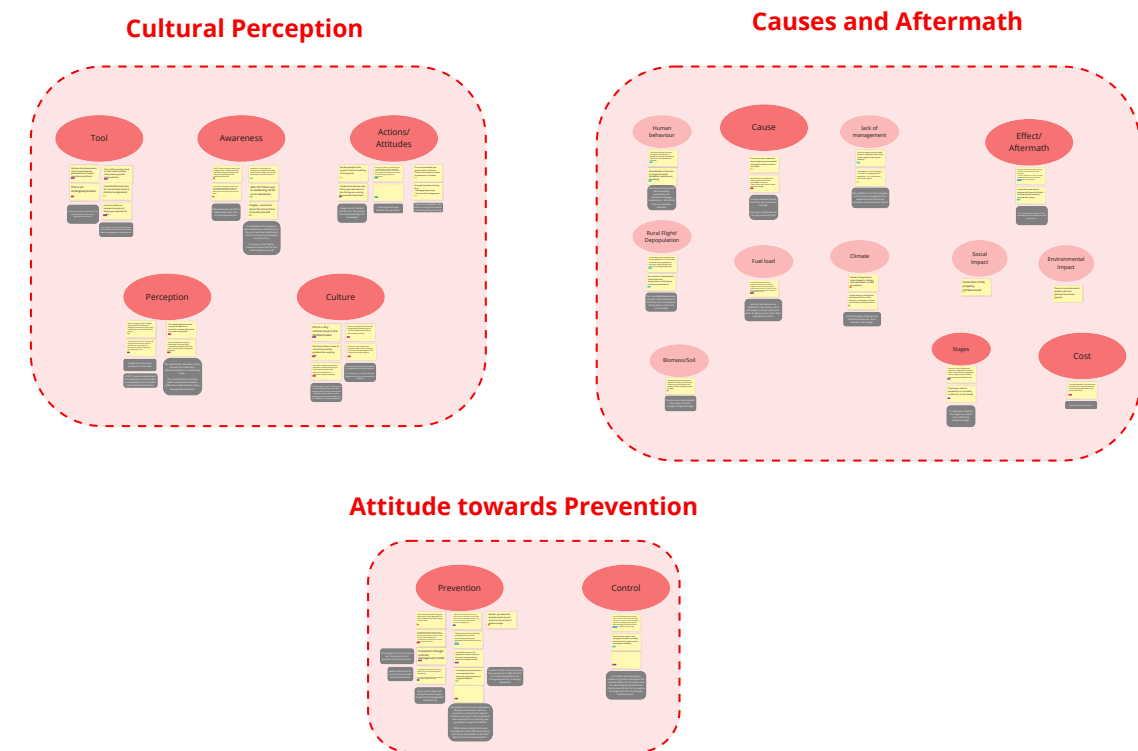
Figure 22. *Result of the second round of affinity diagramming in theme 4*

4.7. System Mapping

Finally, in theme 5, two categories emerged: the Agency of forest, and the Value of forest in the ecosystem (Figure 23). This theme focused on the role of the forest and its elements in the rural fire prevention system.

FOREST AS AN ACTOR/AGENT IN THE SYSTEM

The role of the forest and its elements in the system.

role of the Forest in the ecosystem   **The value of the forest**
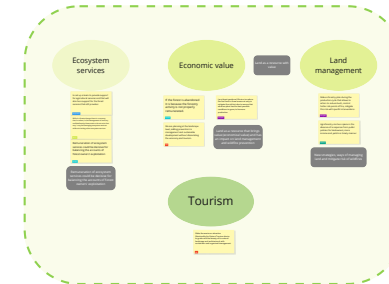
Figure 23. Result of the second round of affinity diagramming in theme 5

The five main themes, and their respective categories, will be dissected and explained in the Findings chapter.

The existing systemic approaches, such as those discussed in Section 2, have significantly aided in the transition from a conventional design approach to a systems-oriented perspective on design. The literature emphasises the importance of designing new and strengthening current systems design methods in light of these theoretical approaches.

As a result of the complexity of the research topic, the systemic approach emerged as a natural method to understand, study, and expose the complex system impacting rural fires in Portugal. It was evident that the actors' roles and responsibilities in the system, particularly those involved in rural fire prevention, could not be analysed without first comprehending the underlying system (Figure 24).
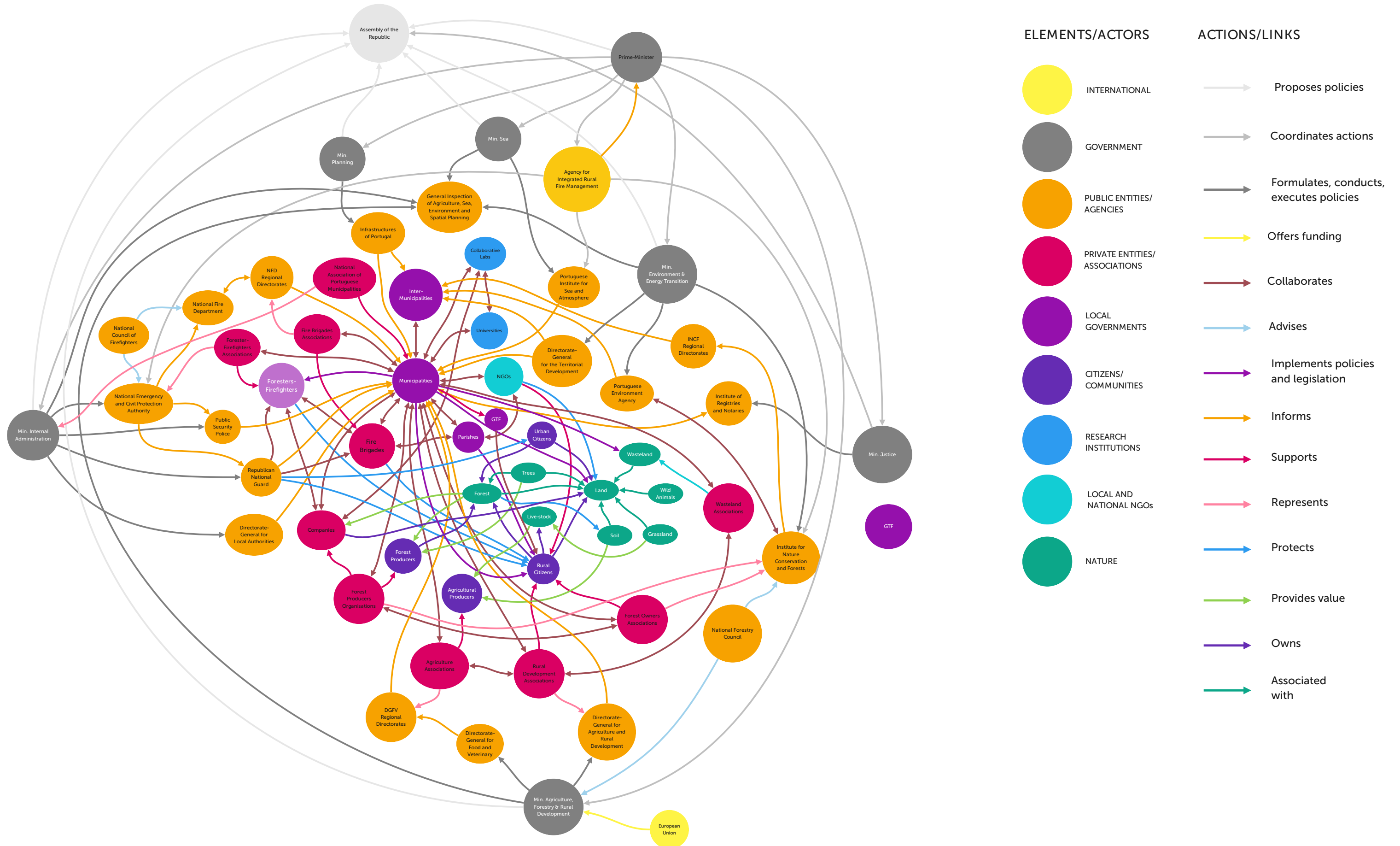
Figure 24. *Systemic overview of the rural fire prevention system.*

ELEMENTS/ACTORS

- INTERNATIONAL
- GOVERNMENT
- PUBLIC ENTITIES/ AGENCIES
- PRIVATE ENTITIES/ ASSOCIATIONS
- LOCAL GOVERNMENTS
- CITIZENS/ COMMUNITIES
- RESEARCH INSTITUTIONS
- LOCAL AND NATIONAL NGOs
- NATURE

ACTIONS/LINKS

- Proposes policies
- Coordinates actions
- Formulates, conducts, executes policies
- Offers funding
- Collaborates
- Advises
- Implements policies and legislation
- Informs
- Supports
- Represents
- Protects
- Provides value
- Owns
- Associated with

Chapter 5.
Results & Findings

Based on the literature review and interviews, this chapter presents the five main findings (1) Roles & Responsibilities of Actors, 2) Institutional Structure, Mindset and Attitude, 3) Management and Heterogeneity of Rural Areas, 4) Phenomenon of Fires, and 5) Forest as an Agent) of this research concerning the understanding and study of rural fire prevention in Portugal. The first three topics cover different aspects regarding the institutional system, the role of the actors and the characteristics of the Portuguese rural areas. The last two topics relate to recognising the role of the fire and the forest as non-human actors in the rural fire prevention system.

The following figure (Figure 25) visually represents the participants' level of activity within the rural fire prevention system.
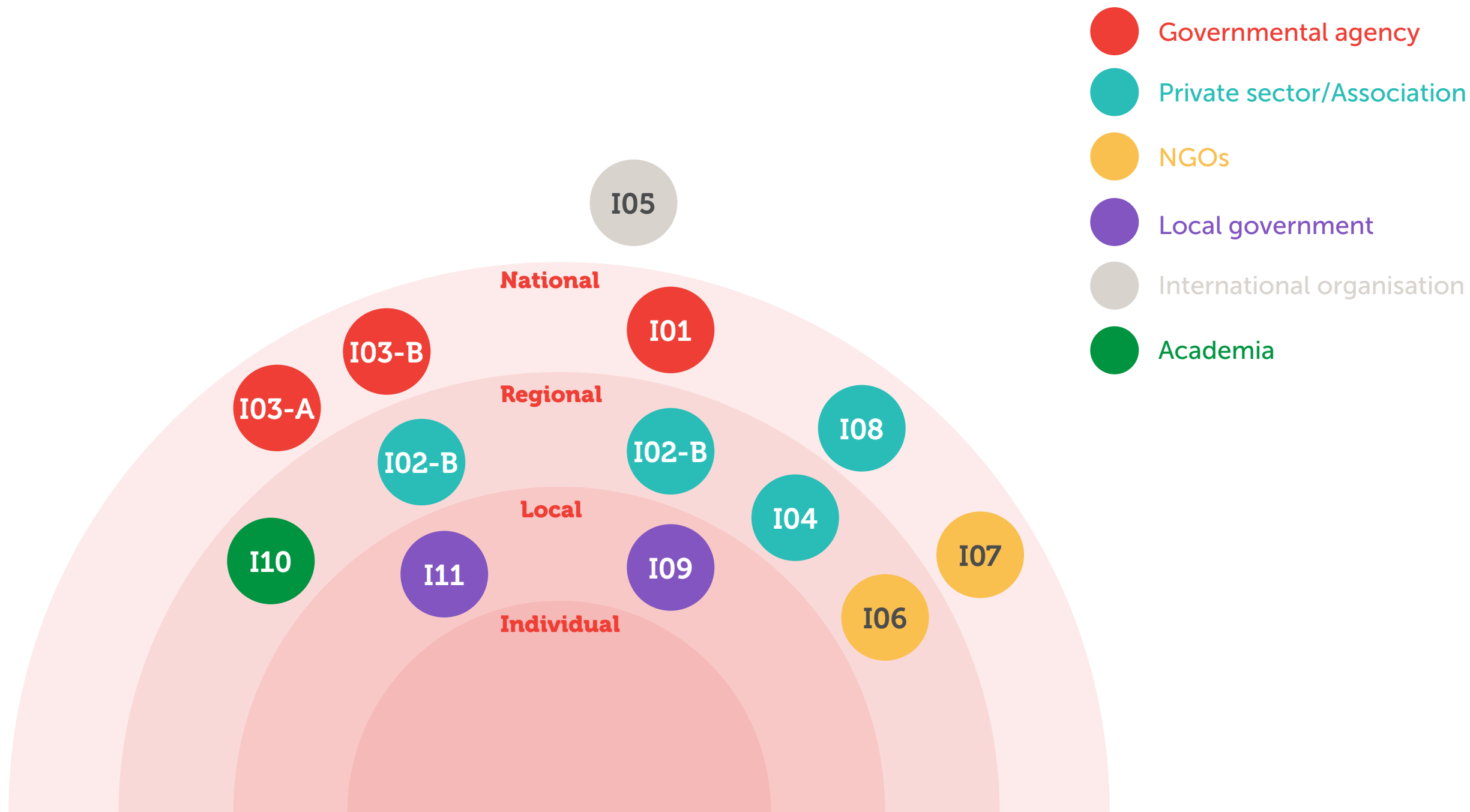
Figure 25. *Visual representation of the level of action of interviewees.*

Legend:
- Governmental agency
- Private sector/Association
- NGOs
- Local government
- International organisation
- Academia

National
Regional
Local
Individual

I05
I03-B
I03-A
I01
I02-B
I02-B
I08
I10
I11
I09
I04
I06
I07

5.1. Roles & Responsibilities of Actors

The complexity of wildfires involves many actors, resulting in a mismatch of skills and understanding about the problem. The result from the interviews shows that different actors have different roles and responsibilities within the system. Those responsibilities can be divided into four levels of action: the national, the regional, the local, and the individual level (Figure 26). These action levels demonstrate how the system is structured and the impact that various actors have from a strategic to an operational level and general population.
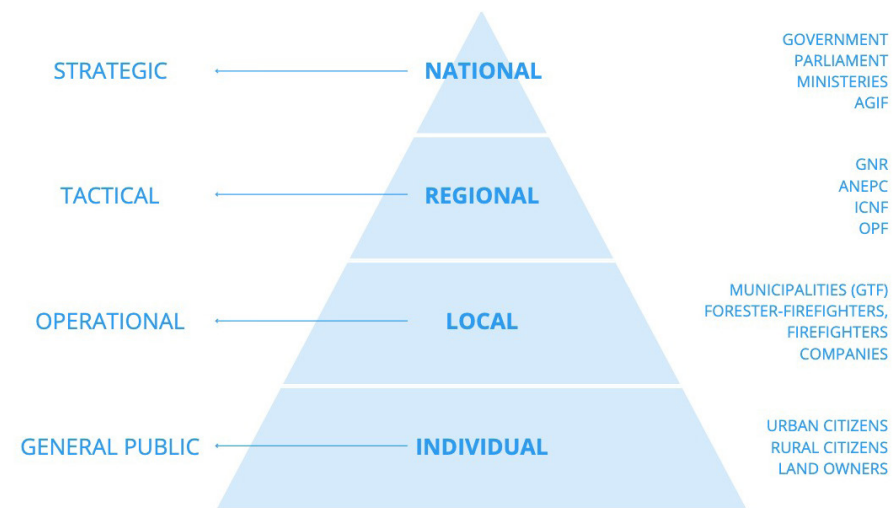

Figure 26. *The four levels of action in rural fire prevention.*

Individual Level
The individual level includes the general population, particularly landowners and citizens who live in rural and urban areas who do not own land. The majority of landowners live in rural areas. However, there still is a relevant percentage of landowners that live in the urban and metropolitan areas. According to the interviews, one of the main actors of the system is the landowners. Their role is vital in the management of private lands and properties. Land management is a crucial activity to "reduce the fuel load to mitigate the risk of rural fires but also to ensure that what is planted has the best possible conditions to be more productive and generate income" (Forest producer, I04). However, landowners are not performing these duties and responsibilities as part of their regular activities. Instead, many leave their lands abandoned without adequate management. The director of a governmental agency (I03-A) said that the lack of managementactivities is related to the landowners' high absenteeism. The high cost of managing lands can explain this phenomenon. Many landowners

do not have the economic resources to execute such activities, which result in inadequate land management. Another factor that affects this issue is rural-urban migration. Several people who live in cities are not aware of their lands inherited from previous family members who lived in rural areas. The lack of awareness and knowledge of who owns the property leads to deficient land registration (Head of GTF, I09).

"In my opinion, the main stakeholders should be the (land) owners. Without them, it is difficult to achieve success."
(Head of GTF)

"There is a high absenteeism of the landowners."
(Director of governmental agency)

The interviews with the Head of GTF and the president of the forest association suggest that the high cost of managing lands results in the lack of action in mitigating rural fires' risk. The amount of land management investment is higher than the amount of income that the land and its resources generate for the owners. This economic factor contributes to the low level of commitment of the landowners in protecting their assets and generating new income. The trust of the landowners in the governmental authorities is also an important aspect to tackle. Without suitable policies that address the landowners' real needs, they lose confidence in the governmental structure, and therefore, in the rural fire prevention system. As stated by the Head of GTF, it is fundamental to have proximity with the local communities. Only this way it is possible to create trust between the government and the landowners. A closer connection between the government and landowners can enable a more proactive approach.

"It is costly and challenging for the owners to keep the areas clean only with their income."
(Head of GTF)

"The forest producer, if he has no income, is not interested in the forest."
(President of forest association)

Behaviour and awareness are also essential factors in the general population's role in preventing rural fires. More reliable communication and better education can improve the understanding of the risks of their actions. Hence, contributing to better use of the resources and the spaces in rural environments.

"It is important to know the rural space and how it should be used."
(President of forest association)

*"There is the population that lives in the countryside,
which eventually has some risky behaviours."*
(CoLab Researcher)

Local Level
The local level relates to the implementation of policies and operations on a local level. The actors range from local governments, such as municipalities and parishes, to forester-firefighters, fire brigades, private companies, and NGOs. They are responsible for implementing policies, taking action and performing activities towards the prevention of rural ires.

The local governments, alongside the landowners, are considered the key actors in the system. Both municipalities and parishes have an essential role in bridging the local population and the higher governmental organisations and agencies. Local governments know the territory and are the first line of forest management responsibility on a local level. Together with a more substantial presence close to the communities, this responsibility promotes trust between the locals and the municipalities, which helps minimise the number of fires and burnt areas.

"Municipalities also have an important role, and are fundamental. They are associated with management, prevention and the economy and tourism."
(Head of foresters)

"There is a strong connection with the municipalities and the local communities through multiple channels."
(Director of governmental agency)

The interviews with the director of a governmental agency and the Head of GTF indicate that municipalities in Portugal are diverse and have different needs. Portugal's rocky northern coast and mountainous interior show the diversity of landscapes and the differences in local governments' resources. Municipalities and parishes know the local territory's characteristics, but they need more support and investment in human and material resources to conduct their rural fire prevention activities. The older municipalities with fewer resources and

with more limitations have a higher risk of rural fires. Even though they have an autonomous election process - they do not depend on the central state - they depend on a budget provided by the government. With more human, economic, and technological resources, local governments could better support the landowners and the local communities.

"Each municipality is different."
(Director of governmental agency)

"The faults and conditions of each Municipality and institutions should be evaluated and reinforced."
(Head of GTF)

Collaboration at a local level is essential to create policies that address local needs. A representative from the local government (I09) suggests that "if everyone sits at the same table, all have responsibility for the proposals, but also the execution of the plan". By empowering the local actors and taking a bottom-up approach, it is possible to reach and influence policy-making at a national level.

"Local policies are fundamental because it is at the local level that concrete action on the ground takes place."
(NGO member)

"Work better in local government to reach the central level."
(NGO member)

At the local level, the fire brigades and the forester-firefighters work as links between municipalities and land and forest owners. They assist in cleaning fuel and in the slash-and-burn, where the natural vegetation is cut down and burned as a method of clearing the land for cultivation. Their interventions in private and public spaces promote awareness among the population to comply with cleaning and burning rules. The forester-firefighters' knowledge of the local territory is necessary to provide high safety and land management levels.

5.2. Institutional Structure, Mindset & Attitude

Regional Level

The translation of policies and strategies into concrete action plans are the main activities at the regional level. Actors such as ANEPC, GNR, and ICNF provide the local governments and regional directorates information on new regulations and norms.

Since ICFN is the entity responsible for preventing and protecting rural spaces, it needs to be closer to the local communities, creates trust, and gain confidence from forest owners and municipalities. Their role should work as a hinge between the government, traditionally distant, and those who feel the problems. More excellent proximity with the local governments would result in a better coordination capacity to intervene in the rural areas.

> *"One of the critical points of the ICNF is its discredit;*
> *nobody believes in the ICNF."*
> (President of forest association)

National Level

At the national level, the actors are responsible for developing new policies and strategies implemented at the operational level. The government and its ministries and the AGIF are the strategic level's key actors.

According to I08, the organisations at the higher level are not aware of the needs and issues in using the land's resources and its management for rural fire mitigation. It is, therefore, necessary to stimulate a closer connection with the local communities through the actors at the regional and local level. Supported by effective collaboration and cooperation between these two levels, the government can create policies that respond to the local governments' needs and the landowners.

> *"The important thing is that there is a correct public policy orientation*
> *in the use of forest production, without contradictory measures*
> *that destroy value and cause market distortions"*
> (President of forest association)

National policies do not seem suitable for the local context

In Portugal, the rural fires in the summer of 2017 showed that the rural fire management system was not prepared and designed to resist such devastating events.

In the opinion of the president of the governmental agency (I01), the director of the governmental agency (I03-B), the president of the forest association (I08), the Head of GTF (I09) and the Head of foresters (I11), the current structure of the rural fire management system is inconsistent. The regular changes in the organisational model in the last 20 years have rendered a distorted view of the system. Based on the president of the forest association, it is critical to creating a strategy to stabilise it with a long-term vision agreed by all the system actors. The first step is to focus on suitable legislation and policy-making for rural areas to integrate knowledge from the academic and scientific institutions (University researcher, I10). This step can be accomplished by acknowledging the importance of nature in preventing rural fires and integrating other topics related to biodiversity and climate change.

> *"The organisational model of the forestry authority*
> *has changed six times in the last 20 years"*
> (President of forest association)

The constant incongruities, contradictions, and legislation changes lead to legal incompatibilities with the rural areas' current state. These inconsistencies can be averted by involving the local governments and communities in designing and planning forestry policies that meet the landowners' needs, promoting a greater forest activity regulation. Additionally, coordination must be decentralised and territorialised to reach diversity and adapt to each municipality with adequate support and monitoring.

> *"There is some inconsistency in the solutions for the forestry sector."*
> (President of forest association)

Lack of collaboration across actors
One of the critical points of the existing institutional structure is the lack of collaborative processes. The ability to cooperate must begin at the strategic and tactical levels. I01 claims that organisations are more focused on themselves and the results rather than collaborating on tasks (President of governmental agency, I01). Collaboration is associated with the assessment systems that are performance evaluation and monitoring methodologies conducted at different times and are focused on the individuals. These evaluation methodologies are not designed for collaborative work.

Governmental organisations are self-centred organisations (President of governmental agency, I01). They still work in silos and have only one focus - suppressing fire instead of focusing on prevention. I08 argues that closer proximity and dialogue with organisations and municipalities can promote trust capital. By involving all the actors, sharing resources and knowledge, defining responsibilities, participating and collaborating in various actions and activities encourages a sense of responsibility, empowerment and ownership.

"The biggest challenge is institutional change and institutions delivering results rather than just tasks"
(President of governmental agency)

"There is a very siloed view, specific from the organisation."
(University researcher)

Gaps within knowledge transfer
The power of knowledge is vital to the mitigation risks of rural fires. According to I04, many opinions within governmental organisations are founded without having contact with the field. Moreover, several people contributing to the national strategies do not possess the appropriate forest management skills to participate in the decision-making process. Hence, supported by a less hierarchical approach, it is necessary to promote knowledge sharing at the strategic, tactical and operational levels, involving research centres and academia.

"When (organisations) talk about prevention, they do not really know what they are talking about, let alone the general population."
(Civil Servant)

The urban population has attitudes and behaviours that are not compatible with the reality in the rural areas. Therefore, education is fundamental to change behaviours of risk and recognise the forest as a factor of production and ecological and economic value creation.

"There is a growing ignorance of risk in society."
Forest producer director)

Internal and External Communication
Communication plays an essential part in the prevention of rural fires. The CoLab researcher (I02-A) claims that exist three dimensions of communication: within the organisation, between organisations, and with the population. These three dimensions are interconnected. For instance, poor and unclear communication within ICNF will directly impact communication with the local governments, which, as a result, will misguide citizens' behaviour and mindset. This miscommunication and misinformation contribute to an incorrect perception of the appropriate behaviours in rural areas.
Detailed documentation and understanding about how the national agencies and the local governments collaborate, think and act can contribute to better internal communication, resulting in more reliable communication to the general population.
Eventually, a structured and comprehensive communication strategy could support a paradigm change on an institutional, political, and, consequently, local level.

"External communication will work more effectively if internal communication between all parties works well"
(President of governmental agency)

5.3. Management and Heterogeneity of Rural Areas

Climate and characteristics of the Portuguese territory

A heterogeneous climate and territory characterise Portugal. For example, the Atlantic climate area is more prone to rural fires, while in the southern rural interior, the risk of rural fires is very low. This heterogeneity demonstrates that forest management policies should be more adaptable to each area's specificities. External factors such as climate can influence the level of vulnerability of the society and increase rural fires' impact. Acknowledging the role of climate and the heterogeneity of the Portuguese territory in the wildfire management system is the first step to reduce vulnerability, protect people and properties and rural environments, particularly forests and their ecosystems (President of forest association, I08).

"The territory within the municipality is very diverse, and in the country, this reality is even more accentuated."
(Head of GTF)

The value of the rural areas

People no longer depend on the rural areas to generate income. The introduction of mechanical means in agricultural and forestry sectors led to a change in the land's resources. Currently, the rural lands are not seen as an essential resource for the Portuguese economy because it is not profitable. To address this issue, the director of a forest production company (I04) defends a new type of economy that uses the resources from the territory in a way that, over time, can reduce the fuel loads and balance the entire ecosystem again. One representative of a forest association supports a policy that increases landowners' remuneration to mobilise them to intervene in their lands (President of forest association, I08). Supporting the landowners to promote better land management will result in better prevention, generating value and employment at the local level. A new approach to encourage new production forms and new management solutions can enable economic activities that generate value and bring people back to the rural world.

"We still need to think as a society about a new economy for rural areas that I think is missing"
(Forest producer director)

Management and use of rural areas

Rural areas today have an extremely high average age and a relatively low population density. Villages have become more desertified, and towns and cities started to grow, which led to the current situation. The abandonment of lands is linked to the low values of compensation by the forest industry. Forest and landowners own areas where the maintenance costs are very high and not financially sustainable, contributing to the absence of appropriate land management.

"The average age is very high, and the population density is very low"
(Forest producer director)

Presently, many landowners live and work in the cities and are not aware of their property possessions in the rural areas. Although legal norms stipulate that landowners are accountable for maintaining and managing their lands, the impact of desertification has limited the collection and registration of information on who has the lands' legal rights.

"The lack of knowledge of who the property is makes our work very difficult."
(Head of GTF)

5.4. Phenomenon of Fires

Cultural Perception
The perception that the Portuguese society has on fire is based on amiss cultural beliefs. Even though rural fires have a negative impact, the phenomenon of fire itself is an ecological process comparable to other natural phenomena such as scrublands, agriculture and forest (Forest producer director, I04). Similarly, the vice-president of an environmental NGO (I07) claims that fire is a tool that can be used under controlled environments for land and habitat management. Ecological ecosystems need fire to regenerate; otherwise, they deteriorate and disappear. The ecological nature of fire demonstrates that it is paramount to accept both the positive and negative effects of fire.

The university researcher believes that fire is a social and political issue that should be addressed at the governmental and strategic levels through policies that better reflect fire's actual impact on social and natural environments. These policies can contribute to locals' empowerment and enable communities to build their mechanisms and structures to mitigate fires' risk.

"Fire is an ecological process."
(University researcher)

"Fire is an inevitability. There is no concern to avoid fire because it is useless."
(Vice-president of NGO)

Causes of Fires
The leading causes of rural ires are associated with climate change and human behaviour. Events like fires are becoming more frequent and more intense due to drier and warmer conditions. Failure in controlling these fires can result in severe social, economic and ecological consequences.

"Climate change forced some change in strategy and commitment, as well as reactions."
(President of forest association)

The rural abandonment (President of forest association, I08) contributed to the forest's abandonment and fuel accumulation in the lands. Leaving fuels without any treatment can activate the potential occurrence of fires. The biomass in the soil affects the condition and the impact of rural fires. As stated by the president of the governmental agency, the issue is not related to the types of trees; instead, it is linked to the absence of land management and the loss of land's economic value.

"(there is an) intensification of fires due to unnatural causes."
(President of forest association)

Attitude towards Prevention
According to most interviewees, the rural fire management system's focus should be on prevention rather than suppression. Fires must be dealt with during the winter season through forest management policies and action plans suitable to the local context. As mentioned by the researcher at the CoLab, the investment in prevention is more relevant than acquiring new equipment to fight rural fires. Focusing on prevention reduces the resources for suppression and enables control of the number of ignitions throughout the summer.

"Investing in prevention is more important than acquiring new equipment to suppress rural fires."
(CoLab researcher)

"What is done during the fire may correspond to only 18% of everything that can be done related to the fires. Most of it has to be done before."
(University researcher)

5.5. Forest as an Agent

Role of the Forest in the ecosystem
Forests ecosystems are considered, by organisations at all levels, an essential element in the mitigation of rural fires' risks and the regeneration of the ecological ecosystem. The statement above reinforces the idea that landowners, rural and urban citizens must respect forests by acknowledging their role in preventing rural fires.
Society cannot overstate the value of forest ecosystems. All citizens should be responsible for taking care of forests since their ecosystem components clean the air and water, control the environment, and recycle nutrients and wastes. Their carbon sequestration is done through the soil and the vegetation, slowing atmospheric pollution and mitigating global warming. The president of the forest association claims that these ecosystem services could provide economic compensation to forest and landowners, balancing their land management costs.

"The forest must be felt like ours."
(Head of GTF)

In the opinion of the forest association president, the measures specifically geared towards the forest should focus on the treatment of primary issues such forestry, reforestation after fires, and better management. Instead, current policies promote deforestation processes, which are not the answer to the rural fires because they pioneer new types of trees that do not burn and maintain those that burn more. To address this issue, the NGO member suggests afforestation as an alternative method. Creating forests in new areas increases carbon capture and prevents other disasters such as floods from occurring.

"Without forest and adequate vegetation, we have no rain."
(NGO member)

The value of the forest
When landowners modify natural forest habitats, they often overlook forest ecosystems' potential implications. For that reason, national and local strategies must promote good practices regarding land management and mitigation risk of rural fires. Forest producers should be required to make a forestry plan during the production cycle that allows actions to reduce fuel load, control hotter risk points of fire, and mitigate this risk with specific interventions. By doing so, they can protect their lands, utilise the forests' resources, and generate income.

"(as a forest producer) we aim to reduce the fuel load in these areas not only to mitigate the risk but also to ensure that what we plant has the best possible conditions to grow, to be more productive."
(Forest producer director)

5.6. Summary of Results

The five themes identified in this chapter address the challenges in the prevention of rural fire in Portugal.

The first one - Roles and responsibilities of actors - describes the complexity of the issue, involving many actors and resulting in a mismatch of skills and understanding. The interviews show that different actors have different roles and responsibilities within the system, divided into four levels of action: the national, the regional, the local, and the individual level.

The second theme - Institutional structure, mindset and attitude - describes the lack of collaboration and communication, which results in a gap of knowledge across the different levels of the system.

The third one – management and heterogeneity of rural fires - outlines the challenges in recognising the value of rural areas to the landowners and the local community in general. Furthermore, it illustrates the difficulty in proper land management actions by the owners.

The fourth theme - The phenomenon of fires – describes the cultural misperception that society has towards fire as a tool and as an ecological process in preventing rural fires.

The final theme - Forest as an agent - outlines the role of forest in the protection of natural ecosystems and in providing ecosystem services that contribute to people's well-being.

Chapter 6.
Strategic Recommendations

This chapter aims to present a series of recommendations that address five core themes, emerging from insights presented in the previous chapter: 1) Roles and Responsibilities of Actors, 2) Institutional Structure, Mindset and Attitude, 3) Management and Heterogeneity of the Rural Areas, 4) Phenomenon of Fires, and 5) Forest as an Agent.
The primary objective of these recommendations is to propose new interventions at a strategic level of the whole (eco)system, where the smallest intervention, can result in a significant shift in behaviour.

The strategic recommendations are formed and explained using Meadows' list of leverage points (1999). According to Meadows (1999), leverage points 7, 8, 9, 10, 11 and 12 are less potent since they include physical components and information flow of the system that takes more resources and effort to change. It entails that even the paradigm that forms our ideologies is constrained and is beyond human understanding (Meadows, 2008). Therefore, only leverage points from 6 to 4 are explored to remain within the rural fire prevention system (Figure 27).

LP 5
The rules of the system.

PORTUGAL TERRITORY & MANAGEMENT OF RURAL AREAS

Climate and characteristics of the Portuguese territory

Economic value of the rural areas

Challenges related with the management and use of rural areas

Regional level

National level

RESPONSIBILITIES & ROLES OF ACTORS IN THE SYSTEM

role of the forest in the ecosystem

Local level

Individual level

The value of the forest

FOREST AS AN ACTOR/AGENT IN THE SYSTEM

Knowledge transfer

National policies not suitable for local context

Internal and external communication

INSTITUTIONAL STRUCTURE, MINDSET & BEHAVIOUR

Lack of collaboration

Attitude towards prevention

Causes and aftermath

Cultural perception

THE PHENOMENON OF FIRES

LP 4
The power to add, change, evolve, or self-organise system structures.

LP 6
The structure of information flows.

Figure 27. *Findings associated with leverage points.*

6.1. The power to self-organise, system structures - Leverage Point 4

Self-organisation refers to the ability of a system to change some part of itself (Meadows, 2009). It is the most powerful type of system resilience since an evolving system can withstand almost any transition simply by modifying itself (Meadows, 2009). According to insights emerging from interviews, the rural fire system structure is currently too hierarchical, which results in a layer of knowledge that requires more time and resources to be understood and implemented.

The Portuguese government wields considerable political and financial power over local government. In addition, the lack of support from the central government in resources hinders the capacity of local governments to conduct practical preventive actions with the local communities. According to the Head of GTF, some decision-making capacity is being taken from municipalities and parishes. This approach is not the most appropriate since it is at the local level and in proximity to the owners that it is possible to mitigate the risks of rural fires. It is worth noting that the national plan makes little mention of the relationship between landowners and municipalities. Changes are needed in the system structure to provide more support from the governmental agencies to municipalities and parishes.

The following recommendations address the themes: 1) Roles and Responsibilities of Actors, and 2) Institutional Structure, Mindset and Attitude (Figure 30).

6.1.1. Decentralisation of Local Governments

An opportunity for local governments to increase capability and support landowners and local communities is decentralisation on a decision-making level. If enforced, this independence will allow local governments to identify and modify local policies independently of the governmental agencies and increase managerial and organisational decision-making authority. Policies are designed at a local level, considering the land conditions and the needs of the locals. Additionally, coordination must be decentralised and territorialised to reach diversity and adapt to each municipality with adequate support and monitoring. The devolution of authority could make the central government more responsible for carrying out its responsibilities, increasing accountability. Granting legislative, logistical, and financial control to local governments would require expanding capacity and cooperation with people, as the local government has strong ties to the government. This strategy enables the change at the government level in response to demands, resulting in a desire to avoid bureaucracy and promote action.

6.1.2. Participatory Approaches to Local Governance

Decentralisation enhances civic interest in decision-making processes that directly impact the local community. As a result, landowners become involved in decision and policy-making for land management and rural fire prevention. The participatory approach aims to turn locals into "shapers" of legislation through improved policy deliberation and increased government transparency. The local government transparency improves the wishes and needs of locals, instilling landowners with a greater sense of trust in their government.

Participatory local government strategies must increase landowners' access to policy-making institutions, change official attitudes toward public involvement, and offer incentives for participation, all while being resilient to local circumstances. Increasing awareness of landowners' rights to mobilise and act together will address and reform established top-down power relationships.

6.2. The rules of the system - leverage point 5

6.2.1. Legislation that supports land management

Meadows (2009) asserts that the rules of a system determine the scope, limits, and degrees of freedom. It is essential to pay attention to the rules and who controls them to comprehend the system's most fundamental malfunctions (Meadows, 2009). Currently, Portugal's rural fire management system is governed by rules and legislation defined by AGIF. AGIF establishes public policies for the management of rural fires and assesses and monitors prevention activities. As previously stated, AGIF's National Plan for Integrated Rural Fire Management (AGIF, 2020) emphasises the importance of enhancing the value of rural areas. However, it neglects to address the needs and the challenges of landowners in managing and protecting their lands. According to the findings, the lack of land management is associated with the forest industry's low compensation for raw resources.

Forest and landowners have areas where the maintenance costs are very high and not financially sustainable, contributing to the absence of appropriate land management. The president of a forest association defends a policy that supports the landowners to promote better land management, resulting in better prevention and generating value and employment at the local level.

The following recommendation addresses the theme 3) Management and Heterogeneity of Rural Areas (Figure 31).

Although current legislation provides economic compensation to landowners for their forests ecosystems services (Santos et al., 2019), many locals continue to neglect their legal responsibilities as forest and landowners. Compensation for ecosystem services can be reviewed to match the natural ecosystems' impact in the region. Rather than punishing negative behaviours, a solution is to support landowners with adequate land management and preventive actions such as access to resources, training and skills against rural fires. This support from the government can work as an incentive to land and forest owners and promote a proactive approach towards property management and prevention. A new approach to encouraging new management solutions could enable further economic activities that generate value and bring people back to the rural world.

6.3. The structure of information flows - leverage point 6

Meadows (2009) states that one of the most important causes of system failure is a lack of information flow. During the off-season of rural fires, many municipalities coordinate teams of foresters to perform surveillance and prevention work. Their actions are to inform and raise awareness of the prevention of rural fires based on the legislation. Those actions raise the population's awareness of the precautions and preventive measures and emphasise what to consider to defend and protect themselves from fires. However, the municipalities' concerns lie in the impact these actions have on the local communities, especially land and forest owners. Despite these preventive actions, many locals, including forest and landowners, do not comply with the national policies. The findings indicate that this negative attitude towards prevention is due to inconsistent communication and a lack of knowledge on the value of forests as providers of ecosystem services.
The forests are seen as a resource to generate income instead of a valuable actor in protecting and regenerating natural ecosystems through its ecosystem services, such as clean air, water, and soil - three natural resources essential to humans. These factors demonstrate that the preventive actions by local governments have failed to contribute to adequate knowledge on the role of forests in natural ecosystems.

The role of fire is also misunderstood by society from rural and urban areas. For many, fire is considered a threat and should be avoided. However, the research data shows that fire is an ecological process. Similar to forests, fire has a significant role in the preservation and regeneration of natural systems. It can be used to dispose of agricultural waste, clean fuel loads and regenerate the soil, thus contributing to rural fires prevention. The research results identified that society is not familiar with non-human actors such as fire and forests in the natural ecosystems and in preventing rural fires.

The following recommendations address the themes 4) The Phenomenon of Fires, and 5) Forest as an Agent (Figure 32).

6.3.1. Education and Knowledge Sharing

A new approach to educating and sharing knowledge on the ecological processes of fire and forests is fundamental to rural fire prevention. This new approach towards education does not take a position or argue for a specific course of action. Instead, it raises awareness and attention to the environment and the role of natural phenomena in ecosystems, broadening the knowledge and comprehension of climate issues. By promoting and sharing the value of forests and fire as ecological processes within society, one could increase awareness of citizens' agency regarding ecological processes and prompt them to change their behaviours. Individuals gain a greater awareness of the role of non-human actors in the system and make rational and conscientious choices as a result. With more knowledge, society can recognise the value of forests and the importance of biodiversity to the region through their ecosystem services. It also recognises the value of fire as a tool to clean or eradicate undesirable plants from natural habitats to minimise fuel loads and the possibility of major devastating fires.

6.3.2. Coherent Communication Strategy

For knowledge sharing to occur, it is crucial to develop a communication strategy that addresses all actors in the system. Local governments' preventive actions have shown that municipalities and parishes are active in reaching locals. However, their communication should be more effective; it should be made more transparent and promote a new behaviour. Owners should understand that their actions can affect the local natural ecosystems. To avoid this attitude and promote a new type of behaviour, national and local governments could establish a new communication strategy that informs people on the value of forests and fire. A communication strategy that considers small-time property owners and local (and national) actors can raise awareness and mobilise people to change attitudes. These experimental communication strategies can include civic activities and several communications adapted to the unique relationship that various landowners have with their lands. A coherent communication strategy can change the cultural perception of society towards the use of fire and the role of forests in the rural areas, contributing to actions and behaviours that prevent rural fires.

Chapter 7.
Discussion

This thesis contributes to a more systemic view on rural fire management in Portugal, the complexity of relationships between actors, and their roles and responsibilities in preventing rural fires. The thesis uncovered factors that had been overlooked in previous studies while corroborating earlier results in the literature. These factors will be discussed below, and at the same time, will address the research questions set at the beginning of this thesis.

7.1. Understanding of rural fire prevention in Portugal

Research question addressed:
- How can a systemic approach contribute to the understanding of rural fire prevention in Portugal?

The research findings suggest that a systematic approach contributes to a better understanding of rural fire prevention in Portugal. The nature of systemic thinking allowed a comprehensive analysis of the rural fire management system, providing valuable knowledge of the actors, roles, relations and connections, exposing the challenges and interdependencies within human and non-human actors. The studies by Rava (2016) and Tanjeela (2015) demonstrated that in addressing complex challenges such as institutional change in governance and climate change adaptation, it is fundamental to study and analyse the issues on a systemic level (Buchanan, 1992). This thesis may supplement previous research on disasters prevention (Burnside-Lawry & Carvalho, 2015; Tiefenbacher, 2013) by supplying data on addressing rural fire prevention on a strategic level through a systemic approach. In contrast with some studies (Buehring & Bishop, 2020; Huang & Anderson, 2011) where the focus is on a bottom-up approach (e.g. focusing on the communities), this thesis applied a top-down approach, including participants mostly from governmental agencies, local governments, private and nonprofit sectors. Through the interviews, it was possible to identify that the different actors perceive rural fires from different perspectives depending on their role in the system. Moreover, the findings suggest that the lack of collaboration and communication across the different levels of action and the different organisations contributes to policies and legislation that do not address the needs of the local governments and communities. Hence, this thesis provided a broader understanding of how the diverse actors within the system perceive rural fires, how they see the role of other actors, and what actions they take to mitigate the risks of rural fires.

Additionally, to comprehend and analyse the rural fires, it was fundamental to simplify the focus and provide some boundaries (Meadows, 2008). The systemic approach forced the author to narrow the focus and limit the boundaries of research from the study of the whole rural fire management system to the prevention stage. Creating boundaries and focusing on prevention contributed to more detailed research providing valuable results on actions and challenges in mitigating risks and preventing rural fires.

7.2. The role of human and non-human actors

Research questions addressed:
- Who are the actors in the rural fire prevention system in Portugal?
- What is the role of the actors in developing strategies and actions for rural fire prevention in Portugal?

Akama et al. (2020) stated that concern for the fate of humanity implies concern for nature as our understanding of life's critical interdependence grows. This view promotes a rethink of relationships, broadening the understanding of agencies, interdependencies, and entanglements between humans and non-human elements (Forlano, 2017). Similar to Akama et al. (2020) and Forlano (2017), this thesis indicates that successful strategies in rural fire prevention imply an in-depth analysis of the interdependencies of human and non-human actors. The research findings reveal that non-human actors such as forest and fire have a role in regenerating natural ecosystems and preventing rural fires. Furthermore, forests provide clean water and air, natural habitats, soil, and leisure facilities and beautify the environment.

Additionally, forests are a significant economic opportunity since they provide sellable wood. Acknowledging the agency of forest and fires by all human actors is the first step to better prevention. These findings can complement previous studies (Karma et al., 2019; Twigg et al., 2004) on disaster management tailored to rural fires. The fusion of human and non-human agency through the recognition of fire and forest as agents in protecting the natural ecosystems and preventing rural fires can contribute significantly to a systemic understanding of the role of human and non-human actors in rural fire prevention.

7.3. Mindset towards rural fire prevention

Research questions addressed:
- *What are the challenges of rural fire prevention in Portugal?*
- *What are the strategic opportunities in rural fire prevention in Portugal?*

The research results demonstrated the need for a shift in the mindset of the actors, from governmental entities to local governments, forest industry associations and citizens. Although altering a system's mindset is more powerful, Meadows (1999) claims that it faces more significant systemic opposition and needs a long-term commitment to effect improvement. In this thesis context, the complexity of the phenomena of rural fires hinders the implementation and development of strategies that address the issues of all actors. The interviews with the participants suggest a difference of perspectives and opinions on how to address rural fire prevention. According to the results, the current mindset is built on previous concepts that are no longer relevant. The challenges of today require a new perspective and a novel way of addressing the issue. However, this requires a closer collaboration between the actors, particularly governmental entities and local communities, to change a mindset.
Furthermore, a more collaborative model may enhance the importance of participatory approaches by engaging and encouraging the actors as decision-makers in the design process, enabling them to shape a new mindset by exchanging their expertise and knowledge (Sepers, 2017). Local governments can have an essential role in bridging the central government with the local communities. The participation and engagement of relevant actors can promote a new mindset, which can be crucial for developing new strategies for rural fire prevention.

7.4. Systemic approach in design

The increased complexity of societal challenges has shown that the traditional design practices are no longer applicable to the current issues that society is facing. There must be a shift of mindset to address abstract and invisible challenges (Buchanan, 1992). The case study has established systems thinking skills as a new basis for design's core competencies and professional success when confronted with complex problems (Jones, 2014; Ryan, 2014). Disasters, in particular rural fires, are one of the most complex challenges that humanity faces. Human activities have profound effects, and the origins of these actions are deeply rooted in all of the processes on which we depend. As suggested by Costa Junior et al. (2019), these criteria mean that solutions to complex challenges cannot be formulated as isolated hypotheses but must include a strategic and systemic transformation of existing processes.

With the need to rethink systems, this thesis suggested that rural fires require a systemic approach to comprehend and address the problem. By incorporating a holistic approach into the design process, it is possible to understand complex, multi-actor infrastructure systems such as those used in rural fire prevention. This systemic approach leverages proven design skills to identify, map, propose, and reconfigure complex systems and processes. This viewpoint provides excellent opportunities for design to expand its reach and contribute to new fields.

Chapter 8.
Conclusion

This thesis aimed to explore how a systemic approach can contribute to understanding the prevention of rural fires by investigating the actors, roles, and interdependencies in Portugal's rural fire management system. Moreover, the thesis aimed to analyse the challenges and identify intervention areas for strategic recommendations.

8.1. Limitations

The thesis employed a qualitative research approach in order to obtain insights into the rural fire prevention system. The research methods included conversational and semi-structured interviews, document analysis and event observation, which laid the groundwork for most of the findings. The thesis made some scholarly contributions when addressing the research questions. First, it offers a comprehensive understanding of rural fire prevention in Portugal by analysing human and non-human actors. Second, it describes actors' roles, presenting collaboration gaps between governmental agencies and locals, such as forest and landowners.
Furthermore, the thesis revealed the role of the forest and fire as non-human actors in the protection and regeneration of natural ecosystems and the prevention of rural fires. Third, the thesis identified the main factors that influence rural fire prevention, particularly the lack of policies that support landowners and the characteristics of the rural areas, the cultural perception of the role of fire in the regeneration of natural habitats, and the recognition of the value of forests as an ecosystem service provider. Finally, it suggests several strategic recommendations for rural fire prevention that can change mindset and attitude towards prevention.

This thesis demonstrates how a systemic approach can provide a holistic overview of rural fire prevention. It contributes with insights to the academic community, providing a deeper understanding of how to address complex societal challenges.

The thesis encountered some limitations. First, the project was conducted during a pandemic, which had a significant impact on the course of the study. Second, even though the data collected has an acceptable representation of the different actors, there were many challenges in reaching out to other actors, prominent representatives from other governmental institutions that have a relevant role in the rural fire prevention system. A broader representation of more organisations and a more significant number of interviews could contribute to richer data. Third, the research methods present also have some limitations. The email interviews provided information limited to the questions sent by email. Also, some of the participants did not feel comfortable sharing their opinion on some topics related to the role of governmental agencies. An in-person interview could provide a deeper analysis of these challenges. Fourth, the analysis of the data was performed solely by the author, without the engagement of the participants. The author's bias and individual perspective might have influenced the research outcomes.
Furthermore, due to the thesis's overlapping timelines, collaboration with participants was not as close as it should have been to ensure the recommendations were valuable. A collaborative approach involving the participants throughout the research process could have contributed to more neutral results. Fifth, the study of the role of non-human actors in the rural fire prevention system was limited. The second round of interviews with the participants could have provided a better analysis of non-human actors' role and interdependencies with human actors.
Lastly, the challenges provoked by a lack of literature have unveiled an opportunity for deeper investment in researching and publishing more about the context of rural fires and systems thinking within the design field.

8.2. Further Research

This thesis identifies many avenues for future studies to improve rural fire prevention through a systemic approach. As stated previously concerning the limitations of this thesis, validating and critically evaluating the results by involving a broader pool of participants from governmental agencies to the private sector, local governments, landowners, forest producers and citizens in urban areas may be a first step toward expanding on this research. Additionally, co-creation sessions with the participants would contribute to a more engaging process and deeper analysis.

Although this thesis makes several references to actor-network theory and the role of non-human actors, it does not include an in-depth study of either; thus, further research is needed to examine rural fire prevention concerning both. When considering the non-human actors, it is essential to consider legislation and policies, in addition to the natural entities. Further research on case studies detailing the role of non-human actors in other contexts could provide different perspectives. Comparing case studies could benefit the field of design in understanding the role of non-human actors in rural fire prevention and disasters in general.

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