

Toward Wildfire Alternatives: Mitigating Wildfire Risk Through Landscape-Based Resilience

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COLOFON

Master thesis report
21/06/2023
Msc Architecture, Urbanism and Building Sciences
Urbanism track
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ACKNOWLEDGEMENT

I am profoundly grateful to all the individuals and institutions who have played a significant role in the successful completion of my master's project.

My first mentor, Nikos Katsikis, who I want to express my deepest appreciation to. His unwavering guidance and mentorship have been a beacon of light throughout this journey. From our weekly meetings, Nikos has consistently provided clarity and direction, ensuring that I stayed on the right path. His support and encouragement have not only alleviated stress and anxiety but have also empowered me to perform at my best. I am eternally grateful for his guidance and the profound impact he has had on my academic and personal development.

I am immensely grateful to my second mentor, Daniele Cannatella, for his invaluable assistance throughout the most challenging technical aspects of my research. His expertise and guidance have enabled me to overcome obstacles and take significant strides in pushing the boundaries of my project. I am indebted to him for his belief in my abilities and his relentless help to my growth as a researcher.

I would like to express my appreciation to my research studio, Transitional Territory. This remarkable group has provided a supportive environment and offered a clear and comprehensive roadmap for our graduation year.

To my dear friends and my boyfriend, thank you for your constant companionship. Your presence and support during moments of disappointment and self-doubt have been a source of strength. I am grateful for your attentive listening, valuable feedback, and always being my audience during presentations.

Above all, I would like to extend my heartfelt gratitude to my family—my parents and grandparents—for their unwavering support, both spiritually and emotionally. Their love, encouragement, and financial assistance have made it possible for me to pursue my studies abroad and experience two remarkable years in the Netherlands.

Finally, I would like to emphasize that this entire graduation year has been an invaluable treasure that will continue to inspire and motivate me in all aspects of life. The knowledge gained, the challenges overcome, and the connections made will forever hold a special place in my heart.

Thank you all for being an integral part of this significant chapter in my life.

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ABSTRACT

Wildfires are widely viewed as key evolving inputs of Mediterranean ecosystem. But anthropogenic climate changes and other socioecological recessions have transformed normal wildfire into megafire, especially under the intensifying challenges posed by agricultural abandonment and the rapid growth of tourism. So that the paradigm shift is needed since the suppression capacity has been increasingly overcome from the fire department. This research is aiming to integrate diverse landscape dynamics and fire regimes, to interpret the interactions between them and identify a series of heterogeneous fire typologies in the Mediterranean region (EU part) in order to support the application of landscape-based approaches. By classifying the land system dynamics into meteorologic, physiographic, biological and anthropogenic indicators (in relation with wildfire ignition and propagation), geographic information system based approaches and statistic analysis are applied to create diagnostic mappings.

The output of this analysis reveals several fire-landscape typologies and their spatial distribution in the Mediterranean, which improves the understanding of land system with natural crisis and is a basis for assessment of future changes under the regional climate, land use and land cover change and changes in management intensity. It also provides a evaluation and decision support tool in some specific locations for fire management, biodiversity protection and conservation of landscape values.

Thus, the downscale works of analysis are still needed for bridging the disconnection between the gap between Mediterranean research and landscape design practice. The prospective use cases must additionally account for the geopolitical and socio-cultural context of the region in question, as a means of establishing an integrated framework for fire management.

To advance the design perspective for mitigating the risks posed by wildfires, several key steps must be taken. Firstly, a toolkit must be developed based on defined fire-landscape typologies. These typologies represent landscape-based approaches that are tailored to the unique characteristics of each type of landscape. The toolkit will provide a range of strategies and design solutions for mitigating the risks of wildfires across different landscapes.

To apply these strategies in real-world scenarios, two key locations have been selected in the Iberian peninsula, namely northern Coimbra District (Portugal) and Marina Alta (a coastal comarca of the autonomous community of Valencia, Spain). These locations are identified as an interface with agricultural abandonment, and a dense littoralised tourism place, respectively, and are all typical fire-prone areas. By integrating the local context of each location with the selected approaches from the toolkit, resilient and adaptive scenarios for wildfire risk can be created. The design actions taken in these representative areas can subsequently be expanded and reproduced across a broad Mediterranean region. This approach allows for a comprehensive and effective mitigation of wildfire risks across a large geographic area while considering the unique characteristics and challenges of each landscape. The combination of landscape-based approaches with cultural and political context facilitates the development and implementation of effective strategies to mitigate the risks of wildfires and protect communities and ecosystems.



Fig. 1. Residents watch as a forest fire burns near Montana Alta on Spain's island of Gran Canaria, on August 18, 2019. Desiree Martin/AFP/Getty Images



Fig. 1. A farmer tries to save his goat during a forest fire in the village of Makrimalli on the island of Evia, northeast of Athens, on August 14, 2019. Angelos Tzortzinis/AFP/ Getty Images

1

PREPOSITION

Thesis Positioning

Study Area

Problem Context

Problem Statement

Global Urgency

Wildfire is one of the most important natural disturbance processes in global ecosystems, critical to ecosystem health, and an important cultural and land management tool for humans. However, an increasing number of adverse human activities significantly influence wildfire occurrence by affecting the state of surface vegetation and combustible materials, actively generating fires, and suppressing catastrophic fires, making wildfire one of the key topics in research on global change and its environmental impacts. Between 2003 and 2012, hundreds of thousands of fires occurred globally on average each year, burning a combined area of 6.7 × 108 hm2 of forest and causing direct economic losses of hundreds of billions of dollars. At the same time, fires destroy surface vegetation, release large amounts of greenhouse gases, particulate matter, and other trace gases, exacerbate soil erosion and air pollution, and are one of the key drivers of global climate change.

A catastrophic mountain fire broke out in Chongqing, China, in the summer of 2022. News from Chongqing told me that the mountain fires had spread so far into the city that residents could smell the smoke as they pushed open the balconies of their homes. It was the first time I felt that wildfires were no longer far from my life as a natural disaster. During that time, social media was flooded with harrowing videos and photos. This became the main interest and motivation for me to make wildfires the subject of my research. It was the same summer that wildfires were raging in the Mediterranean region. Algeria became the latest country to be hit by wildfires, after Greece, Turkey and Cyprus, and five people have lost their lives. Firefighters in various countries are still battling wildfires in hot and dry weather conditions. Perhaps the mountain lands will slowly recover from the abundant moisture, but looking back on these scorching days, we need to think: When will the next unusual heat and drought occur? And where will the next mountain fires ignite?

Nature is evolutionary, and the various elements interact with each other with regularity. Landscape diversity is rooted in the physical geography and ecological characteristics of the earth's organisms, and this diversity also reflects the variability of terrestrial environmental functions. The transformation of the landscape by humans in the industrial era has largely obscured the diversity inherent in the landscape itself, thus causing various conflicts between land use and the environment. The mechanisms and risks of wildfires, born as a result of the complex interplay of biological, meteorological, physical and social factors, are also changing. Therefore, it is from the perspective of landscape dynamics that the thesis understands the current fire landscape and wildfire risk. An attempt is made to find ways to manage and reduce wildfire risk through the mechanisms of interaction between landscape factors and fire regimes. Multiple risks, including wildfire, are taken into account in long-term land use planning. It is nearly impossible to completely eliminate the risks posed by wildfires, and communities around the world, have to learn to live with the risks of wildfires and plan appropriately to minimize the damage caused by them.

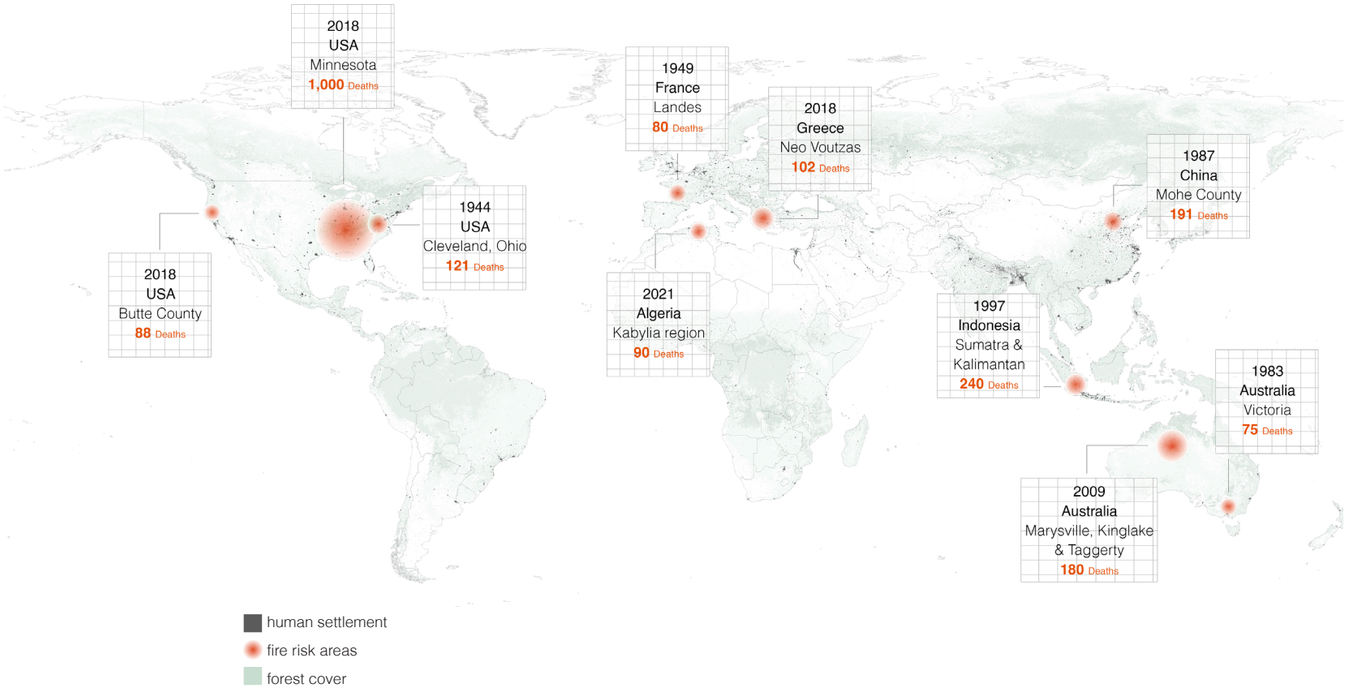


Fig. 1-1. Global fire risk history

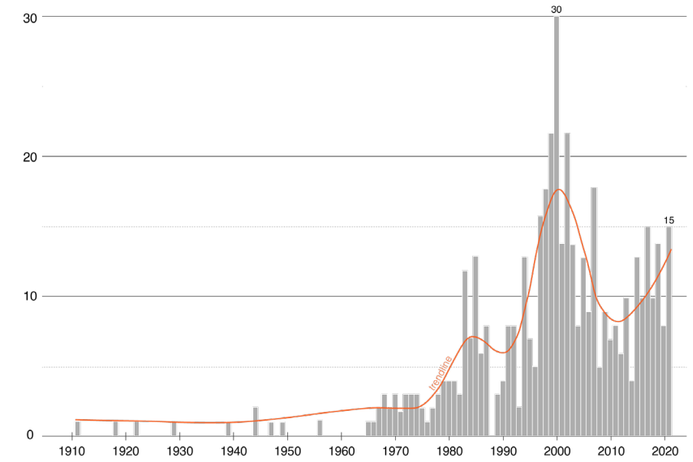


Fig. 1-2. Global fire risk, 1910-2020

Mediterrean Climate Regions

Mediterranean climate, also known as subtropical summer dry climate, is formed by the alternating control of the westerly wind belt and the subtropical high pressure belt, and is a type of climate in the subtropical and temperate zones. It is mainly distributed on the west coast of the continent at 30°-40° north and south latitudes, including the Mediterranean coast, the Black Sea coast, California, Perth and Adelaide in southwestern Australia, southwestern South Africa, and central Chile. The Mediterranean climate is hot and dry in summer and mild and humid in winter. The basic characteristics are: in summer, under the control of the subtropical high pressure, the airflow sinks, and there is little rainfall, and the precipitation in summer only accounts for 20-40% of the annual precipitation; in winter, the subtropical high pressure moves southward, and the cyclone activity in the westerly zone is frequent, so there is abundant precipitation, and the precipitation in the month with the most precipitation is more than three times of the month with the least precipitation, and the climate is mild and wet. Winter temperatures range from 5 to 10°C, summer temperatures range from 21 to 27°C, and annual precipitation is about 350 to 900 mm. The natural vegetation is dominated by drought-tolerant scrub.

The main natural vegetation growing in the Mediterranean climate distribution area is "subtropical evergreen sclerophyll forest", due to the local summer heat and dryness, vegetation in order to spend the summer smoothly, in the evolutionary process to adapt to the local climate, the leaves evolved into smaller and harder leaves, in order to reduce summer water evaporation, leaf surface less stomata, and covered with a waxy layer, the same can reduce water evaporation, such as oil, the oil, the oil, the oil, the oil. The same can reduce water evaporation, such as oil olive tree is a local endemic species. The subtropical evergreen sclerophyll forest, which usually contains more oil, is very flammable and has a strong combustion aid in case of fire.

The Mediterranean basin, the largest interland sea in the world, has the most typical Mediterranean climate zone in the world spread along its shores. It extends eastward as far as West Asia and even Tajikistan region in Central Asia. Considering the problem of uniformity of research data and related information, the scope of this study focuses on the European part of the northern side of the Mediterranean basin under the climate zone, dominated by the southwestern part of the Iberian Peninsula, the Apennines, the Balkans, and the Asia Minor Peninsula, with a winding coastline and numerous islands. A series of folded mountains, including the Pyrenees on the border between France and Spain, the Alps on the border between Italy and Central Europe, the Dinaric Alps on the eastern Adriatic coast, and the Balkan and Rhodope Mountains on the Balkan Peninsula separating the Mediterranean climate from the temperate climate of Central and Western Europe.

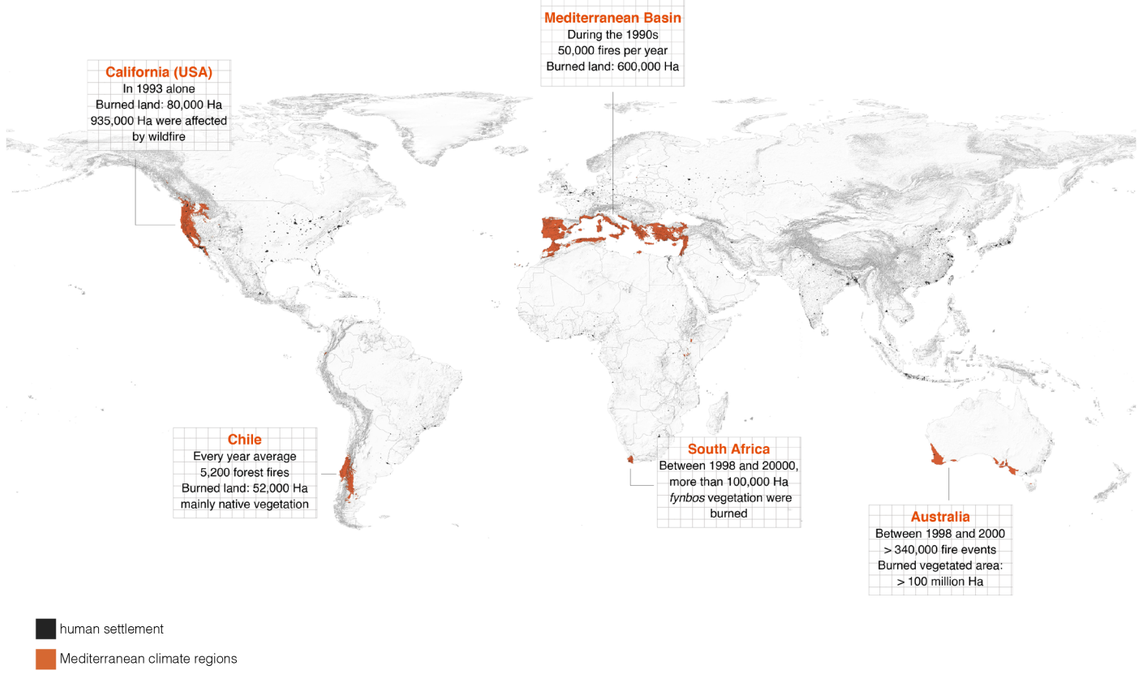


Fig. 1-3. Mediterranean Climate Regions (MCRs) & Fire risk

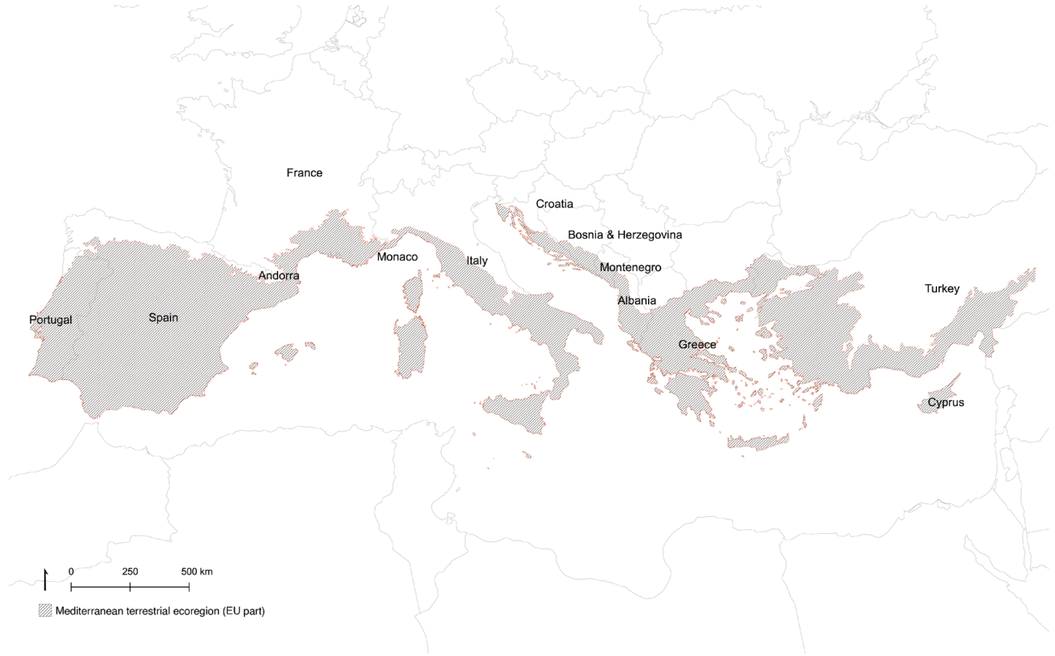


Fig. 1-4. Study area

Accumulation of Wildfire

By comparing the base statistics of the European Forest Fire Information System (EFFIS) before and after the decade, the frequency of wildfires in the Euro-Mediterranean climate zone has increased significantly. The result is not only an expansion of the affected area, but also an extension of the fire season. The latter now exceeds the traditional summer months. Exacerbated by the increase in fire risk conditions under existing climate change scenarios, it remains to be noted that 96% of these wildfires are caused by human actions. A comprehensive and coordinated approach to wildfire prevention and mitigation is therefore needed.

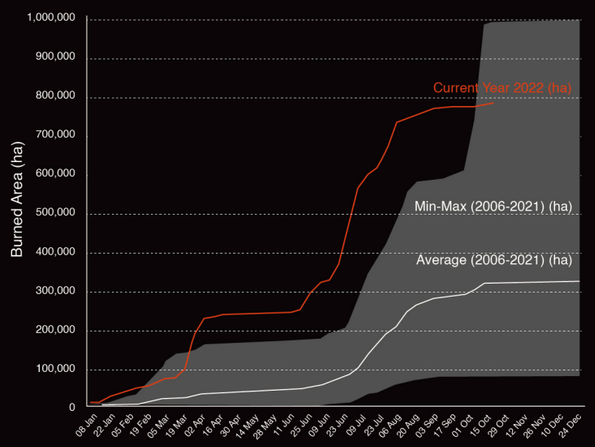


Fig. 1-6. Statistics of fire risk
Data source: EFFIS

2000-2011



2012-2022



Fig. 1-5. Accumulation of fire in Mediterranean Basin
Image Source: Forest Fires in EU (2000-2022) by Dick Vogel, https://esrinederland.maps.arcgis.com/apps/instant/slider/index.html?appid=62ababfde6364097b07c2c6ee8563bb5

Suppression-led Fire Management

The limitations of the existing firefighting means, which are mainly suppression-based, are very obvious as far as the technical aspects are concerned. The high frequency and intensity of summer wildfires puts the fire service in an unprecedented state of fire danger. Ground-based fire suppression such as opening containment strips and digging firebreaks are more common. They are based on the principle of clearing combustible materials in advance to stop the fire from spreading, and then waiting for an opportunity to extinguish it when it becomes smaller. The specific method depends on the terrain, wind, wind direction and other factors to decide. Aerial firefighting is a relatively effective way to fight forest fires, which means using aircraft to sprinkle water or some chemicals in the air to carry out firefighting operations. Firefighting aircraft are generally converted from helicopters and can carry up to 80 tons of water, which is equivalent to the capacity of more than 10 medium-sized fire trucks. In addition, artificial rainfall or direct blasting are also options for fighting forest fires.

However, with current firefighting technology, the speed of wildfire suppression is largely weather dependent and carries more of an element of chance and luck. The density of the forest results in an unimaginable amount of combustible material, and once the temperature is too high a fire tornado is formed, which will roll sparks into the sky and then eject them everywhere. At the same time, the ground temperature is also extremely high, is the forest firefighters commonly known as "ground fire", open fire is still far away from their own fire shoes but began to sticky, and then the surrounding vegetation suddenly on fire. As you can imagine, forest fires of a certain size are impossible to extinguish manually.

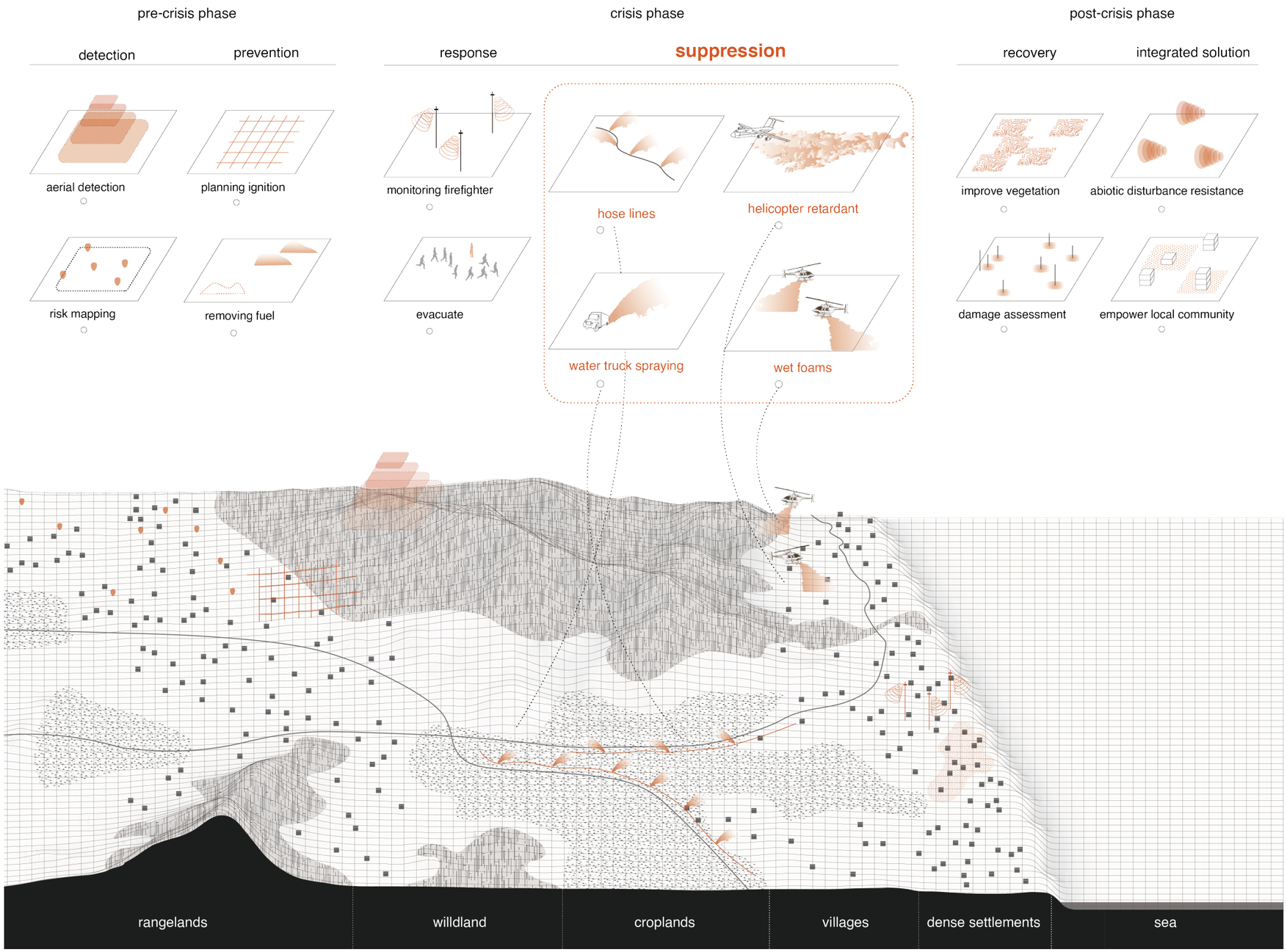


Fig. 1-7. Suppression-led fire fighting approaches

Expenditures on Fire Suppression

The cost of fire prevention is higher in European countries. 2019 fire prevention and fire fighting costs in each country are the highest in France, spending $640 million, with an average cost of $28.6 per hectare of forest for fire prevention. Italy, Turkey, and Germany also have higher fire prevention investments per unit area of forest, with annual fire prevention costs of $7.63, $8.51, and $7.12 per hectare, respectively. 2013-2020 average fire prevention investments per hectare of forest in Italy are $5.63, $5.51, and $6.12, respectively; 2018 and 2019 average fire prevention costs per hectare of forest in Turkey are $7.85 and $9.92, respectively.

Currently, direct response to wildfires in many European countries typically accounts for more than half of the associated expenditures, and rising each year, while less than 1% is spent on planning, prevention, preparedness, and recovery. European governments and ranchers lack the most basic wildfire prevention and control preparedness, including failure to install fire buffers and train firefighters, and fire prevention equipment is woefully inadequate. There is also no emergency response plan for emergencies due to a lack of adequate fire season response preparedness. Take the 2018 fire in Mati, a town in the Attica region of Greece, for example, the Greek government was slow to respond to the fire and residents were not evacuated in a timely manner. At the same time, uncontrolled local town construction and road planning also contributed significantly to the wildfires getting out of control.

"The current government response to wildfires is often putting money in the wrong place. Those emergency service personnel and firefighters who are on the front lines risking their lives to fight forest wildfires desperately need support." UN Environment Executive Director Inger Andersen said, "We must be fully prepared to minimize the risk of extreme wildfires; increase investments in fire risk reduction; work with local communities and strengthen the global commitment to combat climate change." Wildfires disproportionately affect the world's poorest countries. Even when the flames are extinguished, the effects last for days, weeks and even years, hindering progress toward the Sustainable Development Goals and deepening social inequality.

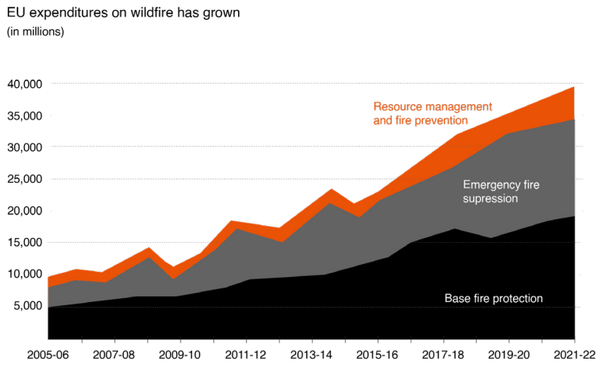


Fig. 1-8. EU expenditures on fire fighting
Data source: EFFIS

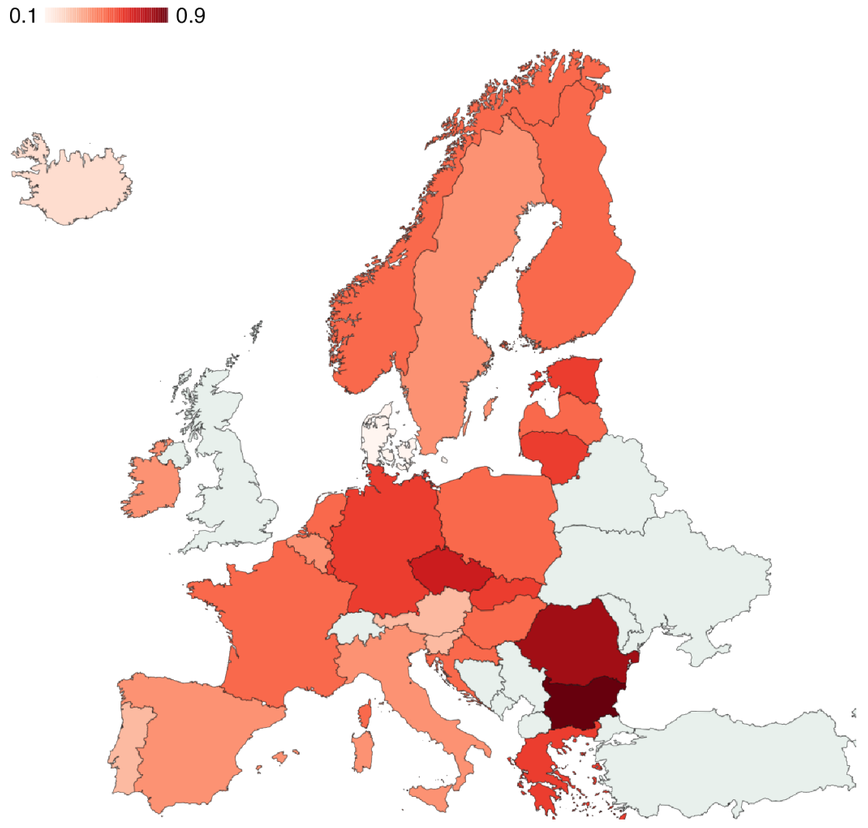


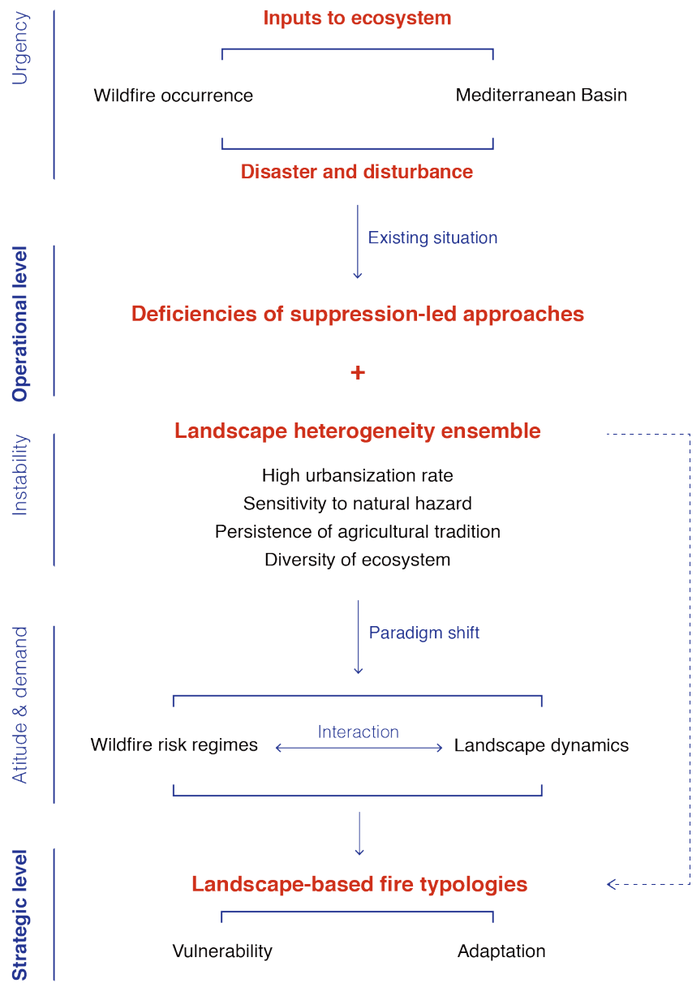
Fig. 1-9. Government expenditures on fire-protection services (as part of total expenditures)
Data source: Eurostat

PROBLEM STATEMENT

Historically, wildfire are widely reviewed as key inputs to Mediterranean ecosystems by stimulating regeneration, where humans and fire can form a co-evolving system. But current alterations, mostly anthropogenic factors, have led to strong changes in fire regimes. These trends indicate longer and more intense heat and drought with rising frequency of unprecedented wildfire occurrence which has already converted wildfire into a major landscape disturbance factor in the Mediterranean basin. The burning cycle leads to large burned areas invading from forest to non-forest surface with species dispersing, losses of human life and property, damaged infrastructure, and destroyed ecosystems, etc.

Although such catastrophic events have been apparent and partly-solved for some time, contemporary wildfire management policies in Mediterranean climate regions have continued to focus almost entirely on short-sighted fire suppression-led reaction. They are seeking to minimize burned area in the short-term during the crisis-happening phase, treats fire as delivering negative impacts, and react to public opinion with ever-expanding investment in firefighting capacity, while failing to adequately and proactively address the underlying causes of the problem. The high urbanization rate of most bordering countries in Mediterranean Basin, coupled with a widely known sensitivity to natural hazard, the persistence of old agricultural practices, and the diversity of ecosystems form a high and local complex heterogeneity landmark ensemble. Events such as political instability also quickly modify human–environment balances with large-scale spatial implications.

The paradigm shift and pragmatist approach are urgently needed when confronted with the demand to coexist with wildfire in Mediterranean Basin where is a privileged area for a broad scale study and for observing and understanding interactions between landscape dynamics and wildfire risk constructs. The potential approaches then in reducing territorial vulnerability and facilitating adaptation of wildfire can be formulated in a holistic perspective through pyrogeography considering both ecosystem and socioeconomic aspects.



2

METHODOLOGY

Theoretical Framework

Relevance Fields

Research Questions

Methodological Framework

Research Framework

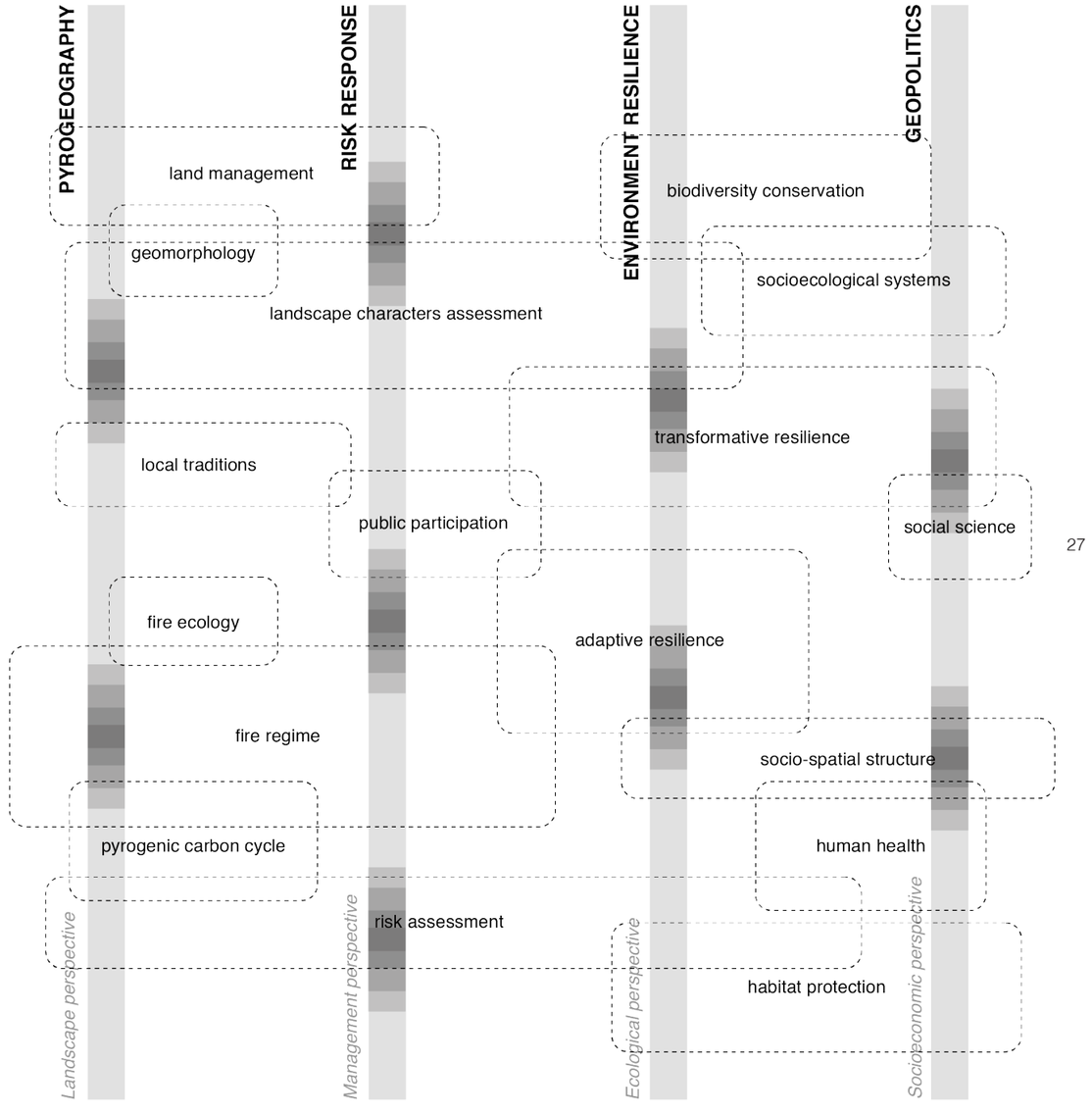
THEORETICAL FRAMEWORK

Theoretical framework is the structure that holds theories of pyrogeography, risk response, environment resilience and geopolitics to support the project of Transformative Firescape, correspond to the perspectives of landscape, management, ecological and socioeconomic domains. Each of the domains has branches of sub-theories. They are interrelated together and shape the theoretical framework.

The first part of pyrogeography provides the emerging discipline that illustrate complex direct and indirect effects of fire on landscape, uniting biological, atmospheric and social aspects on fire. Pyrogeography provides a global and evolutionary perspective of fire activity based on the recognition that landscape fires are an ancient, fundamental component of terrestrial ecosystems. It supports the necessary framework to understand fire in the Anthropocene, including the management of pyrogenic regimes, conservation of biodiversity, provision of ecosystem and protection of human life. Pyrogeography captures the totality of anthropogenic impacts on the Earth system following the Industrial Revolution. The fields of biological, atmospheric and social from pyrogeography also provide ideas for classifying complex landscape dynamics.

Risk response here does not refer to emergency response in the sense of dealing with disasters, but rather is a comprehensive disaster risk management that includes both vulnerability and exposure reduction components. It involves activities related to: prevention, mitigation, transfer, and preparedness. The details will be explained in the theory section. The part of environmental resilience illustrates the ability of resistance, self recovery and regeneration of ecosystem when it encounters the external disturbance. Both risk response and environmental resilience help to frame the part of promoting the adaptation to protect communities and natural habitats through protecting and restoring ecosystems and building defenses, warning systems and resilient infrastructure and agriculture to avoid loss of homes, livelihood and human lives from wildfire risk.

The final part of geopolitics helps balance the relationship between strategic operation and social stability. In one way, it discusses about the establishment and operation of adaptive strategies and policies, coordinating the relationship between individual, organization and nation within them. On the contrary, just as natural-resource insecurity can cause displacement and vulnerability, effective natural-resource management and strategies can support conflict resolution and sustainable economic development.



Pyrogeography

An emerging discipline that provides the intellectual framework to understand the complexity of fire on Earth is “pyrogeography”. Like biogeography, this approach spans geographic scales from the local to the global, has an evolutionary frame, and thus has a geological dimension. And, like other geographic disciplines, pyrogeography has a clear commitment to understanding the interrelationships between cultures and their environment.

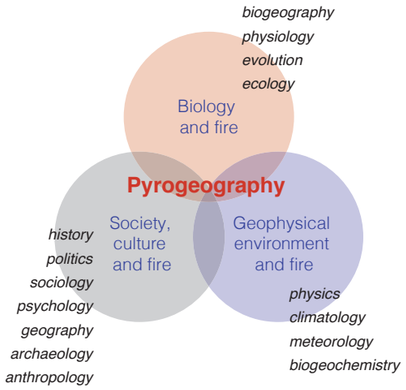


Fig. 2-1. Framework of Pyrogeography

The field of pyrogeography also provides an intellectual arena for consideration of fire in a global context by enabling currently isolated scholars studying varied aspects of fire to add value to each other's work. Such a synergy of perspectives is crucial given the increasing evidence that current fire management paradigms are unable to cope with the manifold challenges associated with (a) an increasing vulnerability of human settlements caused by two-directional migration trends—by an urban fringe expanding into fire-prone vegetation (the so-called wildland-urban interface, WUI) and the rural exodus leaving behind abandoned and increasingly flammable land-use systems, (b) increasingly severe fire weather associated with global climate change, (c) more stringent air quality guidelines to regulate wildfire smoke, (d) concern about the impact of fire on the global carbon balance, and (e) increasing tension between biodiversity conservation and fire management objectives.

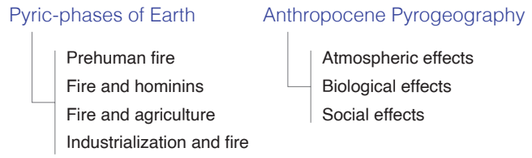


Fig. 2-2. Trasition of fire activities

The future issues will be the followings: a) Understanding the spatial and historical variability of the core components of fire regimes (area, intensity, severity, season, frequency of burning) remains rudimentary for most biomes on Earth. b) Detailed descriptions of fire regimes and their biogeochemical effects demand coordinated cross-disciplinary research collaboration. c) The development of a way of better quantifying the direct and indirect economic costs of fire disasters will improve the cost-benefit analyses of contrasting fire-management approaches at regional and international scales. d) Knowledge sharing among fire managers is embryonic and demands international leadership. e) Incorporation of fire effects into Earth system models is a pressing research challenge given the risk of underestimated powerful positive feedback on climate change. f) Broader appreciation of the pervasive and complex beneficial and deleterious influences of fire on the environment must be established among policy makers and the global community.

Risk Response and Management

Historically, dealing with disasters focused on emergency response, but towards the end of the 20th century it was increasingly recognized that disasters are not natural (even if the associated hazard is) and that it is only by reducing and managing conditions of hazard, exposure and vulnerability that we can prevent losses and alleviate the impacts of disasters. Since we cannot reduce the severity of natural hazards, the main opportunity for reducing risk lies in reducing vulnerability and exposure. Reducing these two components of risk requires identifying and reducing the underlying drivers of risk, which are particularly related to poor economic and urban development choices and practice, degradation of the environment, poverty and inequality and climate change, which create and exacerbate conditions of hazard, exposure and vulnerability. Addressing these underlying risk drivers will reduce disaster risk, lessen the impacts of climate change and, consequently, maintain the sustainability of development.

Disaster risk management involves activities related to:

Prevention: Activities and measures to avoid existing and new disaster risks (often less costly than disaster relief and response). For instance, relocating exposed people and assets away from a hazard area.

Mitigation: The lessening or limitation of the adverse impacts of hazards and related disasters. For instance, constructing flood defences, planting trees to stabilize slopes and implementing strict land use and building construction codes.

Transfer: The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party. For instance, insurance.

Preparedness: The knowledge and capacities of 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. For instance, installing early warning systems, identifying evacuation routes and preparing emergency supplies.



Fig. 2-3. Innovation curve - from destructive to regenerative approaches.
Image source: UNDRR 2019

Landscape Typologies

A characteristic of landscape research has been the many attempts to make sense of the field of studies. Typology refers to types and classes. Planners, geographers and others often treat landscape as a feature to be classified and mapped, similar to the treatment of soils, landforms or vegetation. The credibility of the method typically relies on the reputed expertise of the individual applying it. They establish certain assumptions (e.g. that mountains and rivers have high landscape quality) and evaluate the landscape accordingly. A notable example of this approach is Meeus (1995), who developed the first approach towards a European landscape map by qualitatively combining information from national typologies, maps and scientific expertise. In several national typologies this method was also used, ranging from pure expert-based interpretation (e.g., Hungary; Márton, 1989) to the combination of thematic maps to form a composite map (e.g., Lithuania; Kavaliauskas & Veteikis, 2006

Landscape structure is scale-dependent and refers to the spatial heterogeneity of the landscape, for example the arrangement of land uses or cropland fields, or the prevalence of linear landscape elements. On a regional scale, landscape structure is closely linked to ecosystem services provisioning, especially for a number of regulating services (e.g. erosion prevention, pollination) and cultural services (e.g. landscape aesthetics and tourism), as well as the biodiversity-friendliness of agricultural landscapes. Land cover, land management, and landscape structure are also central features differentiating landscapes with exceptional cultural heritage and values. Cultural landscapes – a term adopted in the 1990s by international bodies as a conservation category – often have relatively high structural complexity, traditional, low-intensity landscape practices and historical elements, altogether contributing to the often exceptional value of these landscapes.

Europe is an interesting case for such analysis, as landscape characterization and assessment is a key aspect in European landscape research. To better understand the large spatial of heterogeneity of landscapes across Europe, and to monitor changes in landscape functions and values, it is necessary to reduce the complexity in landscapes to manageable units that could be an interesting target for policy-making at the European scale. Several initiatives have sought to identify and classify landscapes in Europe since the 1990s (Paleo, 2010), including the Pan-European Biological and Landscape Diversity Strategy (PEBLDS, Council of Europe 1996) and the European Landscape Convention (ELC, Council of Europe 2000).

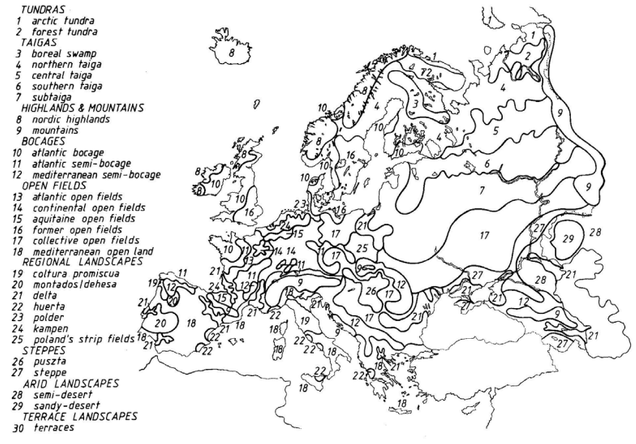
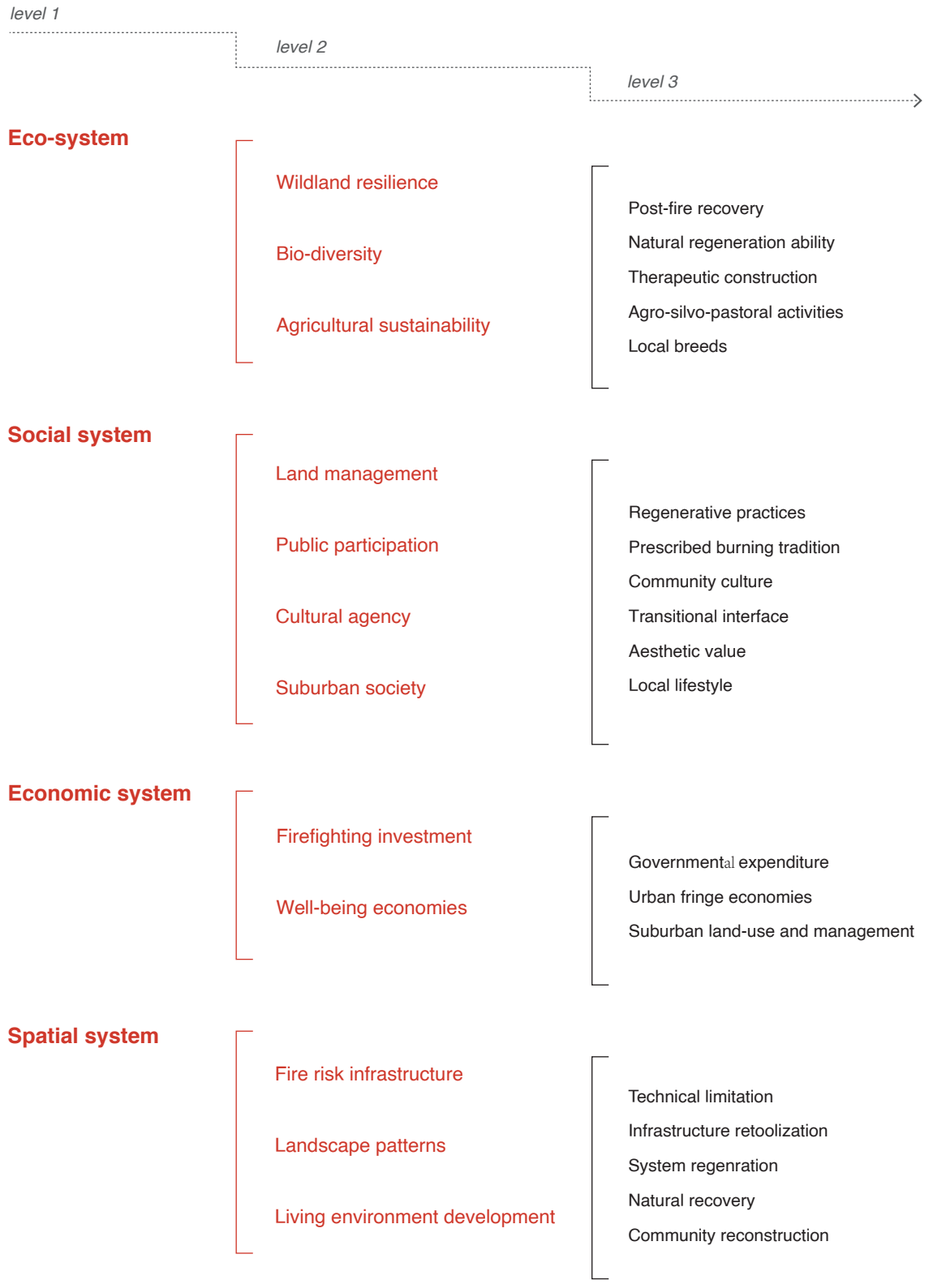


Fig. 2-4. Pan-European landscape types. Meeus, 1993.



RESEARCH QUESTIONS

Research question

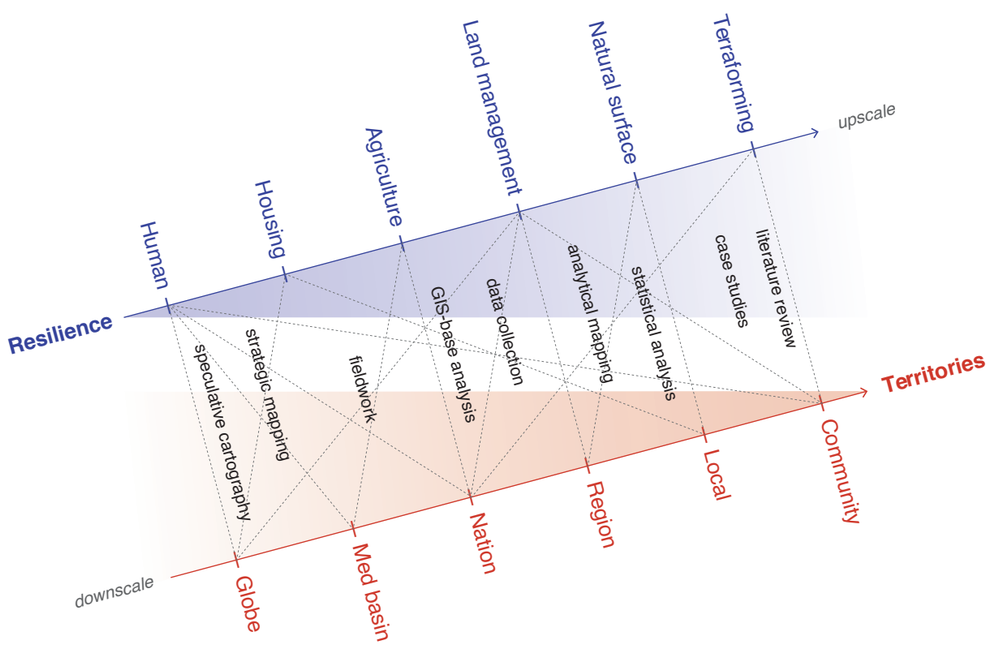
Under the intensifying challenges posed by **agri-cultural abandonment** and the **rapid growth of tourism**, how to facilitate territorial **adaptation and resilience** to wildfire risk by establishing the **landscape-based fire typologies** in **Euro-Mediterranean Basin**?

Sub-questions

- What are driving forces of wildfire regimes especially in the aspect of agriculture and tourism and how can they reshape and transform our territories?
- How to identify and characterize the landscape dynamics in the Euro-Mediterranean Basin?
- What are the socioeconomic and cultural values of these fire typologies?
- How to develop adaptive and resilient strategies in view of landscape-based fire typologies?
- How these typologies and strategies are applied in a multiscalar way (from Mediterranean to local scale) ?

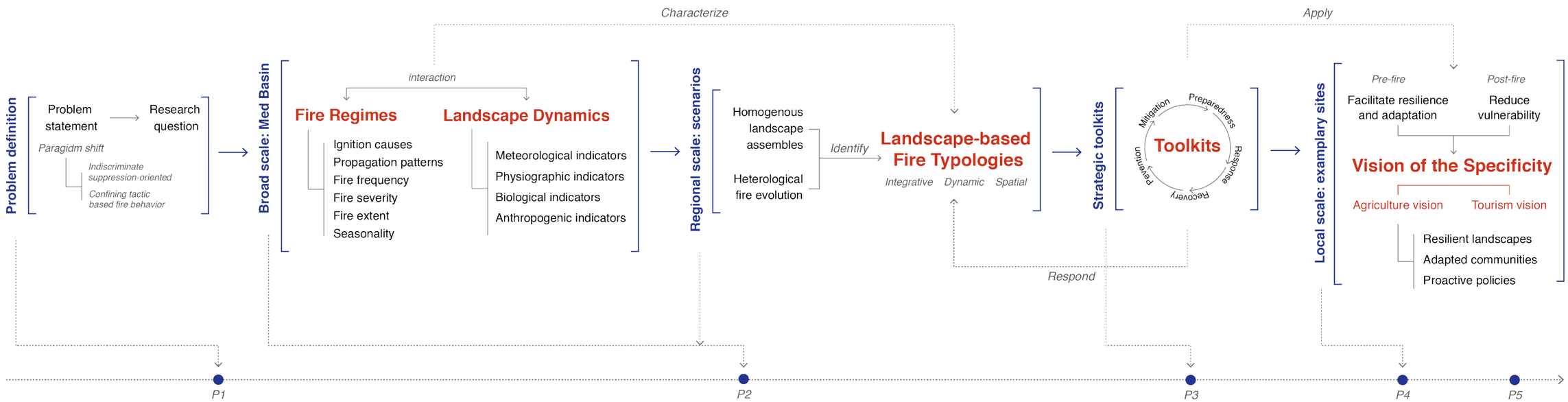
METHODOLOGICAL FRAMEWORK

This framework illustrates the methodology of bidirectional cooperation of territorial research and resilient design, varying and operating in multi scales. It integrates the down-scale territorial investigation and up-scale resilient intervention. The core of investigation lands mainly in the Mediterranean Basin scale in order to understand the interaction between fire regimes and landscape dynamic factors. Within this scale and path, the result goes to a set of landscape-based fire typologies. Thus, the strategies in a comprehensive and macroscopic perspective are reflected in the toolkits aiming to these fire scenarios. It provides a systemic approach for analysing sites, developing place-based visions, supporting design processes and help monitor the state of fire risk. The design part locates in regional and local community scale. It bases and represents the clusters of fire scenarios, illustrating the application of toolkits and context-specific design strategies.



The research framework combining with research timeline are supported by five parts: the fire regime and landscape dynamics interaction, definition of landscape-based fire typologies, the puzzle language that responses to the scenarios and the design vision in a transection scale. The whole structure elaborates the research narrative and the final design vision. The main analytical results are called Landscape-based fire typologies which is a set of landscape typologies in Mediterranean Basin clustering by the study of relationship between of landscape elements and fire regimes. The toolkits in general, as well as the puzzle language, are corresponding to each typologies. They support a systemic approach for the design site. Finally, the design practices will be reflected in a transection site showing the cluster of the typologies. It contains not only the toolkit application, but also reflects the context-specific design on the community scale.

RESEARCH FRAMEWORK



3

FIRE ANATOMY

Tradition of Fire

Pyrogenic Carbon Cycle

Propagation Patterns

Landscape Approaches

Fire Use & History

The free use of fire was a turning point in the development of human technology and cultural evolution, allowing the size of human groups to expand significantly, and the range of habitation gradually expanded to temperate zones and even cold zones. Gradually, the power of fire eluded primitive humans, and the consciousness of fire worship gradually took shape. The worship of fire was practiced in both the Eastern and Western worlds, and many religions and customs of fire worship were developed. Wildfires have been a powerful tool for space exploitation used by humans for nearly 10,000 years, using fire to maintain hunting clearings and clear the ground for grazing or farming. These disturbances have had a major impact on many ecosystems, changing land use types and promoting biomass accumulation.

In the 16th century, with the growth of the world economy, the production of fuel wood was not sufficient to meet the needs of people, especially for industrial production. As a result, the development of the coal industry and technological innovations in production drove the fuel transition. After the Industrial Revolution, humans began to use external energy sources, such as fossil fuels, significantly to increase the speed and scale of production. At the same time, the potential for global temperature rise was laid.

In the figure Anthropogenic fire regime and burning belt, the outer circles show the different purposes and percentages of human use of fire in four eras: pre-industrial, transition, industrial, and post-industrial. The red dots overlaying the image represent the regions where burning fires were detected using the tropics. Africa appears to have the highest concentration of fires. These are most likely agricultural fires. Farmers often use fire to return nutrients to the soil and to remove unwanted plants. While fires help improve the quality of crops and forage, smoke from fires can also reduce air quality. In other places, such as North America, fires are mostly wildfires. In South America, particularly Chile, an alarming number of wildfires have occurred in recent years. In Brazil, fires include both wildfires and human arson to clear debris from a growing season on farmland. Fires are also often used during drought periods in Brazil to cut down forests and clear them for livestock or other agricultural or extractive uses. Australia's hot, dry summers mean a longer fire season, and the spread of urban to forested areas will put more people at risk of fire outbreaks.



Fig. 3-1. Burning & hunting
Image source: https://askabiologist.asu.edu/human-fire-history

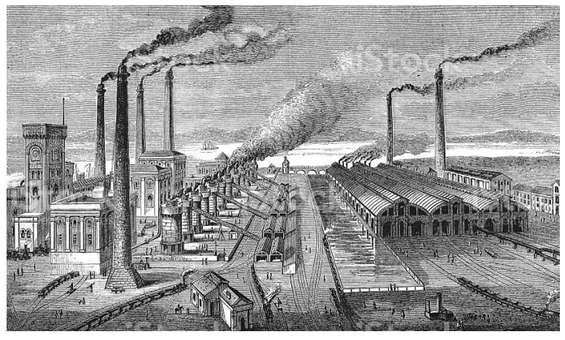


Fig. 3-2. Fuel combustion in the industrial age
Image source: https://www.istockphoto.com/nl/vector/barrow-hematite-steel-works-gm517470919-49228594

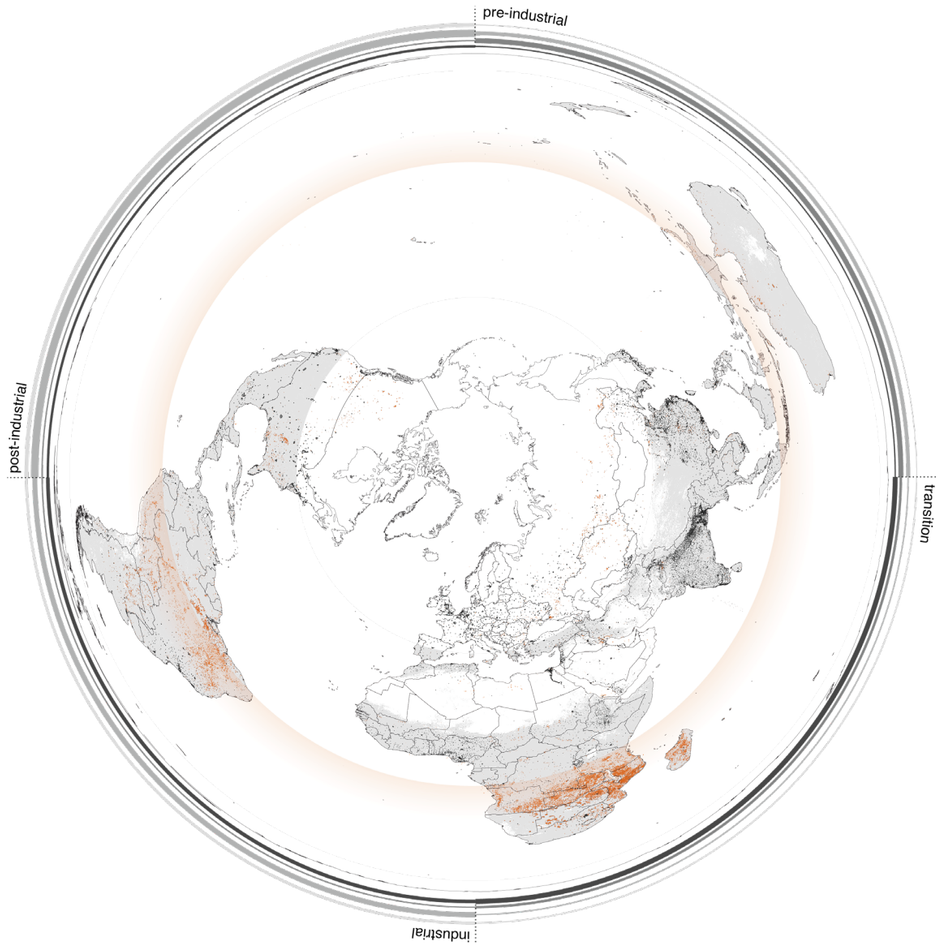


Fig. 3-3. Anthropogenic fire regime & burning belt

Fire in Global Carbon Cycle

The geochemical cycle of carbon controls the transport of carbon between sediments at or near the surface and the atmosphere, biosphere and oceans. The vast majority of carbon in nature is stored in the rocks of the earth's crust, and the carbon in the rocks enters the atmosphere and oceans after decomposition by various natural and anthropogenic chemical interactions, while dead organisms and various other carbon-containing materials keep returning to the earth's crust in the form of sediments, thus forming part of the global carbon cycle.

Pyrogenic carbon (PyC; includes soot, char, black carbon, and biochar) is produced by the incomplete combustion of organic matter accompanying biomass burning and fossil fuel consumption. PyC is pervasive in the environment, distributed throughout the atmosphere as well as soils, sediments, and water in both the marine and terrestrial environment. The physicochemical characteristics of PyC are complex and highly variable, dependent on the organic precursor and the conditions of formation.

As long as there has been reduced carbon at Earth's surface, sufficient atmospheric oxygen, at least periodically dry conditions, and a source of ignition, PyC has been produced in the terrestrial biosphere. Evidence of the operation of a PyC cycle in the past can be found in the occurrence of PyC in the sedimentary record. This record suggests dramatic changes in the production of PyC that can be linked to changes in the main drivers of fire activity—atmospheric oxygen, climate, vegetation, episodic catastrophic events, and, more recently, human activity.

Wildfire is an important climate-driven disturbance in terrestrial ecosystems, and is also influenced by human activities (e.g., anthropogenic fire sources or fire suppression). Spatial and temporal variability of CO2 released by fire affects the global carbon cycle and has feedback effects on the climate system.

However, we know little about whether future changes in fire activity will exacerbate or slow climate change. Previous studies have shown that two types of feedbacks are involved in the coupled fire-carbon cycle (vegetation)-climate system: on the one hand, warming may intensify the occurrence of future fires, which release more CO2 into the atmosphere, thus increasing global warming and forming a positive feedback between fire-carbon cycle-climate;

On the other hand, due to human activities (e.g., farmland expansion, urbanization, etc.), global fires have recently shown a decreasing trend, and the reduced fires will, to some extent, slow down the global warming trend by increasing terrestrial carbon sinks, creating a negative feedback process. These two opposing feedback mechanisms co-exist and show significant regional differences in terrestrial ecosystems, and their net effects may change with future changes in climate and human activities.

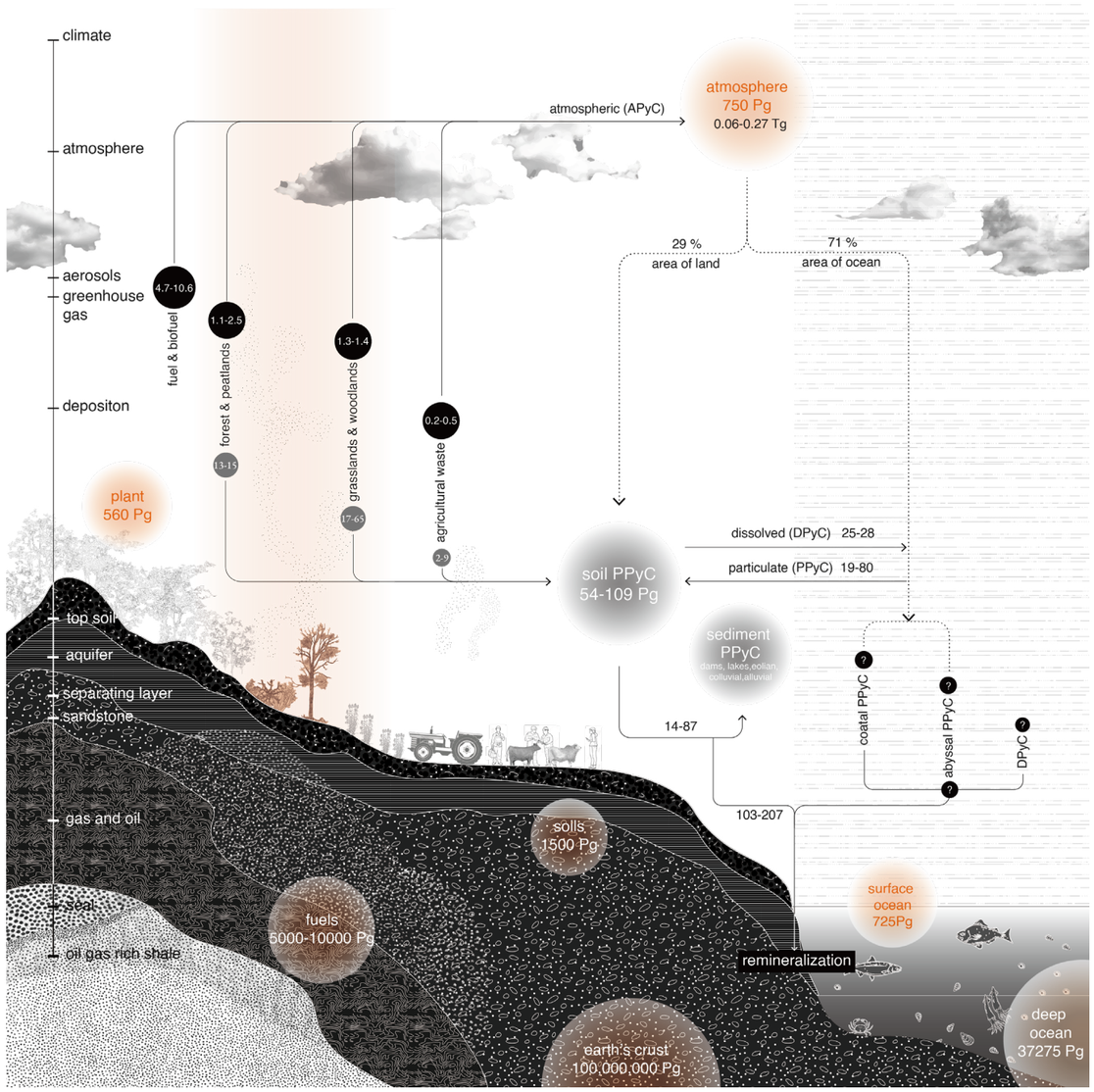


Fig. 3-4. Pyrolytic carbon in global carbon cycle

Propagation & Landscape dynamics

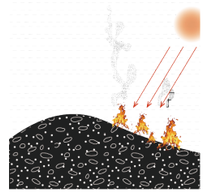
Wildfire propagation patterns are influenced by changes in the landscape environment. With the advancement of multi-metric quantification and multi-scale modeling techniques for wildfires, the relationship between wildfire systems and their drivers and ecological-environmental effects has been increasingly studied.

Vegetation fires can be compared to the spread of fire lines through the vegetation canopy. The rate of movement of the flame front, often referred to as the rate of spread, varies according to three parameters: the structure of the vegetation (dieback, grass, brush, forest, etc.) and the state of the vegetation (water content), the surface topography (flat, sloping, rising or falling relative to the flame path), and the weather conditions (wind, temperature, relative humidity of the surrounding air). These three elements (fuel, terrain, weather) are compared to the three key elements in the fire triangle (fuel, oxygen, heat) used in fire safety to explain the elements required to start a fire on combustible materials.

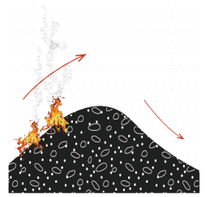
Burning intensity varies significantly depending on the nature of the fire, ranging from a few hundred kW/m for an apathetic burn to nearly 104 kW/m for a forest fire. For example, the catastrophic wildfire that occurred in the Melbourne, Australia area in February 2009 (Black Saturday) had an observed intensity of about 80,000 kW/m; propagation velocities ranged from 1 to 3 m/s, and smoke plumes reached 15 km high (bottom of the stratosphere). Comparing wildfires in the boreal forests of Eurasia and North America, systematic differences in fire intensity, forest damage, and fire resilience of different tree species can be observed between the two regions.

The propagation patterns of vegetation fires documented in the literature can be divided into two typical scenarios: (I) "wind-driven fire" literally means that the wind drives the fire to move and spread; (II) "plume-dominated fire" means that the plume mainly influences the fire spread. In different modes, the interaction between the fire line and the real environment results in different outcomes. In the first model, when gases flow from the fire front to the front, it helps vegetation to be ignited by thermal convection, while in the second model, when the fire is strong enough to draw fresh air in front of the front, the energy transfer between the flame and vegetation is basically through thermal radiation.

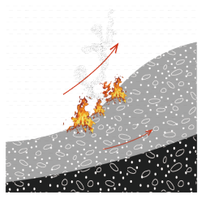
Ecological environment



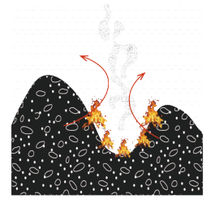
Aspect: more radiation for the south-facing slope



Slope direction: fire moves faster uphill than downhill



Slope angle: fire moves faster in the steeper slope



Convective wind: fires are promoted in the canyon zone

Temporal effect

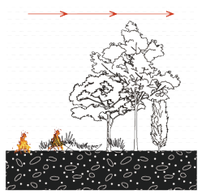


Afternoon: heated and dried up fuels lead more ignitions

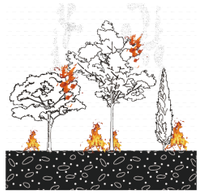


Night: fire spreads faster with more wind at night

Fuel bed



Surface friction: bare soil >grassland>forest>wet-land>water



Density: relatively low-density fuels have more surface area and oxygen



Texture: propagation pattern depends on the vegetation types

Fig. 3-5. Propagation patterns of wildfire

Fire Embankment

Fire embankment was introduced to enforce the fire resistance of open spaces and expanded roads in the city. It can be used to protect adjacent district and offer recreational space for citizens. The size of an embankment is usually about 20-30m width, 7.2 meters high, and it had plantation of top. In some cases, it can also be called fire resistant berm. The berms perform better than convential buffer in case of fire emergency, and it also provide urban park on its residential side slope for daily use.



Fig. 3-6. Fire embankment, in Hakugin-cho, Japan

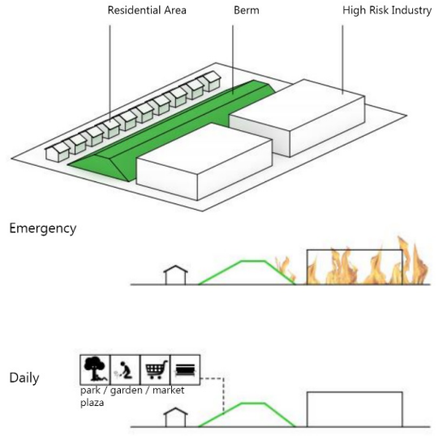


Fig. 3-7. Proposed embankment

Firebreak Network

The basic principle of a firebreak network is to split continuous forest areas (where a lot of fuel is built up) into smaller patches separated by vegetation-free strips in order to prevent large forest fires. The main purposes are:

1) to interrupt the continuity of hazardous fuels across a landscape to decrease the area affected by fires;

2) to provide areas where fire fighters are protected and can work more efficiently;

3) to slow down a fire, to reduce the fire intensity and caused damages;

4) to provide strips where fuel management is facilitated.

This parcelling aims in limiting the burnt area to a maximum of 6000 ha. This technology is also applied in other countries, e.g. Portugal, South Carolina or South Africa.

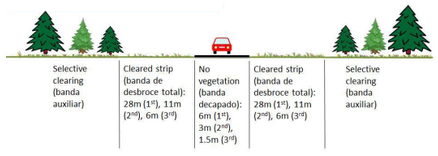


Fig. 3-8. Section of firebreak



Fig. 3-9. Ayora, Valencia, Spain
Image source: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1592/

Functional Greenbelt

The greenbelt plays and important role in serving as strategic locations for wildfire defense, acting as natural wildfire buffers to create separation from wildlands, increasing overall wildfire resilience through land stewardship and providing wildfire-resistant green spaces inside and surrounding neighborhoods.

It reiterates the demand for future growth to be channeled within existing cities and towns to address the housing crisis while avoiding new development in the high wildfire risk areas. And it emphasizes the need for enhanced land stewardship of greenbelts to unlock their wildfire-resilience benefits with sustainable funding allocated for permanent protection and longterm management.

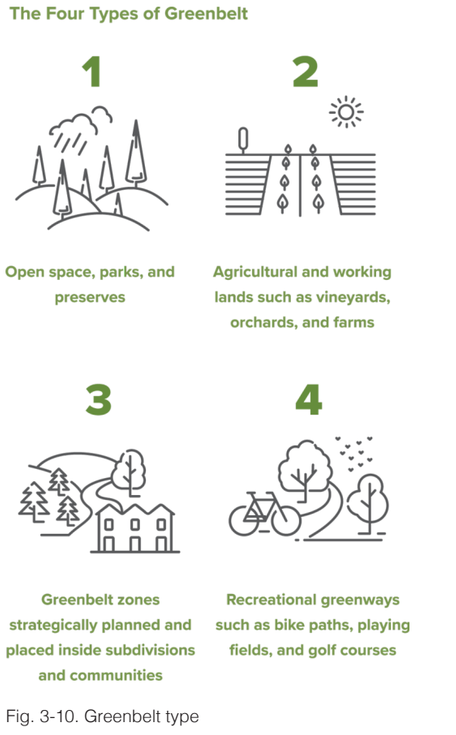


Fig. 3-10. Greenbelt type



Fig. 3-11. Fire in Sonoma County, USA. Image by George Rose

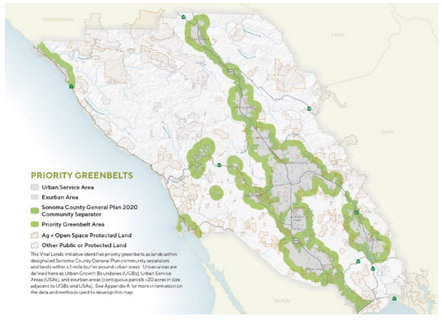


Fig. 3-12. Vital Lands Initiative: Priority Greenbelts Courtesy of Sonoma County Agricultural Preservation and Open Space District

Hydrology System

Hydrology infrastructure is effective in protecting people and developing post fire vegetation resprouting. The water ditches and stone walls are ready-made and sustainable structures to be integrated in future fire pattern controlling.

Prescribed / Conctrolled Burning

Prescribed burning is the careful application under specific fuel, low temperature and weather conditions to meet specific resource management objectives and long-term management goals. It is a used in active fire suppression where prescribed burning operations are based on the use of low-intensity fires that aim at reducing fuel loads, promoting medicinal plants or regalia materials, providing fertilizer to the soil and therefore reducing the risks of high-intensity fires.



Fig. 3-13. Controlled burning, photo by Kelly Bougher

Prescribed burn managers try to find a natural firebreak, such as a creek (1), from which they set down a wind backfire (3). This creates a blackline (2) at which the spot-headfires (set in successive ignitions (5, 6, 7) will stop. Crew members patrol a handline (4) to ensure that the burn is contained.

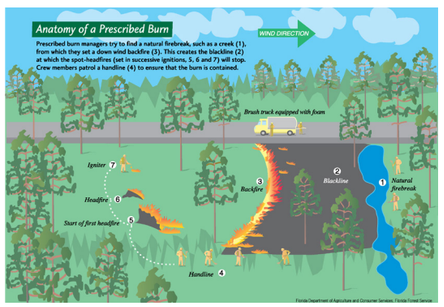


Fig. 3-14. Anatomy of a prescribed burn
Image source: https://www.fdacs.gov/Forest-Wildfire/Wildland-Fire/Prescribed-Fire/Anatomy-of-a-Prescribed-Burn

Fire-retardant Vegetation

Vegetation change is to remove invasive species maintain large fire resistant native species. for example, amongst the proposed strategies to offset the climate-driven fire risk is the introduction of broadleaf species into dense-coniferous landscapes so as to decrease the intensity and rate of spread of future wildfires.

The most flammable trees are Cyprus, pines, eucalyptus, some of which have been known to explode once engulfed in flames. Tree selection is a crucial factor as the right ones may slow and/or cool the fire down. There are three core reasons that we put fire resistant trees to make them safer;

1) The fire retardant tree is a physical heat barrier to the heat blast coming through.

2) The fire retardant tree acts as a green shield and stops the embers. As the fire comes through fine embers fly up, and the trees that resist fire will help stop those embers from getting through.

3)Many trees will actually stop the fire from moving through because the amount of moisture in the leaf tissue of the plant is enough to stop the fire.



Fig. 3-15. The yucca, shown blooming amid scorched trees and vegetation along the Angeles Crest Highway, is one of several fire-resistant plants that work well in California gardens. (Allen J. Schaben/Los Angeles Times)

Water Storage Tanks

Fire protection water storage tanks provide fire fighters, residents and businesses with water in locations where the demand for water can exceed the available municipal water supply. This is especially true for suburban or rural areas served by wells, with limited delivery, or locations prone to wild fires.

Fire fighting water storage tanks have multiple options that can supply fire hoses during an emergency. Corrugated steel water tanks with hydrant outlets are an economical option for commercial, industrial, or municipal fire fighting water storage. Open top onion tanks and folding frame tanks are portable water storage tanks that fire fighters can easily transport, set up, and fill at remote locations.

the Mediterranean mountainous forests are the best place to conduct the experiment, because of the steep terrain which they possess that helps gravity. One just has to construct water tanks over hill sides and nearby a road. So, during the “dangerous” hot days one can let the water of the water tanks flow downhill in order to increase ground humidity.

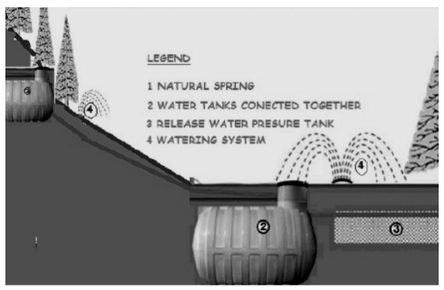


Fig. 3-16. Preventing system for forest areas

Strategic Management Points (SMPs)

Characterising the fire types of a region allows to identify the operational opportunities for the suppression systems during a large wildfire in a specific mountain range through identifying the key points where infrastructures need to be created or maintained to limit the extent of large wildfires. These points may resemble suppression opportunities, and are called SMPs.

SMPs provides stand-level and spatially explicit quantitative results is essential to identify high emission hotspotsand redirect management efforts at sufficient intensities.

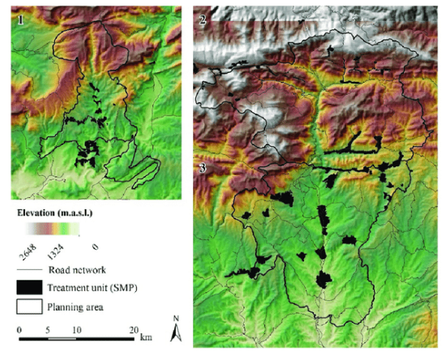


Fig. 3-17. Location of the treatment units or strategic management points (SMPs) in the different planning areas. The design was based on expert criteria and provided bythe Bombers GRAF team of the Fireghters of the Catalan Government.

4

MONOGRAPHS

Lines of Inquiry

Matter

Topos

Habitat

Geopolitics

Based on theories of pyrogeography and landscape assessment, the monography of “lines of inquiry” dedicate to the investigation on fire anatomy in four countries in the Mediterranean region (EU part). It is a hybrid of representation of fire-landscape interaction in different areas that are visualized following four topics: matter, topos, habitat, geopolitics. All of these exploration builds the foundation of upcoming fire-landscape typologies characterization.

Matter: The atmospheric conditions in northern Attica in Greece includes the metropolitan of Athens and its preurban areas, reflecting the fire evolution process under the climate and environmental change. By composing the sectional stratification of wind currents, temperature, humidity and ground surface realities, the propagation patterns of wildfire shows among atmospherically relations.

Topos: The increasingly disturbance of wildfires have replaced regeneration caused by biological ecosystem and are at the origin of the very strong spatial and temporal heterogeneity of hinterlands in Italy. The larger the interfaces between human and wildland means the larger the risk of a fire to happen due to accident, negligence or provoked actions.

Habitat: The rural exodus and economic recession leads to large amount of abandoned agriculture land transforming into unmanaged wildlands nearby the central mountain range of Spain. The ecological succession after abandonment often allows the increase in biodiversity but is on the other hand responsible for the increase in continuity and load of flammable fuels.

Geopolitics: Managing in the face of uncertainty of wildfire in forest relates from local groups to national organizations, complicating the appropriate allocation to management and policy efforts. Addressing the structural causes, namely land ownership structure, forest and land management, the State authority and social cohesion are needed to be reinforced in a consistent path.

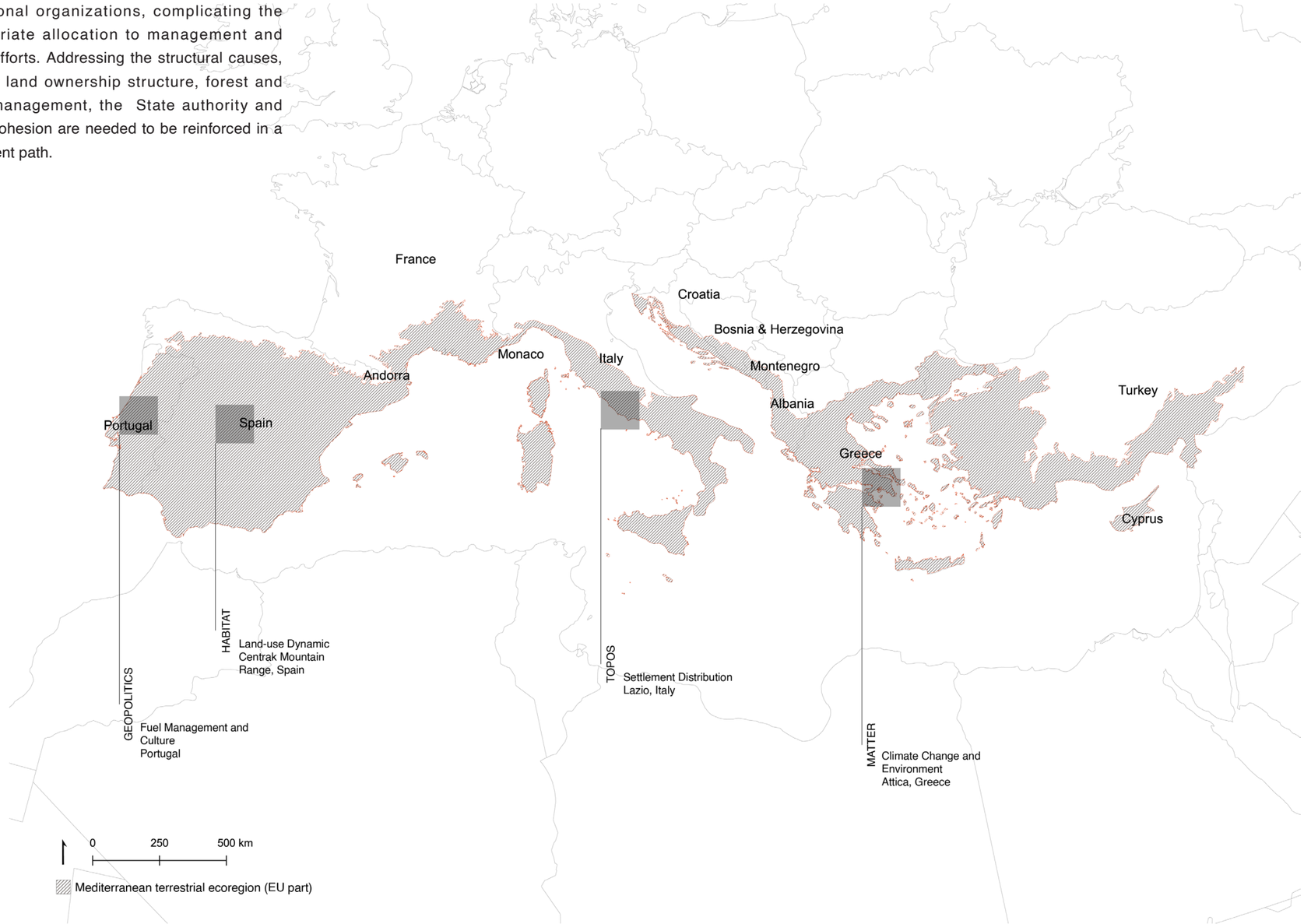


Fig. 4-1. Framework of monographs

The region of Northern Attica, Greece as a selected area for the investigation of Mediterranean climatic condition with wildfire is characterized by hot and dry summers and mild and rainy winters, as well as a unique natural environment encompassing a diverse landscape that encompasses mountains, forests, and coastal areas. The dynamics of this landscape are influenced by various factors, including topography, geology, and climate.

In Northern Attica, the relationship between wildfire regimes, climate change, and topographic characteristics is of paramount importance. The region is vulnerable to wildfires due to its climatic conditions, especially during the summer months when temperatures are high and precipitation is low. Additionally, the topography of the area plays a significant role in determining the extent and severity of wildfires, with steep slopes and narrow valleys accelerating their spread, while forests and vegetation act as fuel.

Anthropogenic factors have also contributed to the heightened frequency and severity of wildfires in Greece, including land-use changes, deforestation, and urbanization, which have disrupted the natural ecosystems of the region, rendering them more vulnerable to wildfires. Furthermore, human activities such as campfires, cigarette smoking, and agricultural practices have also been implicated in the ignition of wildfires in the region.

The issue of land-use change before and after fires is a crucial one in Northern Attica. Prior to a wildfire, land may be utilized for agriculture, grazing, or forestry purposes. However, after a wildfire, the landscape can undergo significant alterations, resulting in significant changes to vegetation and soil composition. This loss of vegetation can cause soil erosion, which can have an impact on water quality and availability. Moreover, the destruction of forests and woodlands can impact biodiversity and the carbon balance of the region. Following a fire, the land may either be allowed to recover naturally or may be actively managed to restore the natural ecosystem. Restoration efforts can include the planting of new vegetation, erosion control, and the management of invasive species. Such measures can assist in reinstating the natural balance of the ecosystem and in reducing the risk of future wildfires.

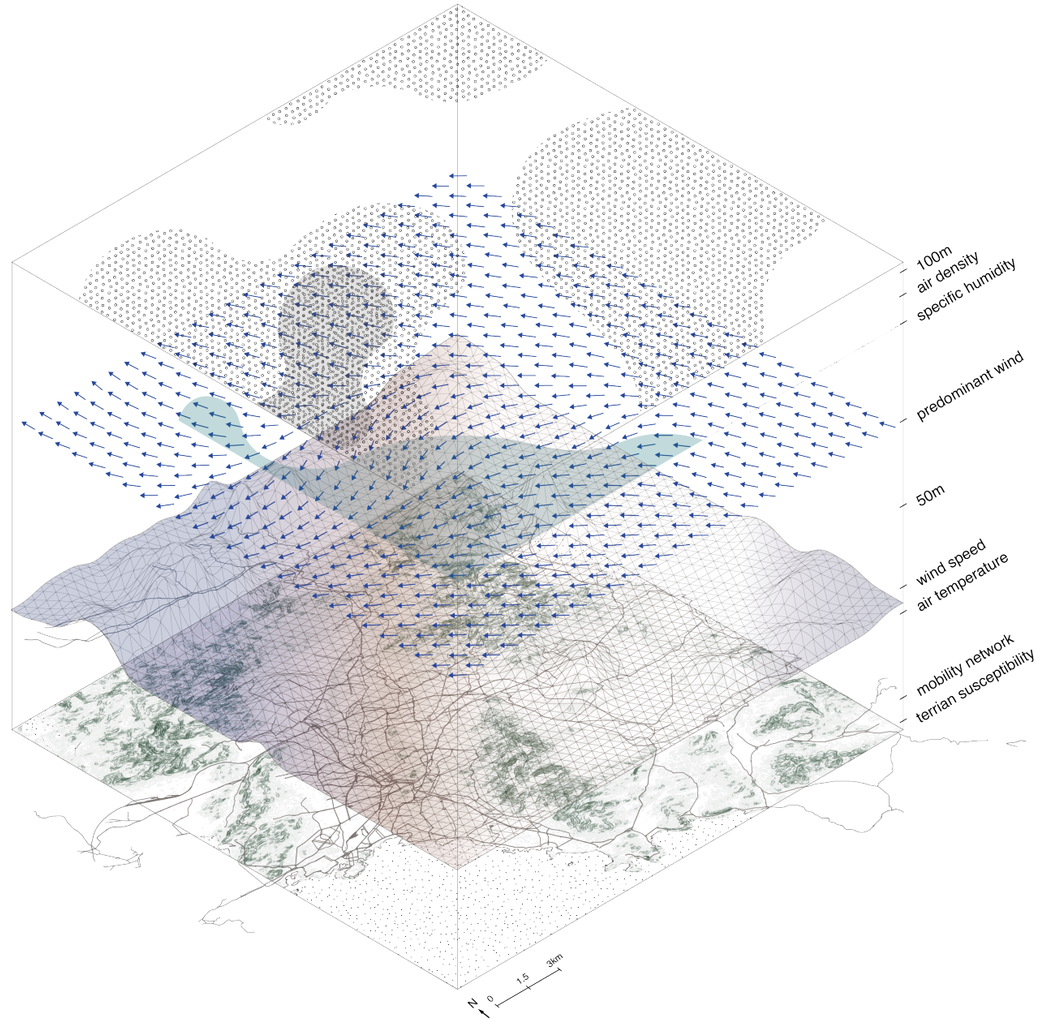


Fig. 4-2. Matter-Composition

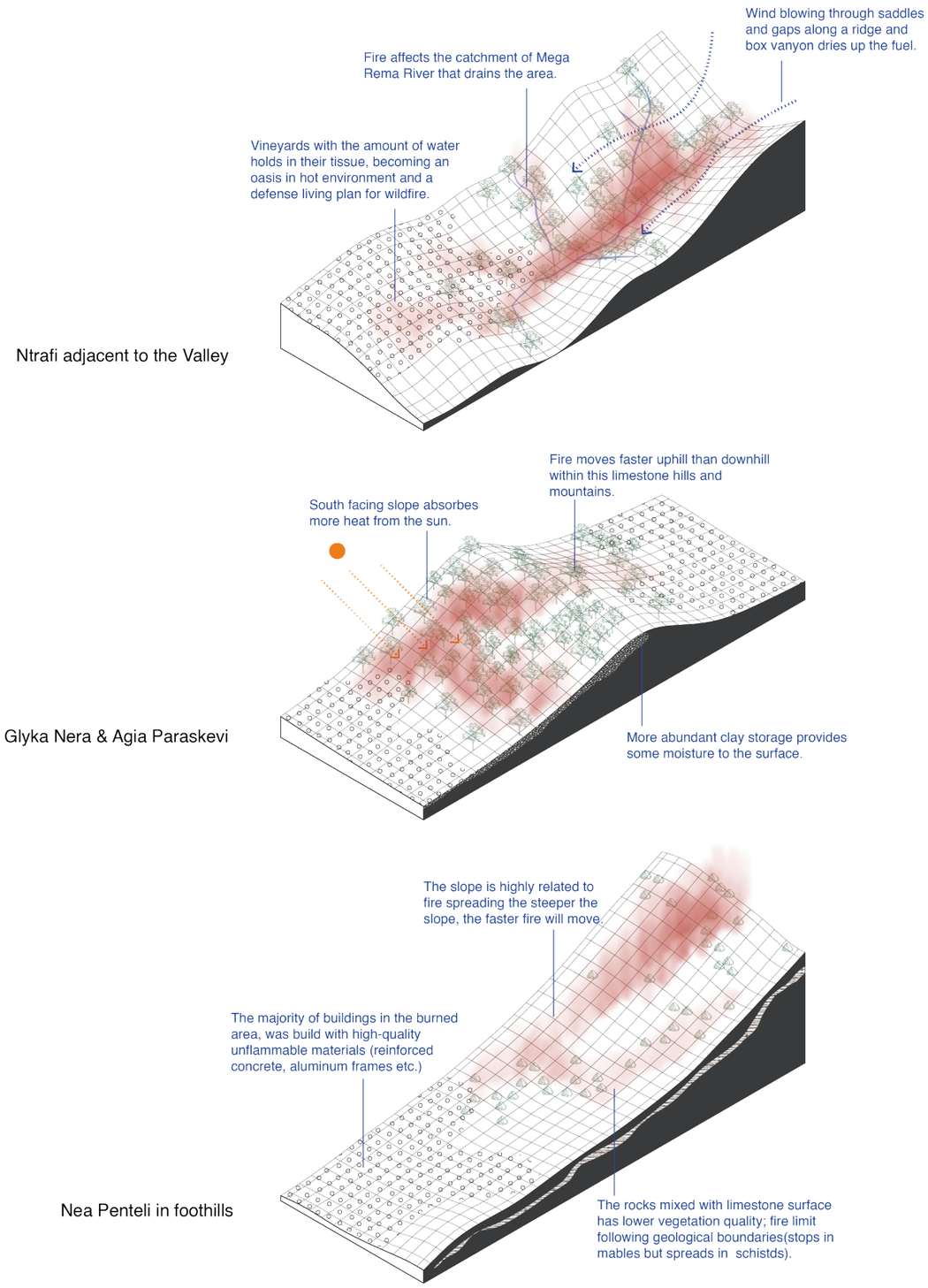


Fig. 4-3. Matter-Alteration

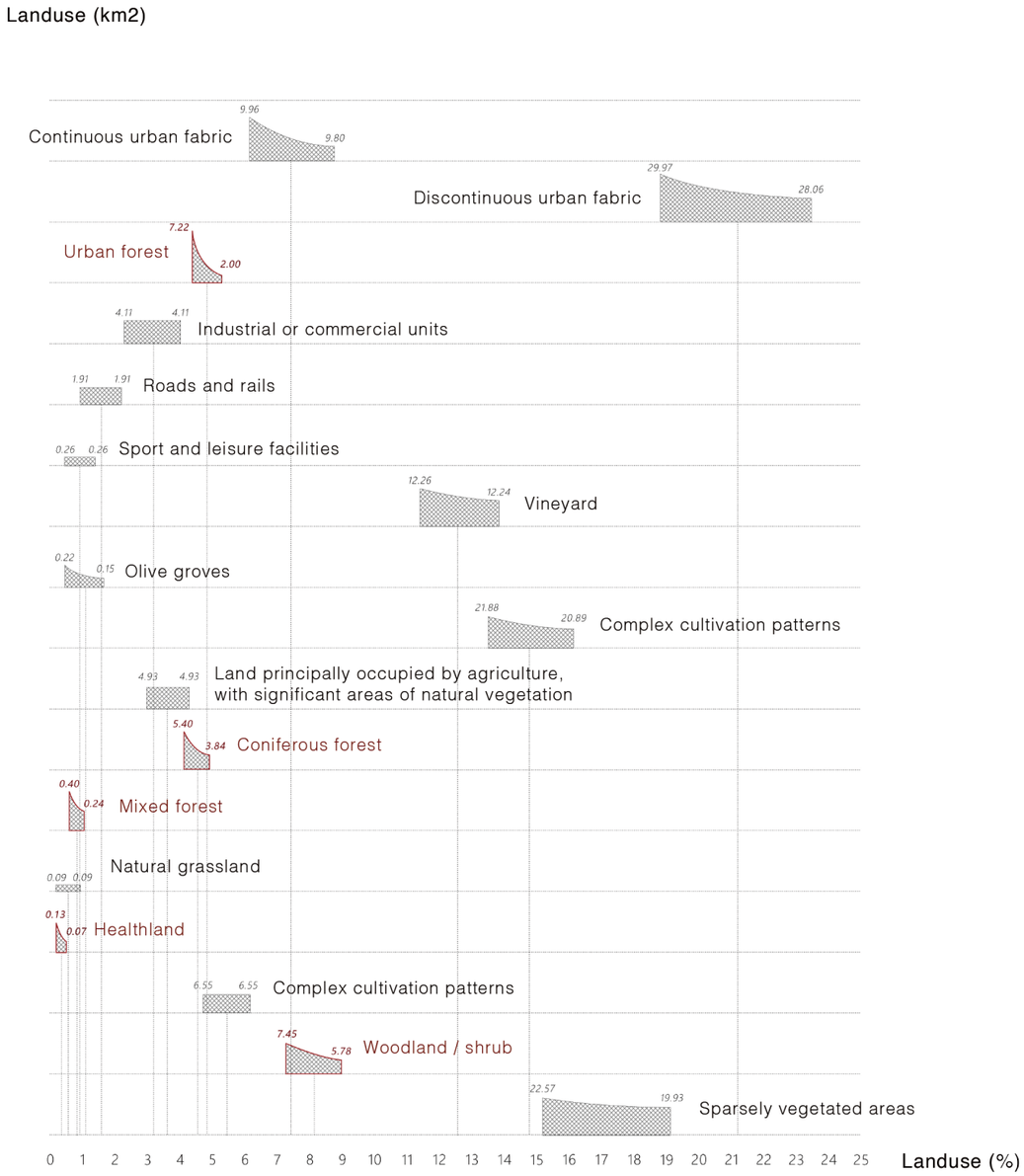


Fig. 4-4. Matter-Limits

The central region of Italy, particularly the pre-urban area of Rome, exhibits landscape heterogeneity characterized by diverse vegetation types such as forests and agricultural land. The occurrence and spread of wildfires in this region are closely related to the heterogeneity of the landscape. Natural causes such as lightning and human activities including agricultural practices and the use of fire for land management are responsible for starting wildfires. The presence of a heterogeneous landscape exacerbates the spread of wildfires as fires can rapidly move from one type of vegetation to another.

The wildland-urban interface (WUI) conditions in Italy contribute significantly to the incidence of wildfires in the region. The distribution of settlements, forest patterns, and other factors are responsible for creating WUI areas where urban and natural environments come into contact. In Italy, the proximity of human settlements to wildland areas characterizes WUI areas, which increase the risk of wildfire. Urbanization, forest fragmentation, and land-use changes can also lead to the occurrence of WUI areas in Italy. The occurrence of catastrophic wildfires in the pre-urban area of Rome is significantly attributed to human intervention. Uncontrolled agricultural practices, overgrazing, tourism, and ignorance of fire safety measures are some of the factors that have contributed to the incidence of wildfires in the region. A lack of awareness of fire safety measures among residents and visitors has also contributed to the incidence of wildfires as individuals may accidentally ignite fires or fail to report them in a timely manner.

The recovery process after a wildfire in the pre-urban area of Rome is a long and complex process. The severity of the fire, the type of vegetation, and the extent of soil erosion all play a critical role in the recovery process. Reforestation, erosion control, and the management of invasive species are some of the efforts aimed at restoring the natural balance of the ecosystem and reducing the risk of future wildfires. These measures help in the recovery process of the ecosystem, which in turn restores its functionality.

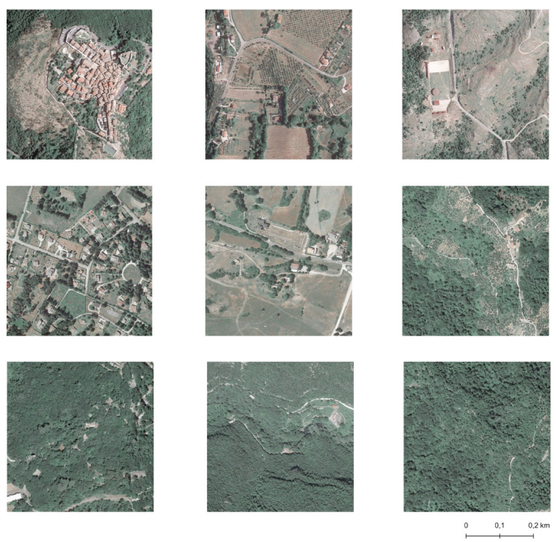


Fig. 4-5. WUI matrix

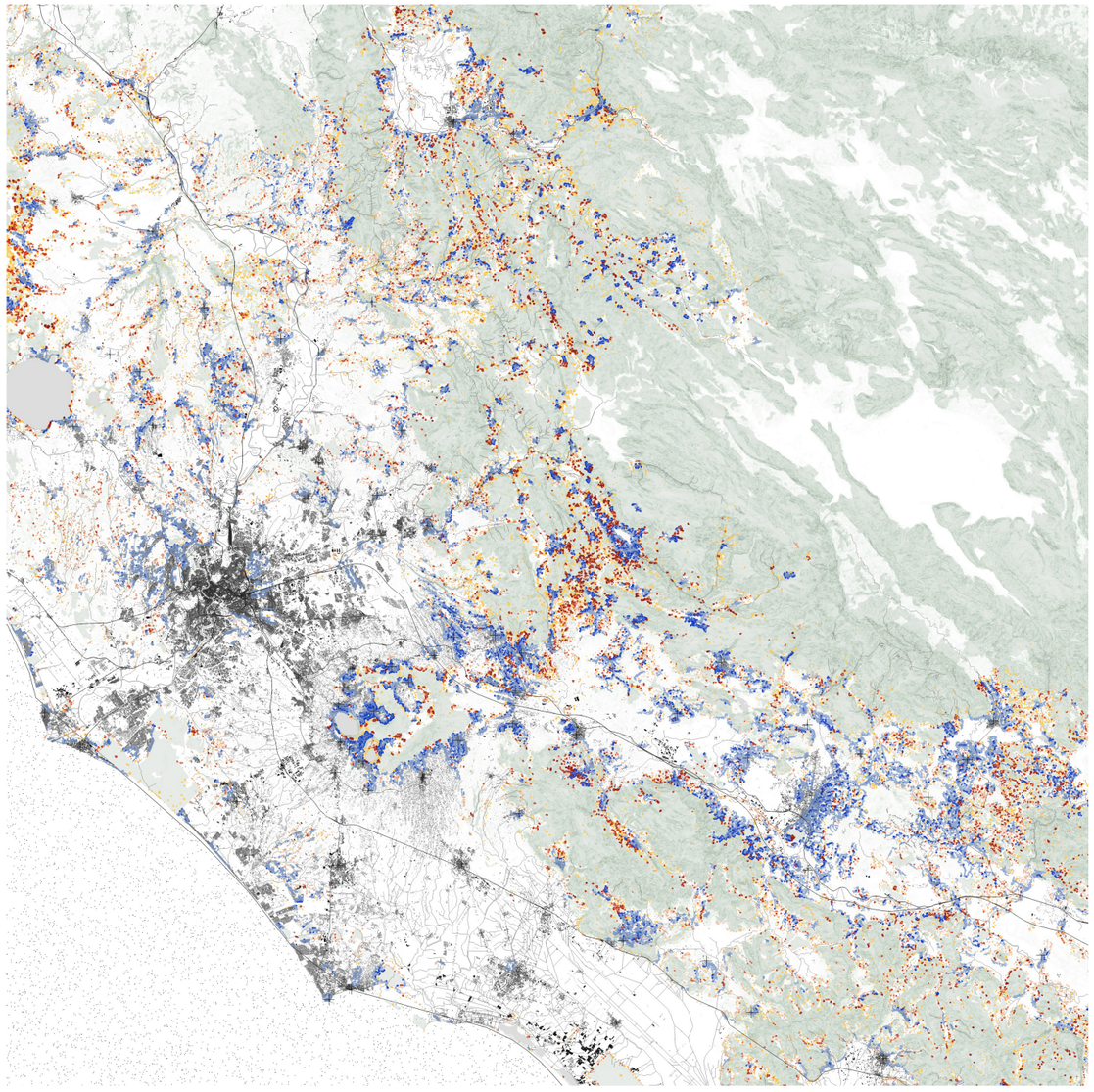


Fig. 4-6. Topos-Composition

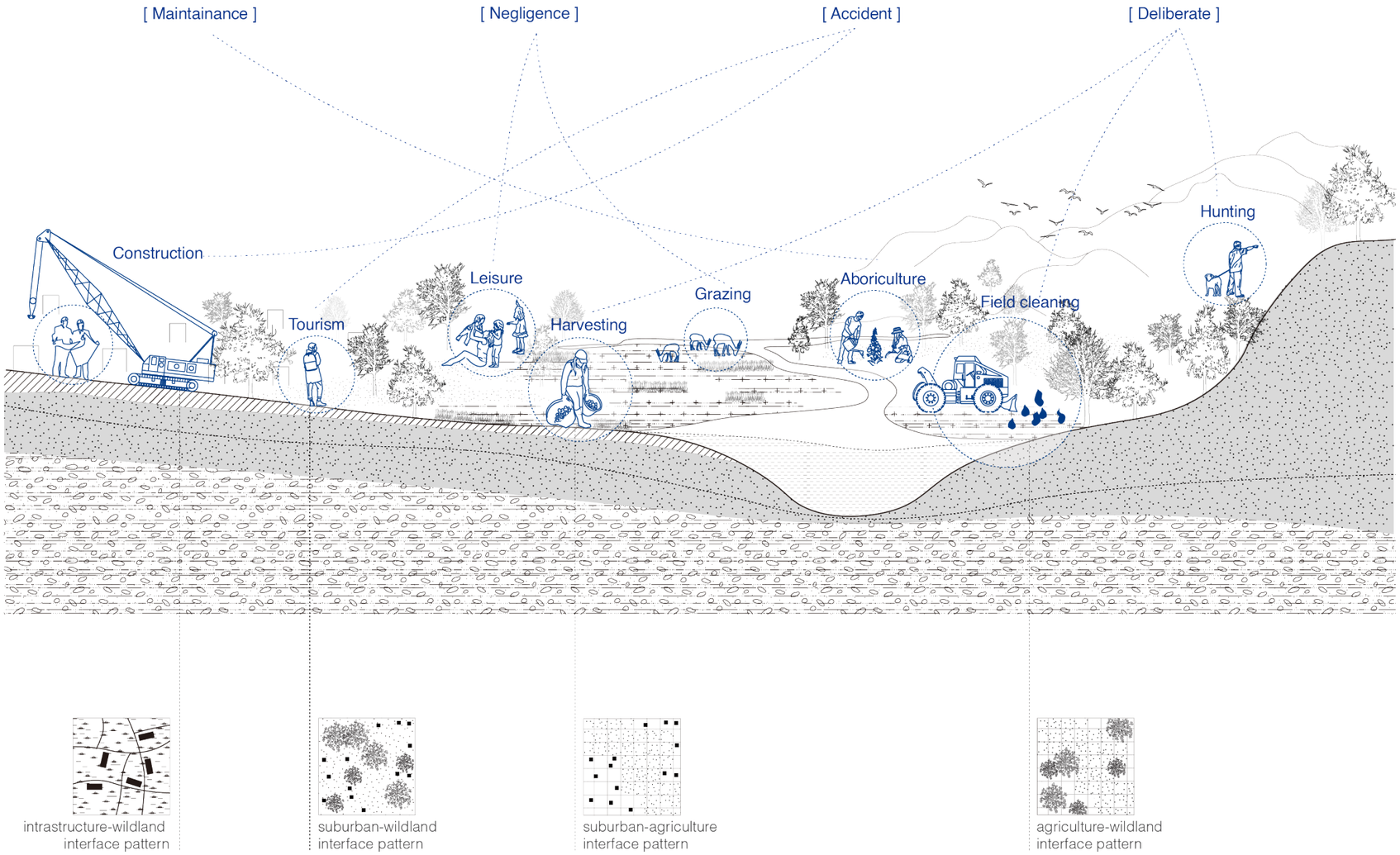


Fig. 4-7. Topos-Alteration

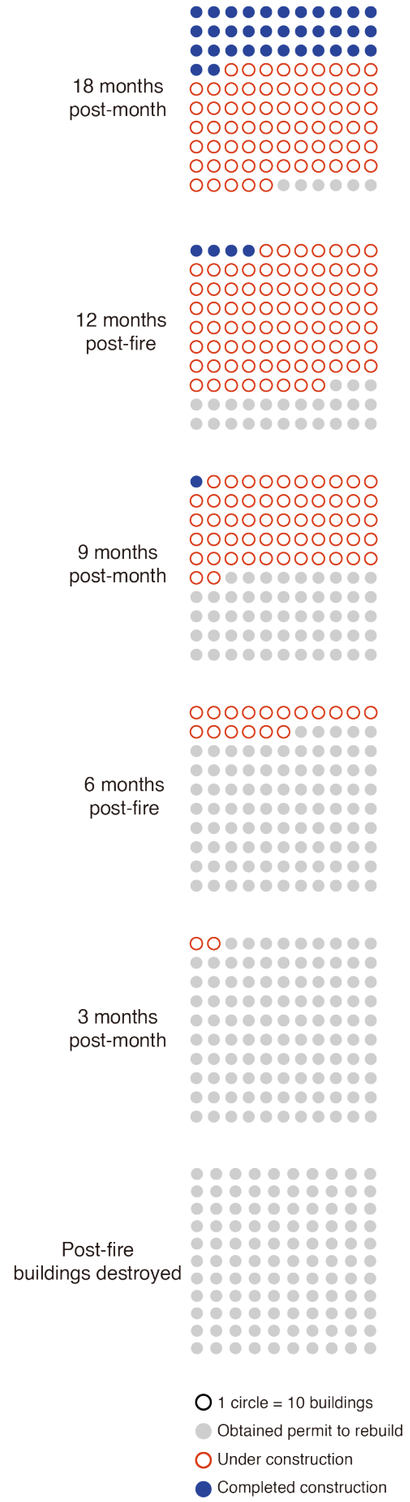


Fig. 4-8. Topos-Limits

The Mediterranean region has been witnessing a notable trend of rural depopulation and agricultural abandonment, which has become a major disturbance in the area. The central mountain range of Spain, located near Madrid, has been selected as a typical area for exploring the interaction between rural agriculture dynamics and wildfire. The region's heterogeneous landscape comprises forests, grasslands, and agricultural fields, which provide different fuel types for wildfires.

The current state of rural depopulation in the pre-urban areas of Madrid has resulted in the abandonment of agricultural practices. The migration of younger generations to urban areas and an aging population has led to a shortage of people available to manage the land and maintain the agro-silvo-pastoral system in the region. This has led to the growth of unmanaged wildland, which has become a significant fuel load in the area. The impact of agriculture abandonment has led to an increase in the amount of unmanaged wildland, which has become a highly flammable fuel load in these areas. This situation is further compounded by the accumulation of dead and dry vegetation, which is highly susceptible to ignition. Consequently, wildfires have become more frequent and severe in these areas.

The agro-silvo-pastoral system in these areas, commonly referred to as "dehesa," has the potential to be revived as a fire-resistant tool and a way of life. The dehesa system is a type of land management system that combines grazing, forestry, and agriculture in a sustainable way. The system involves maintaining a mix of trees, shrubs, and grasslands that are grazed by livestock. The dehesa system provides multiple benefits, including carbon sequestration, biodiversity conservation, and wildfire prevention.

Revitalizing the dehesa system can have numerous benefits, including reducing the risk of wildfire, supporting local communities, and promoting sustainable land management practices. The system can help to maintain a healthy and diverse landscape that is less vulnerable to wildfires. Furthermore, the dehesa system can provide economic opportunities for local communities through the production of high-quality meat and other agricultural products.

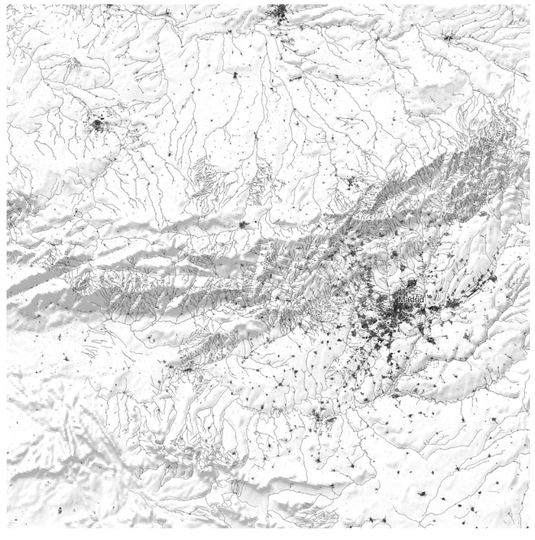


Fig. 4-9. Territoral conditions

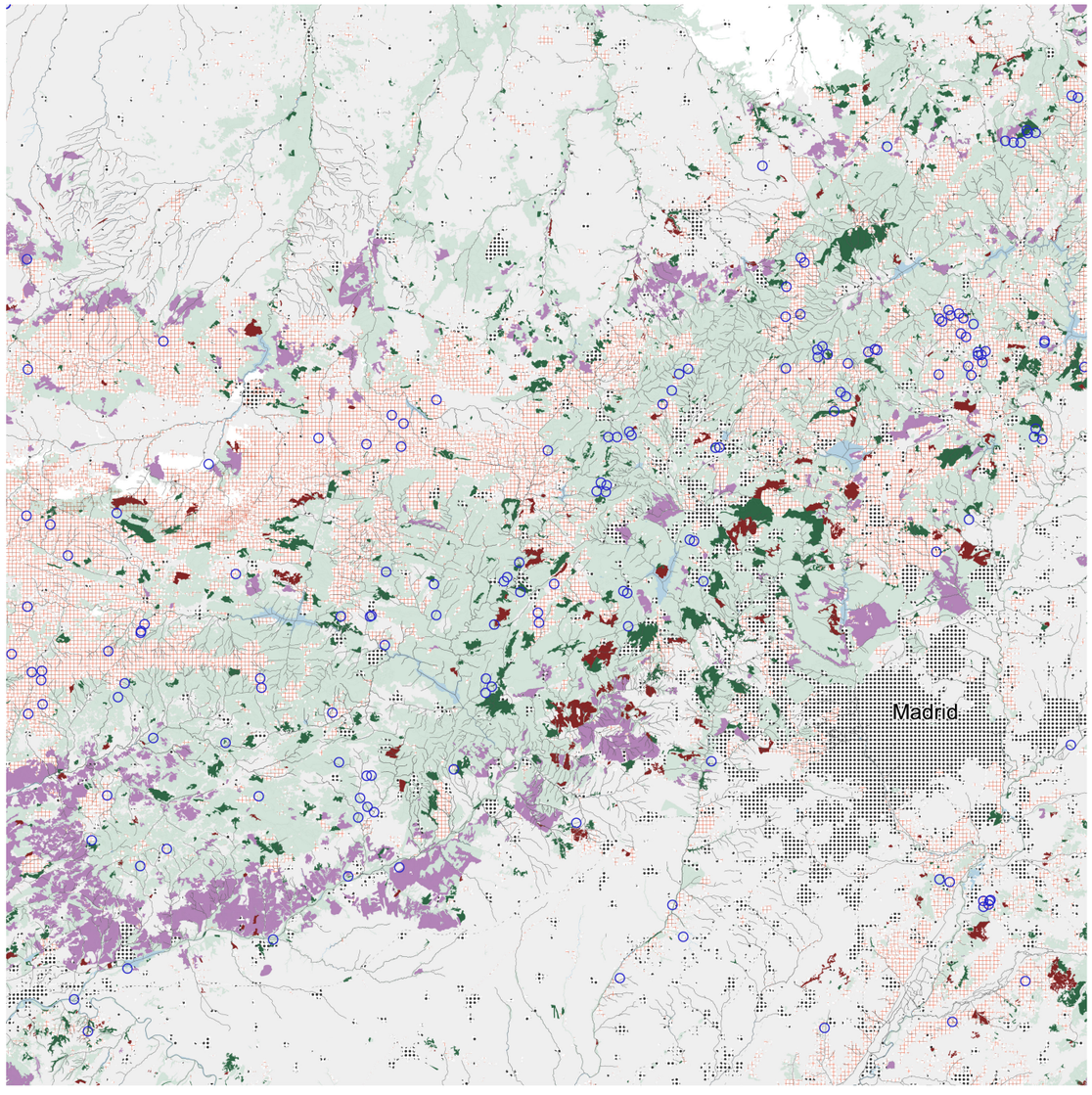


Fig. 4-10. Habitat-Composition

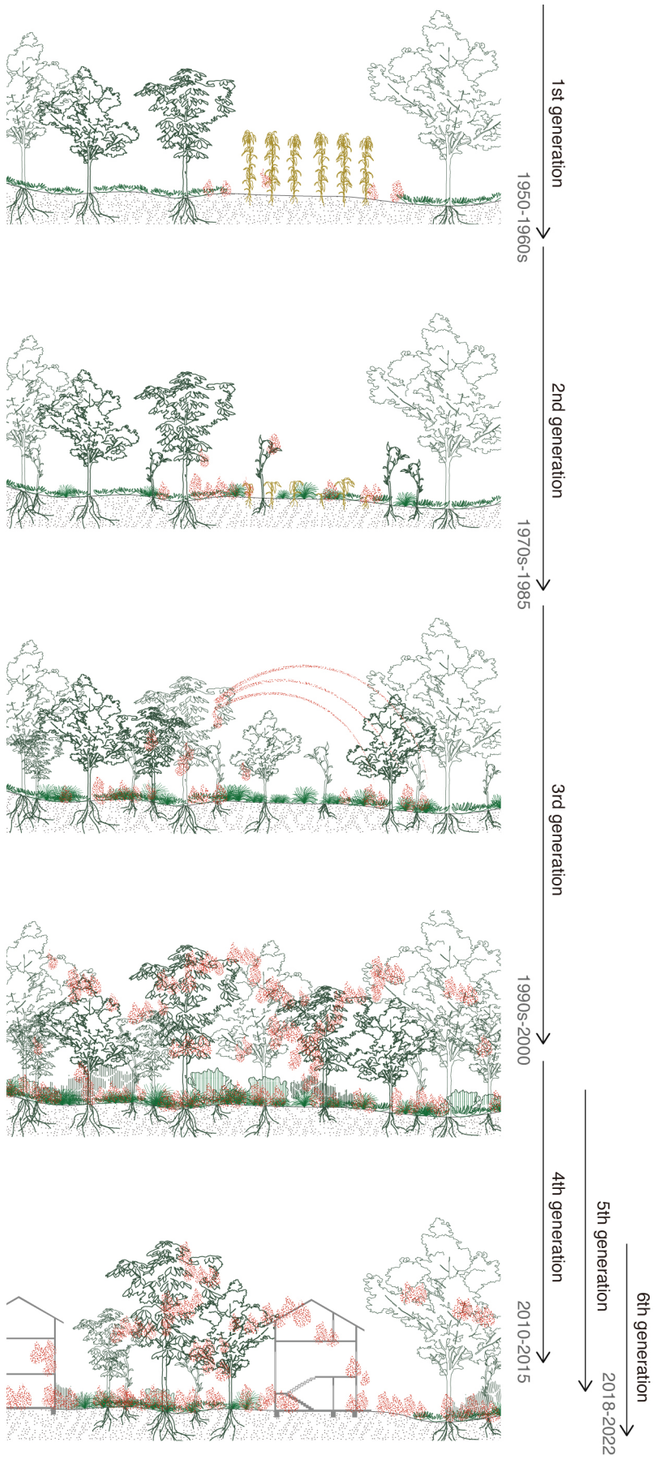
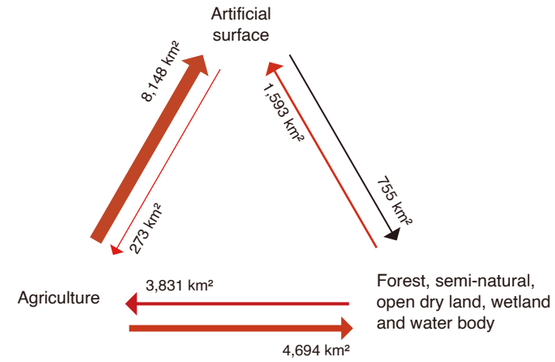
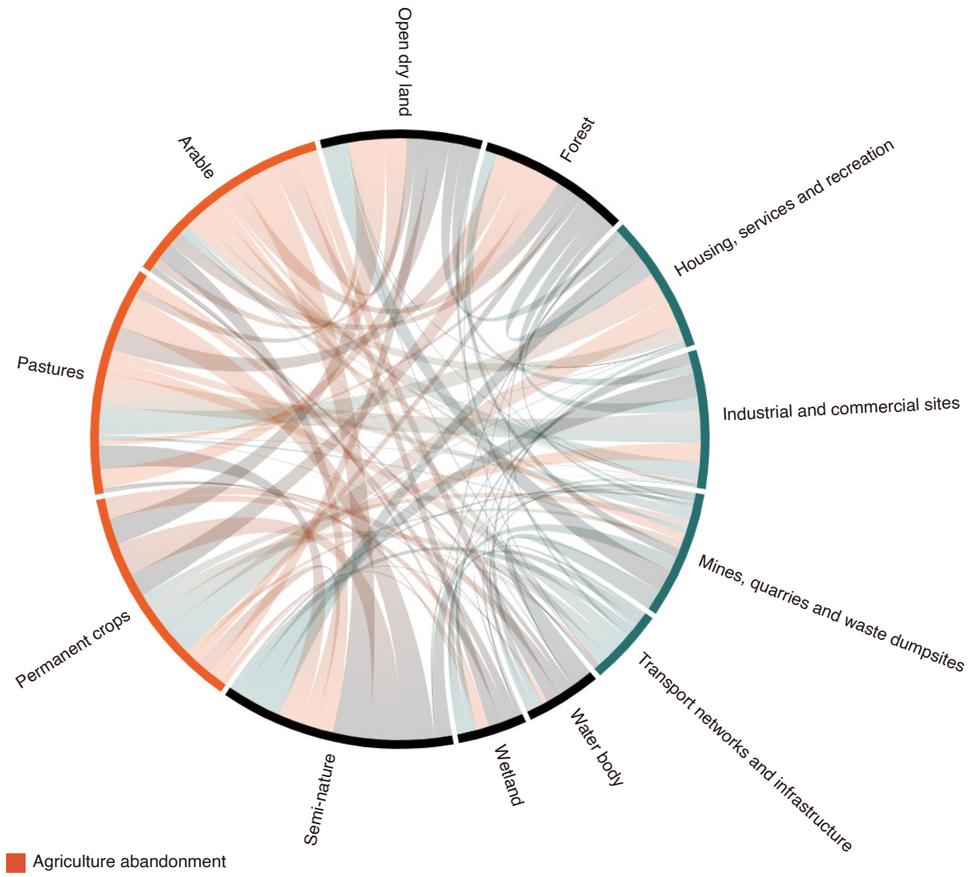


Fig. 4-11. Habitat-Alteration





Data source: European Environment Agency, Land accounts for Europe 1990–2000
European Commission, Agriculture Land Abandonment in the EU within 2015-2030

Fig. 4-12. Habitat-Limits

Forest management intensity is a crucial factor affecting wildfire risk. The central region of Portugal, located near Lisbon, has been selected as a typical area to investigate the relationship between wildfire regimes and geopolitical conditions. The region's landscape is characterized by a mix of forests, pastures, and rural settlements that provide different fuel types for wildfires.

The current situation and attitude towards forest management in central Portugal are diverse. Community-based management, community-forest service collaboration management, and private management are the most common forest management systems in the region. While these different management systems have different goals and strategies, they all aim to prevent and mitigate wildfires in the area. Community-based management involves local communities managing forests collectively, while community-forest service collaboration management involves collaboration between local communities and forest services. Private management is carried out by individuals or private companies who own forest land. The traditional pattern of rural settlement, pasture, and forest system in Portugal is referred to as "baldio." The baldio system is mainly distributed in the central and northern parts of the country and has a complex flow system between different actors, such as local farmers, forest managers, and parish managers. The baldio system aims to sustainably manage forest resources and maintain the balance between economic development and environmental conservation.

The intensity of forest management can lead to different results in forest evolution. Effective forest management strategies can help reduce the risk of wildfires in the central region of Portugal.

These strategies should involve a combination of community-based management, collaboration between local communities and forest services, and private management. The baldio system has the potential to provide a sustainable approach to forest management that balances economic development and environmental conservation. Additionally, forest management practices that aim to reduce forest density can help to mitigate the risk of wildfires and promote healthy forest ecosystems.

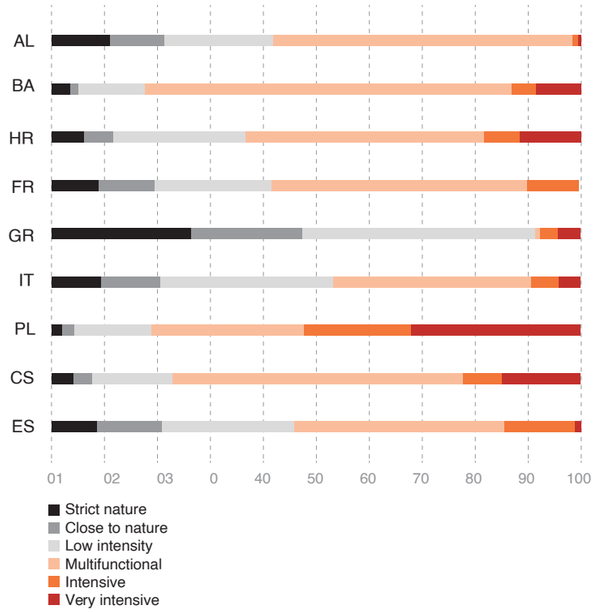


Fig. 4-13. Mediterranean Countries Forest Management Intensity

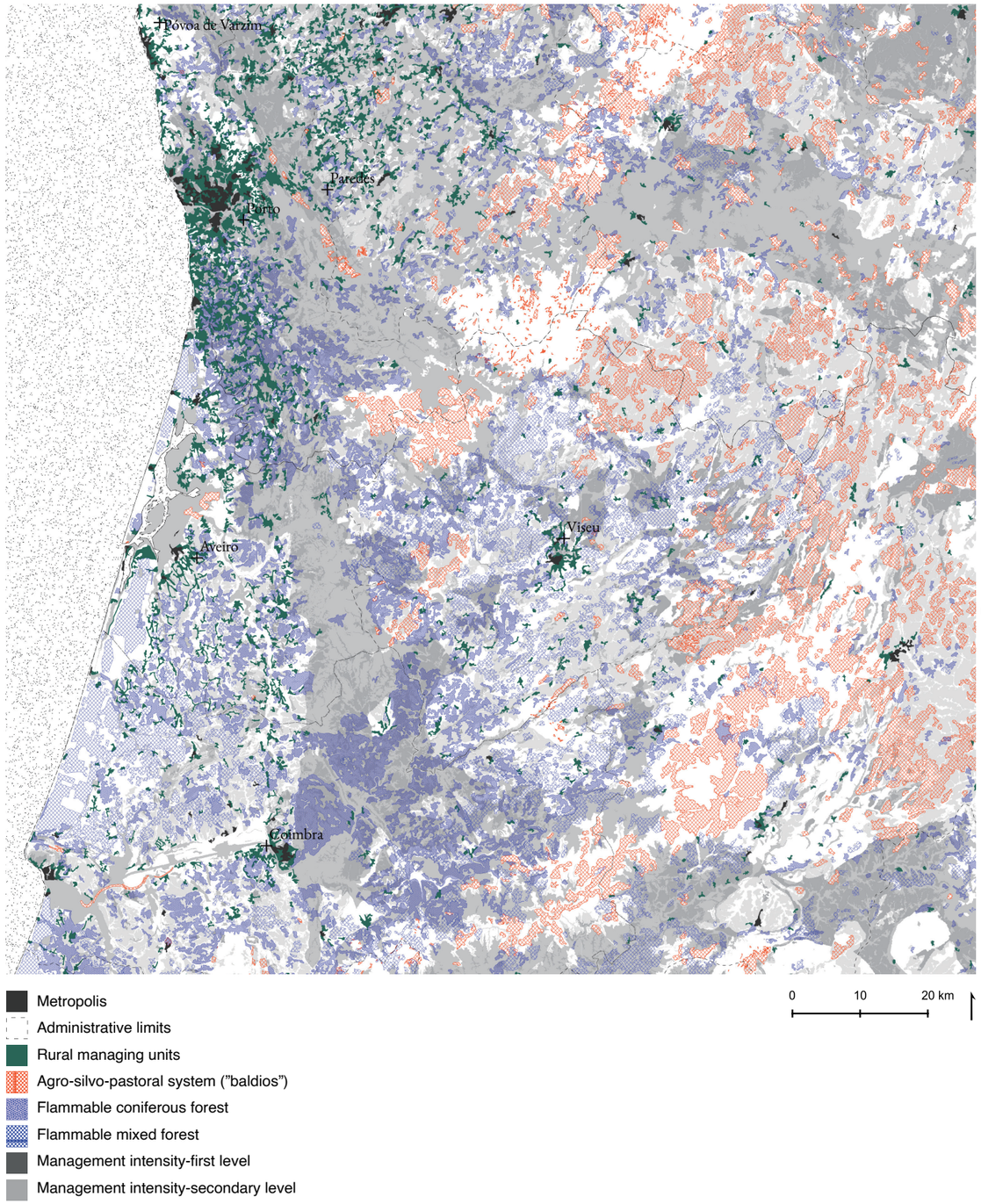


Fig. 4-14. Geopolitics-Composition

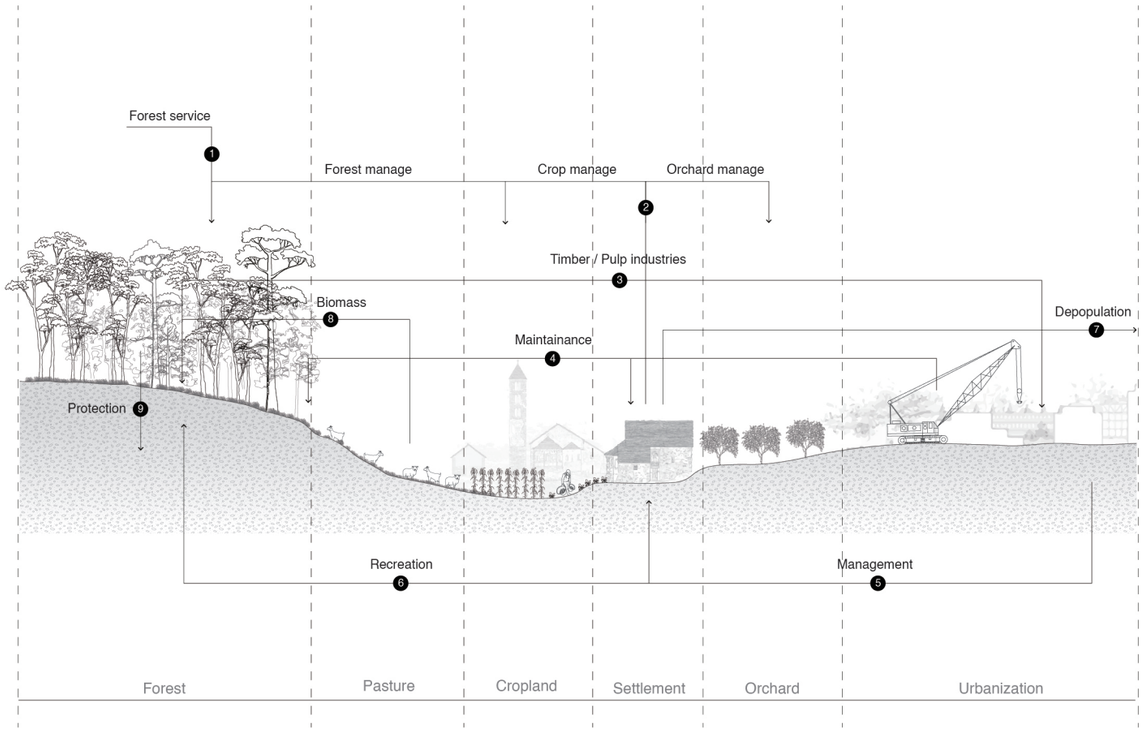


Fig. 4-15. Geopolitics-Alteration

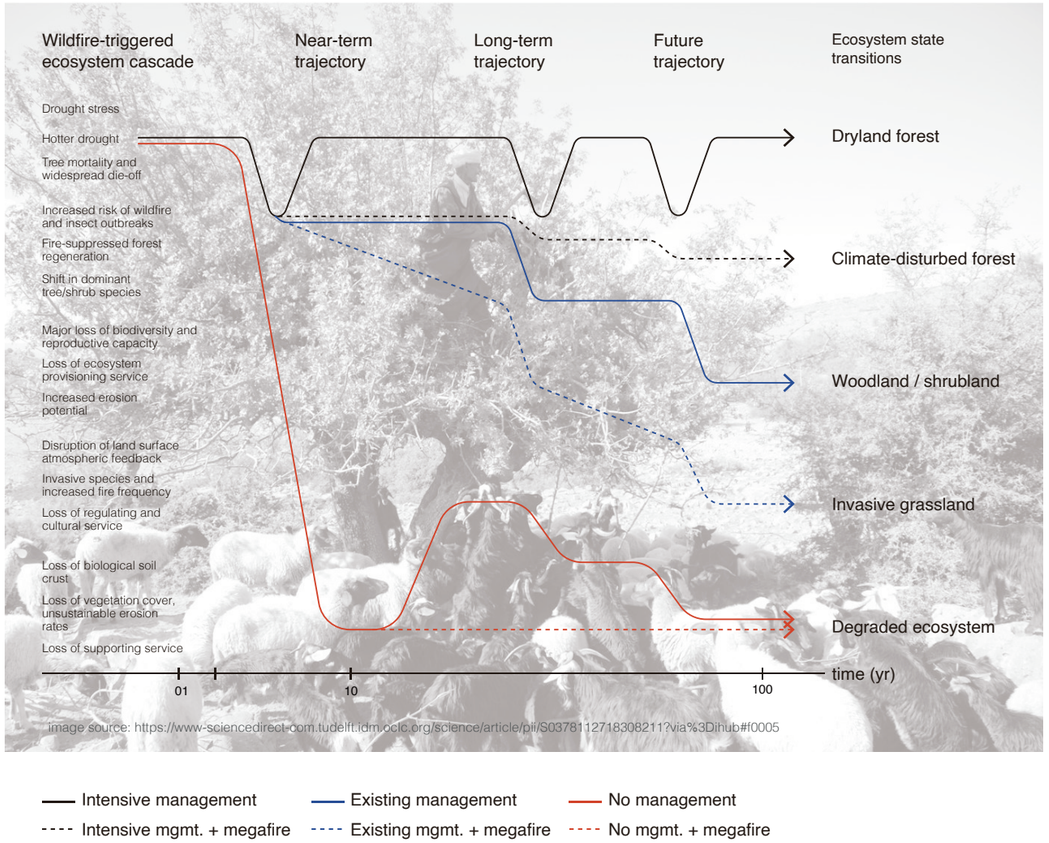


Fig. 4-16. Geopolitics-Limits

5

ATLAS

Analytical Methodology

Meteorological

Physiographic

Biological

Anthropogenic

Landscape-based Fire Typologies

Representation of Land System

GIS-based analysis

Considering fire typologies as landscape units which are defined through the analysis and interpretation of quite diverse territorial factors, geographic information system based methods perform a spatial analysis of the area attributes of homogeneity (Galiana-Martín & Montiel-Molina, 2011). The landscape indicator groups in the extent of Mediterranean are resampled in the spatial vehicle of 10km*10km grid, which allows the normalization of fire-prone data intervals.

Clustering analysis are used for the aggregation of feature similarity which is based on the set of attributes in order to find the spatially correlated landscape patterns (Wu, 2004).

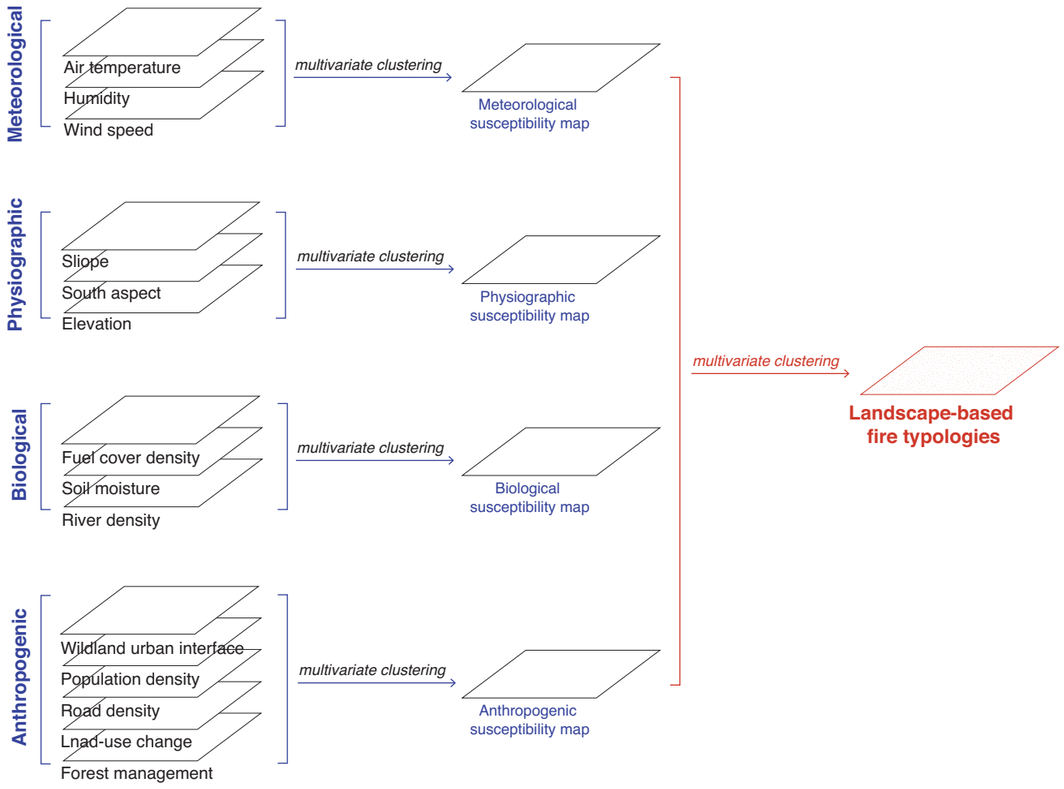


Fig. 5-1. Data category and GIS-based methodology

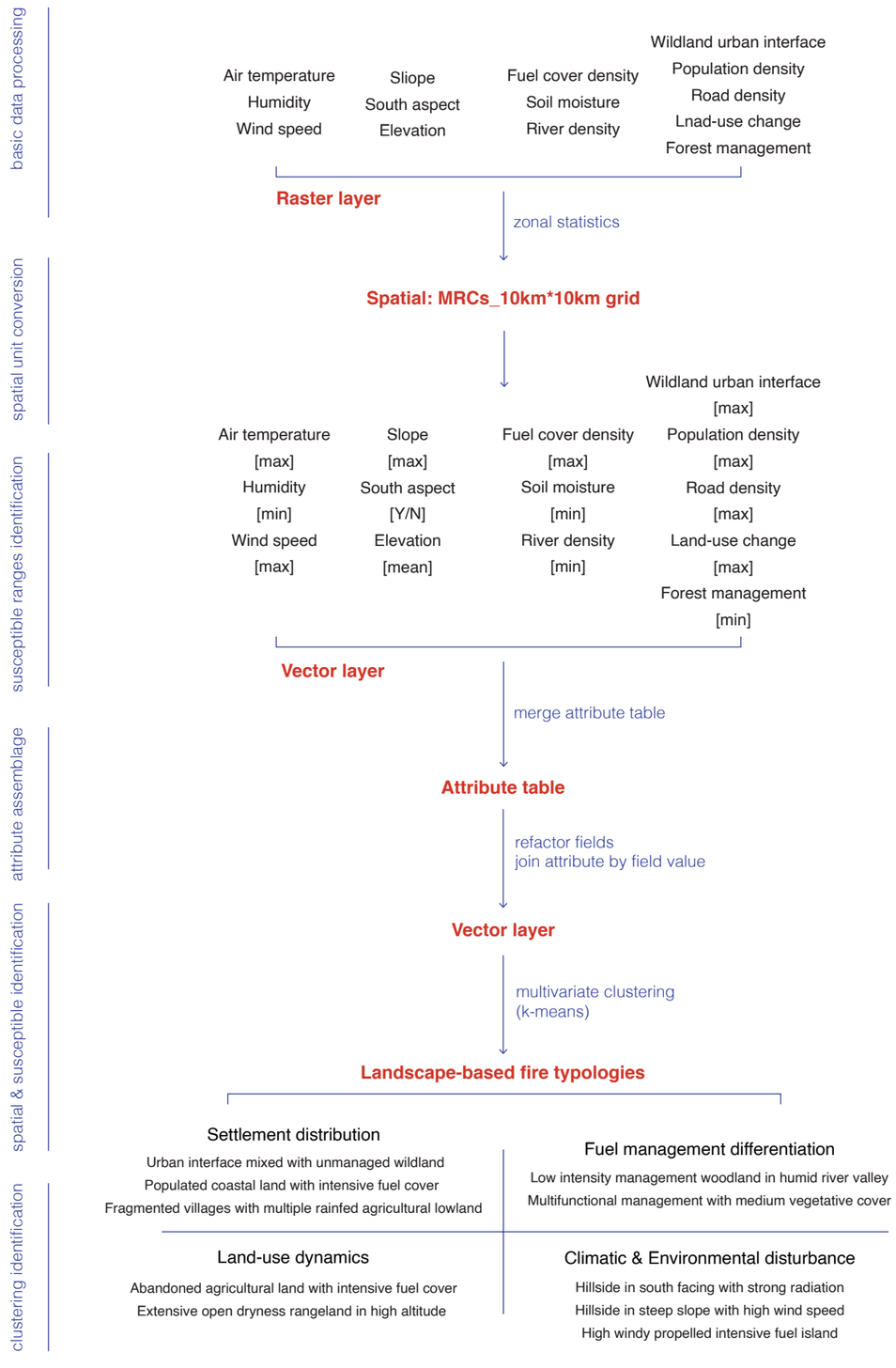


Fig. 5-2. The process of GIS-based methodology

The Mediterranean Basin, located in the southern part of Europe, is an area with a unique climate that is defined by hot and dry summers, and mild and wet winters. The region is bounded by the Mediterranean Sea, the Alps, the Pyrenees, and the Sahara Desert. The climate is subtropical, which means that it has mild winters and hot summers, but it is also characterized by its low humidity, and strong winds.

Air Temperature: The annual air temperature in the Mediterranean Basin varies significantly depending on the time of year. During the summer months, which typically run from June to September, temperatures can reach as high as 35°C (95°F), particularly in inland areas. The coastal regions tend to be cooler, with temperatures ranging from 25°C to 30°C (77°F to 86°F). In contrast, during the winter months, which run from December to February, temperatures are much milder, with daytime temperatures ranging from 10°C to 15°C (50°F to 59°F) in most areas.

Spring and autumn are transitional seasons, with daytime temperatures ranging from 15°C to 20°C (59°F to 68°F). These seasons are generally considered the best time to visit the Mediterranean Basin due to the mild weather, comfortable temperatures, and lower tourist traffic.

Humidity: The Mediterranean Basin is known for its low humidity levels, particularly during the summer months. Relative humidity typically ranges from 40% to 60%, but can drop to as low as 30% in the hottest months. In contrast, during the winter months, relative humidity levels tend to be higher, ranging from 70% to 90%.

Wind Patterns: The Mediterranean Basin is known for its strong and sometimes violent winds, particularly in the spring and autumn months. These winds, known as the sirocco or Mediterranean hurricanes, originate in the Sahara Desert and blow towards the Mediterranean Sea. They can reach speeds of up to 100 km/h (62 mph) and are often accompanied by dust and sand.

In summer, the wind patterns are generally light and variable, with occasional sea breezes providing some relief from the heat. During the winter months, the coastal regions of the Mediterranean Basin can experience strong and gusty winds, particularly during storms.

In conclusion, the Mediterranean Basin has a unique climate that is defined by hot and dry summers, mild and wet winters, low humidity levels, and strong winds. These climatic conditions have shaped the flora and fauna of the region, as well as the way of life of the people who live there. The mild temperatures and abundant sunshine make the region a popular tourist destination, but visitors should be prepared for the occasional sirocco wind and low humidity levels during the summer months.

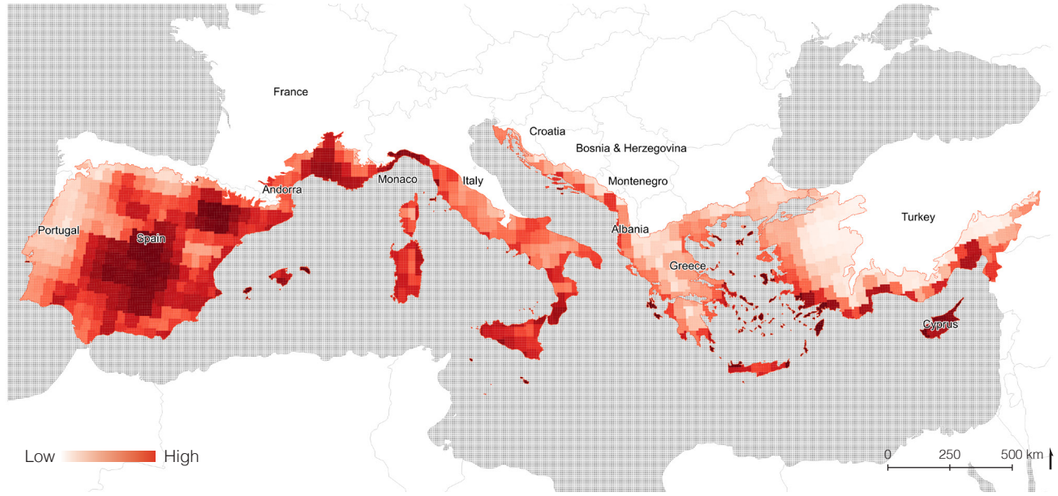


Fig. 5-3. Air temperature

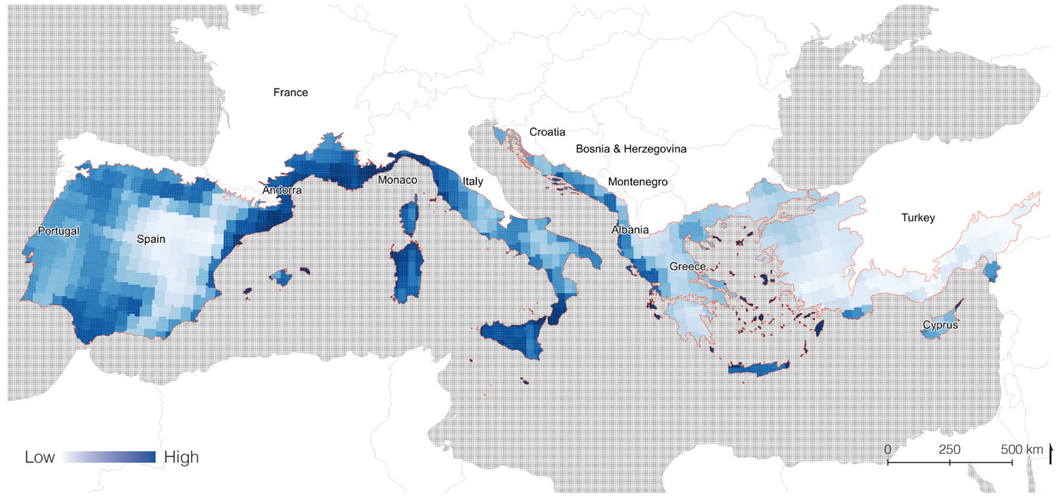


Fig. 5-4. Humidity

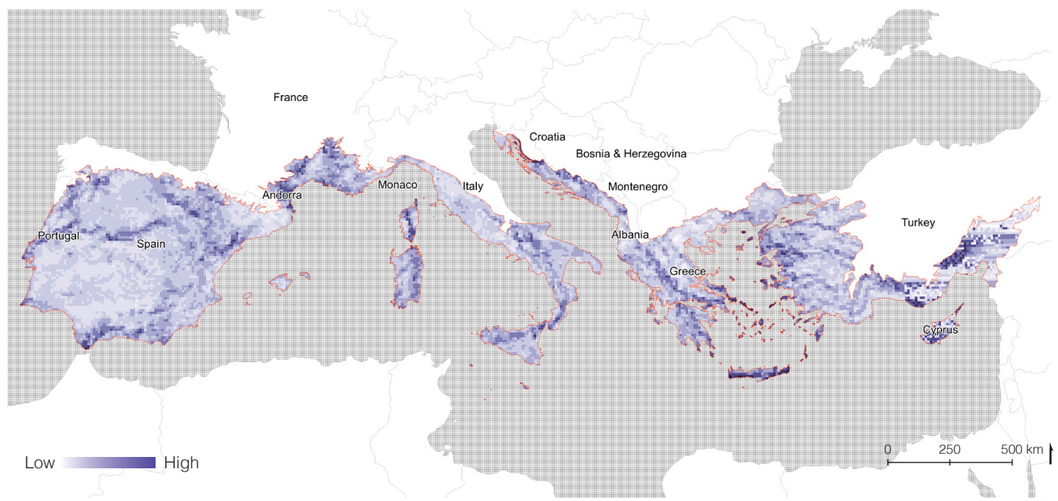


Fig. 5-5. Wind speed

Meteorological susceptibility

Mediterranean climate is characterized by high temperatures and low relative humidity during the summer months which can create conditions conducive to the ignition and rapid spread of wildfires (Syphard et al., 2009). The presence of dry fuels, such as dead vegetation, can further increase the risk of fire. The timing and distribution of precipitation occurs during the winter season, leading to a build-up of vegetation and fuel for fires during the dry summer months. This creates a situation in which wildfires can quickly spread and become difficult to control. Wind speed and direction can also have a significant impact on wildfire behaviour. High-pressure systems can create dry and windy conditions while during the winter months, low-pressure systems can bring wet and windy conditions that can make fire suppression efforts more difficult.

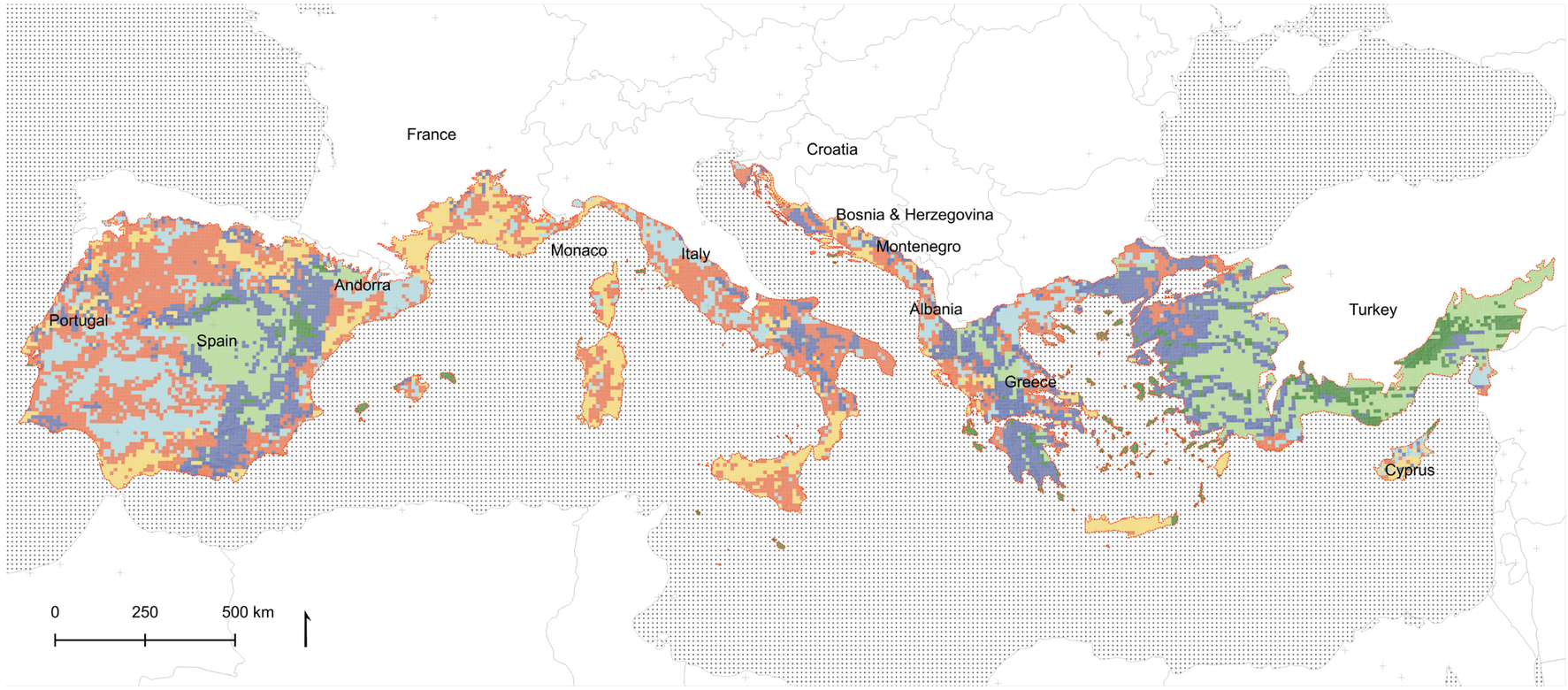


Fig. 5-6. Meteorological susceptibility

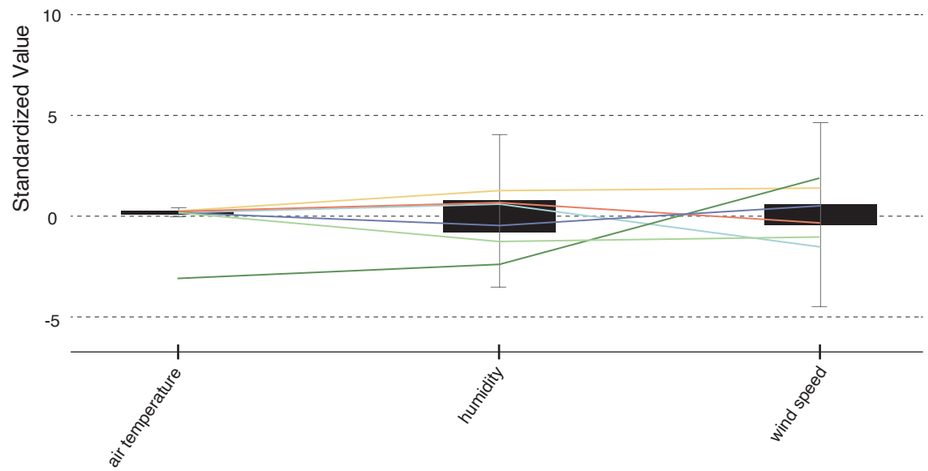


Fig. 5-7. Clustering box-plots

The Mediterranean Basin (EU part) is home to several mountain ranges, including the Alps, the Pyrenees, the Apennines, and the Atlas Mountains. The topography of these mountain ranges varies widely, with different elevations, slopes, and aspects affecting the local climate, vegetation, and wildlife. In this response, we will describe the slope, aspect, and elevation conditions of the mountains in the Mediterranean Basin (EU part) in more detail.

Slope: Slopes can have a significant impact on the local climate and vegetation. In the Mediterranean Basin, mountain slopes can vary from gentle to steep, depending on the location. In general, the northern slopes of mountains tend to be steeper and receive less sunlight, resulting in a cooler and wetter climate. The southern slopes, on the other hand, tend to be gentler and receive more sunlight, resulting in a warmer and drier climate. The steepness of the slope can also affect the types of vegetation that grow on the mountain. For example, in the Alps, the steep north-facing slopes support forests of spruce, fir, and larch, while the gentler south-facing slopes are covered in oak, beech, and chestnut trees.

Aspect: The direction a mountain faces can have a significant impact on the amount of sunlight it receives and the local climate. In the Mediterranean Basin, mountains facing south tend to receive more sunlight and have a warmer and drier climate, while those facing north receive less sunlight and have a cooler and wetter climate. The aspect of a mountain can also affect the types of vegetation that grow on it. For example, in the Pyrenees, south-facing slopes are dominated by grasslands and Mediterranean shrubs, while north-facing slopes are covered in forests of oak, beech, and fir.

Elevation: Elevation has a significant impact on the local climate, with higher elevations generally being cooler and wetter than lower elevations. In the Mediterranean Basin, the highest mountains are found in the Alps and the Atlas Mountains, with peaks reaching over 4,000 meters (13,000 feet). These mountains are covered in glaciers and snowfields and support alpine vegetation, such as dwarf shrubs, grasses, and lichens. Lower elevations in the Mediterranean Basin support a variety of vegetation types, including forests, grasslands, and Mediterranean shrublands.

In conclusion, the mountains in the Mediterranean Basin (EU part) vary widely in their slope, aspect, and elevation conditions, which affect the local climate, vegetation, and wildlife. Visitors to the region can explore a range of landscapes, from snow-capped peaks and alpine meadows to oak forests and Mediterranean shrublands.

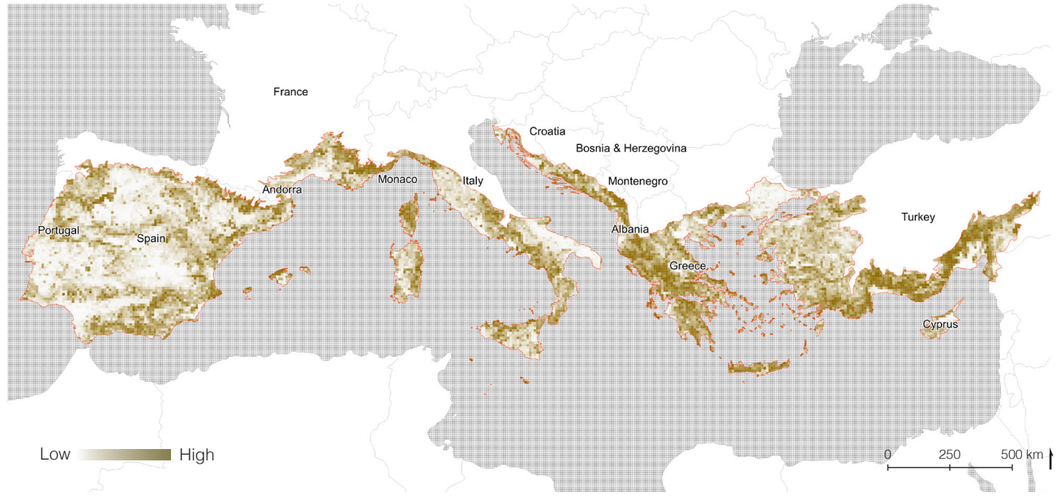


Fig. 5-8. Slope

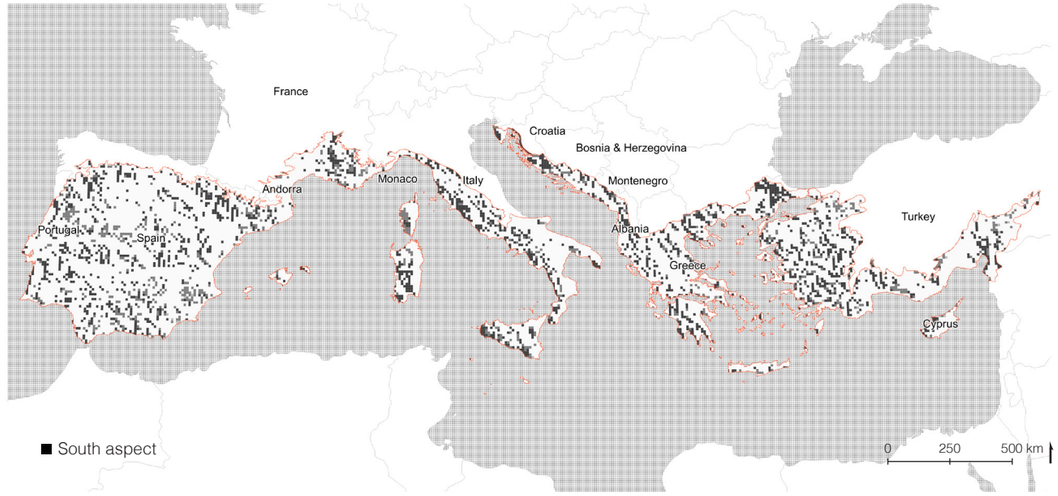


Fig. 5-9. South aspect

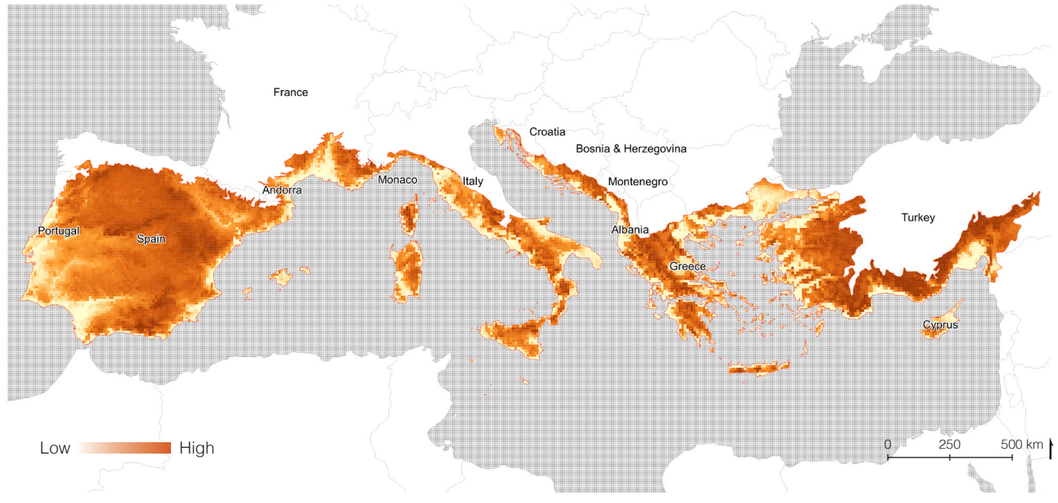


Fig. 5-10. Elevation

Physiographic susceptibility

Specific mountain areas in the Mediterranean region of the European part where topography influences wildfire behaviours include the Pyrenees, the Alps, and the Apennines (Pérez-Sanz et al., 2013; Tinner et al., 2000). These mountain ranges have a range of elevations, slopes, and aspects. For example, steep slopes and south-facing aspects in the Pyrenees and Alps can create conditions conducive to wildfire ignition and spread, while higher elevations in the Apennines can provide cooler and moister conditions that reduce the risk of fire. In addition to these larger mountain ranges, there are also smaller, isolated mountainous areas in the Mediterranean region, such as the mountains of Corsica and Sardinia. These steep canyons or ridgelines that can create chimney-like conditions that accelerate fire spread (Clarke et al., 1994).

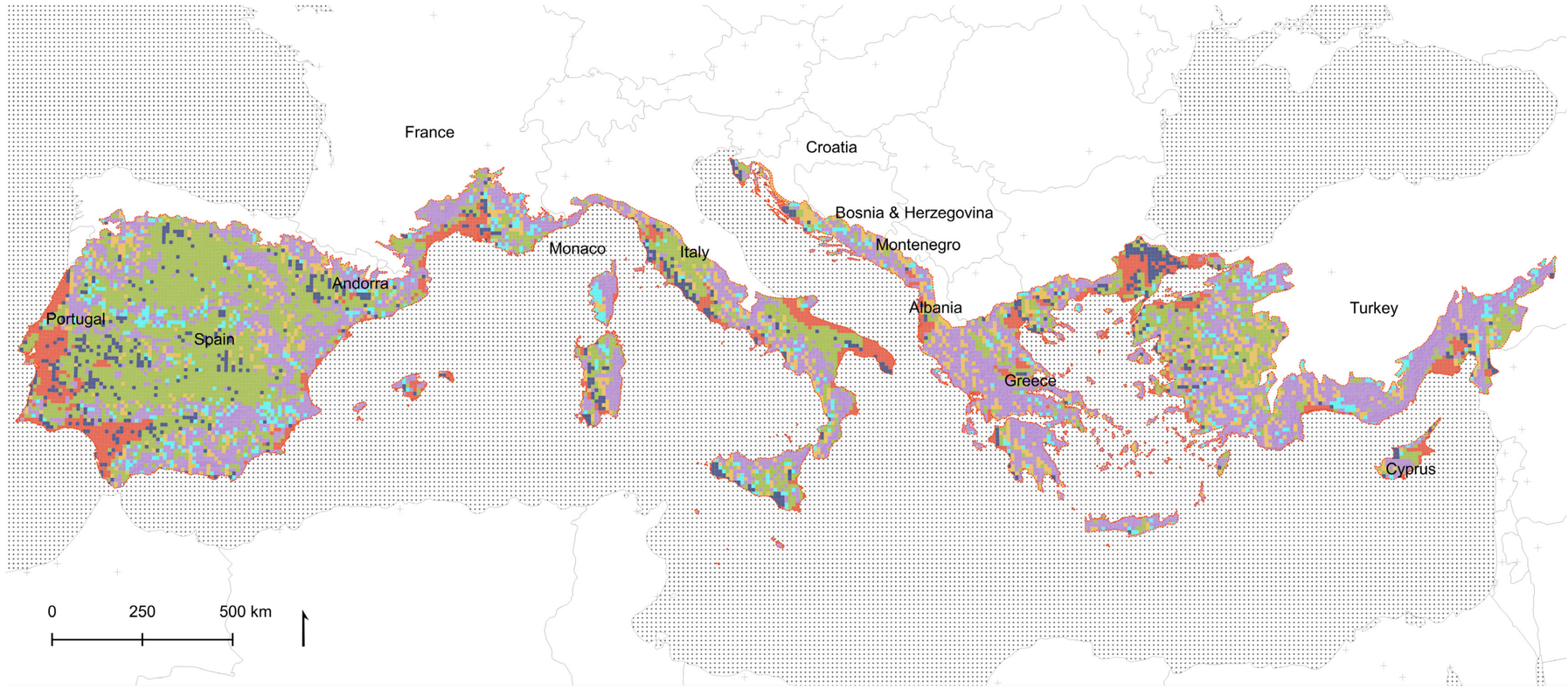


Fig. 5-11. Physiographic susceptibility

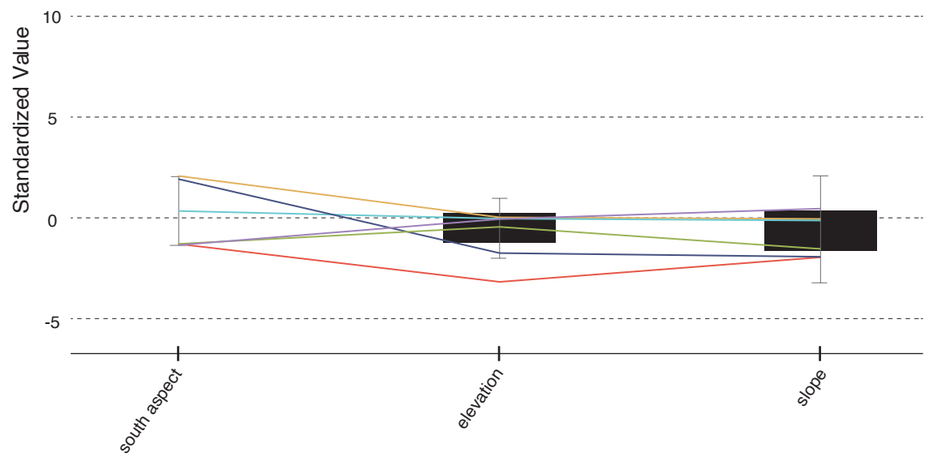


Fig. 5-12. Clustering box-plots

The Mediterranean Basin (EU part) is one of the most fire-prone regions in the world. The combination of a dry climate, high temperatures, and vegetation that is adapted to fire makes wildfires a common occurrence in the region. In this response, we will describe three key factors that contribute to wildfire risk in the Mediterranean Basin: fuel cover density, soil moisture, and river density.

Fuel Cover Density: Fuel cover refers to the vegetation and other combustible materials that can fuel a wildfire. In the Mediterranean Basin, the type and density of vegetation can vary widely, from dense forests to grasslands and shrublands. The density of fuel cover plays a significant role in the spread and severity of wildfires. In areas with high fuel cover density, fires can spread quickly and be difficult to control. In contrast, areas with low fuel cover density, such as rocky terrain, are less prone to wildfires. In general, forests and shrublands with high fuel cover density are the most fire-prone areas in the Mediterranean Basin.

Soil Moisture: Soil moisture is another key factor that contributes to wildfire risk in the Mediterranean Basin. Dry soil can easily ignite and fuel wildfires, while wet soil can slow or prevent the spread of fires. The amount of soil moisture in an area is influenced by factors such as precipitation, temperature, and vegetation cover. In the Mediterranean Basin, soil moisture levels are generally low due to the region's arid climate. As a result, even a small spark can easily ignite a wildfire in areas with dry soil.

River Density: The density of rivers and other water sources is also an important factor in wildfire risk in the Mediterranean Basin. Rivers can act as barriers to the spread of fires, preventing flames from crossing to the other side. In addition, rivers and other bodies of water can be used as sources of water for firefighting efforts. In areas with high river density, wildfires are generally less severe and easier to control. However, in areas with low river density, fires can spread more easily and be more difficult to contain.

In conclusion, fuel cover density, soil moisture, and river density are three key factors that contribute to wildfire risk in the Mediterranean Basin (EU part). Visitors to the region should be aware of the potential for wildfires and take precautions to prevent fires from starting, such as avoiding open flames and cigarette smoking in areas with high fuel cover density and dry soil. In the event of a wildfire, it is important to follow the instructions of local authorities and evacuate the area if necessary.

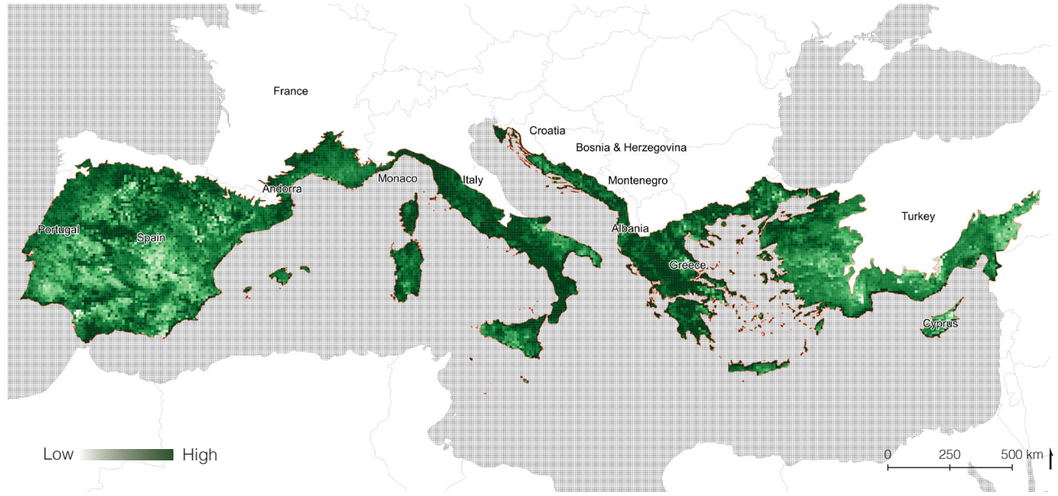


Fig. 5-13. Fuel cover density

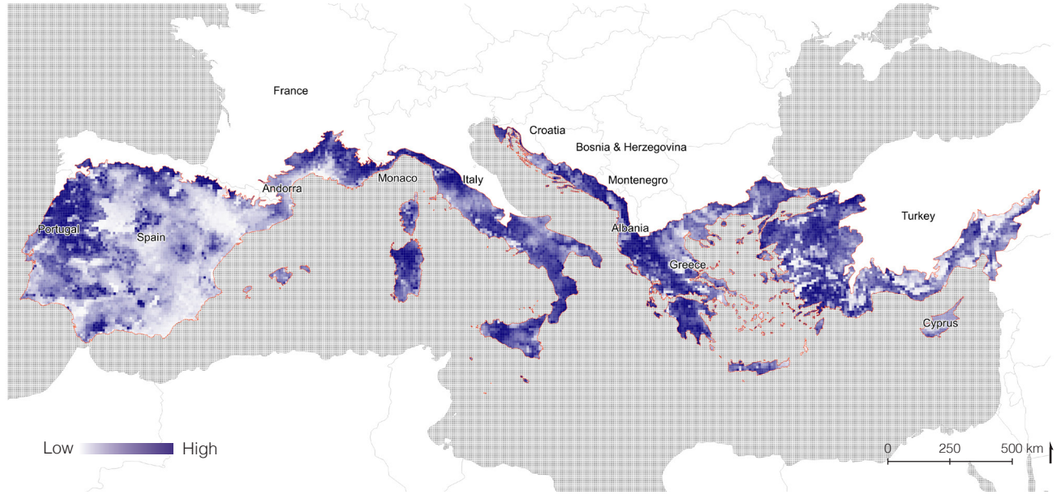


Fig. 5-14. Soil moisture

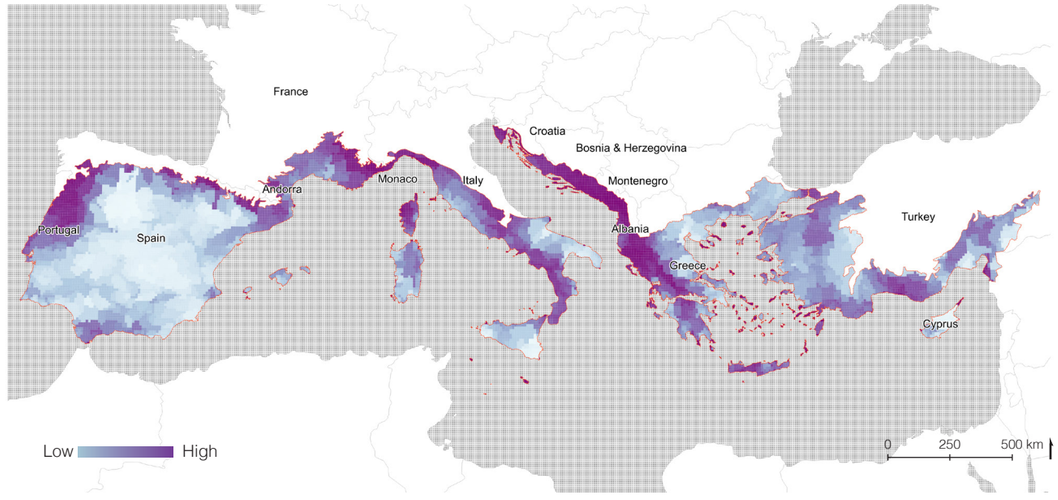


Fig. 5-15. River density

Biological susceptibility

The study area is characterized by a high degree of biological diversity, with a range of plant and animal species that have adapted to the unique climatic conditions of the region (Pausas & Vallejo, 1999). Wildfires shapes these ecosystems with many species having evolved to thrive in fire-prone environments. Mediterranean pine trees and eucalyptus have developed thick bark and serotinous cones that allow them to survive and regenerate after fire. High-intensity wildfires can lead to significant tree mortality, reducing tree cover density and altering the structure and composition of forest ecosystems. In addition, fires can cause changes in hydrological conditions, increasing the risk of soil erosion and altering water quality (Bodí et al., 2014). Specific river valleys and soil types can be particularly vulnerable to the impacts of wildfire, with erosion and sedimentation leading to decreased biological diversity and degraded ecosystem services.

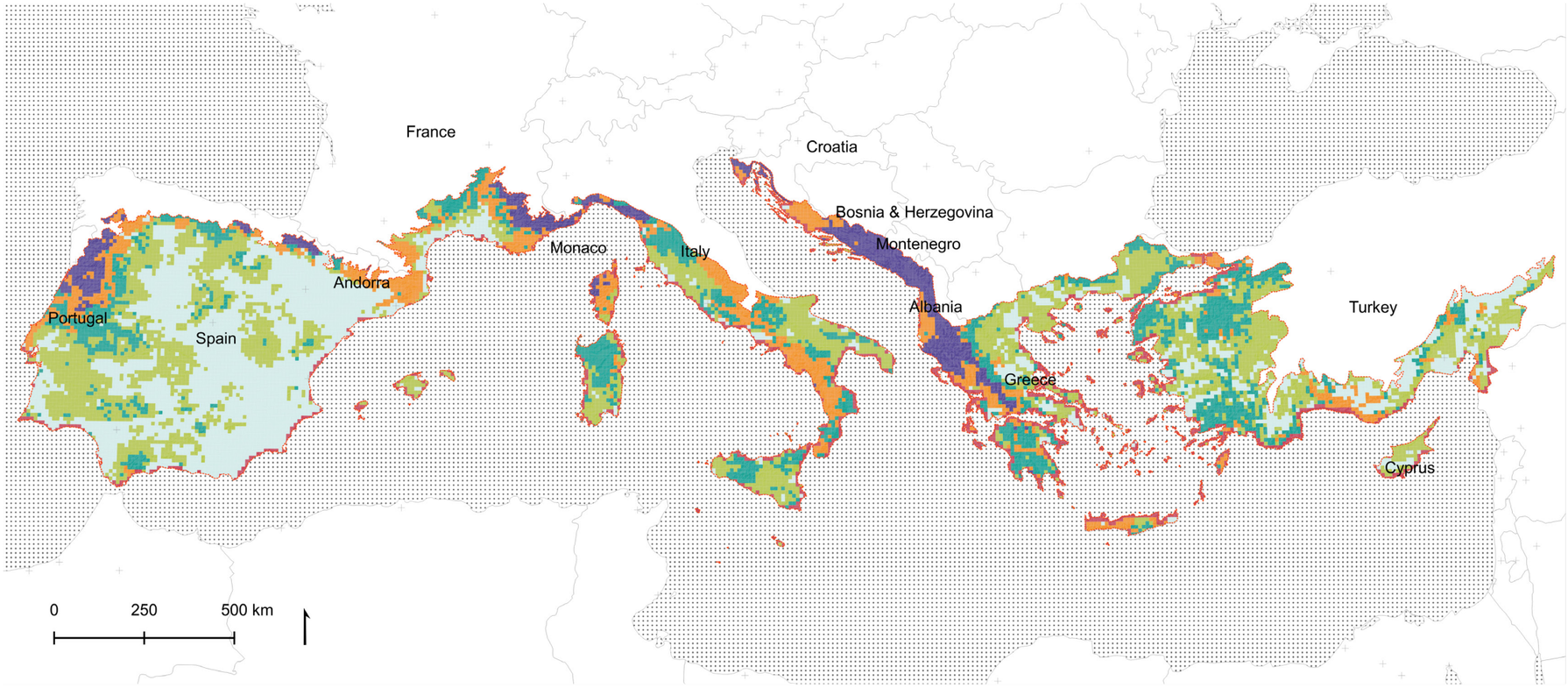


Fig. 5-16 Biological susceptibility

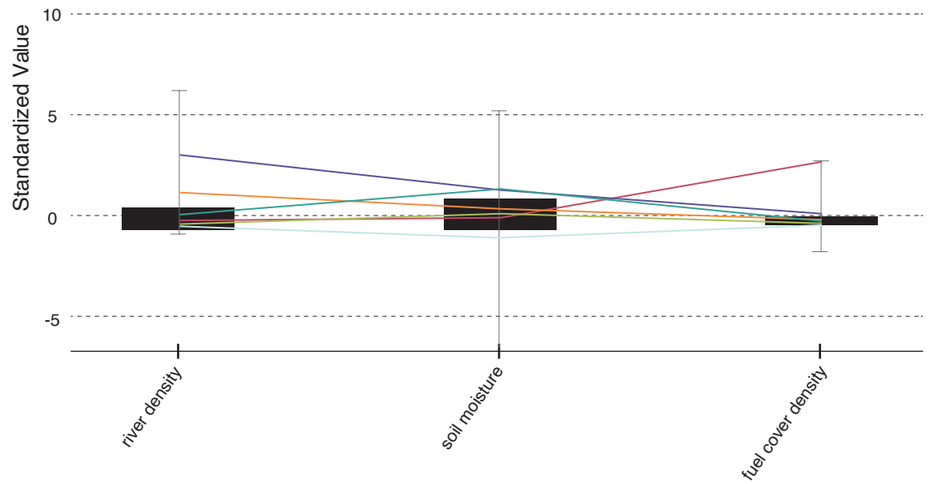


Fig. 5-17. Clustering box-plots

Wildfires in the Mediterranean Basin (EU part) are not only influenced by natural factors such as temperature, humidity, wind patterns, and fuel conditions, but also by human factors such as land use, forest management, population density, and infrastructure. In this response, we will explore the human dimensions of wildfire risk in the region, focusing on wildland-urban interface, population density, road density, land-use change, and forest management intensity.

Wildland-Urban Interface: The wildland-urban interface (WUI) refers to the areas where natural vegetation meets human development. In the Mediterranean Basin, WUI areas are particularly vulnerable to wildfires, as they combine high fuel loads with the presence of structures and people. As more people move into WUI areas, the risk of wildfires increases. For example, in many Mediterranean countries, rural populations have been moving to urban areas, leaving behind unmanaged forests and farmland that can easily ignite and spread fires.

Population Density: Population density is another important factor in wildfire risk. In the Mediterranean Basin, many urban areas are located near natural landscapes, increasing the potential for fire to spread from wildlands into urban areas. As more people move into the region, the risk of wildfires increases due to the increased likelihood of human-caused fires and the potential for fires to impact populated areas. For example, in Greece, the population has grown rapidly in recent decades, with many people moving into WUI areas, increasing the risk of wildfires.

Road Density: Road density is also a critical factor in wildfire risk, as roads provide access to remote areas and can facilitate the spread of fires. In the Mediterranean Basin, the construction of roads and other infrastructure can fragment natural landscapes, making them more vulnerable to fires. For example, in Spain, the construction of roads and buildings has led to the fragmentation of forests, increasing the potential for fires to spread quickly and over large areas.

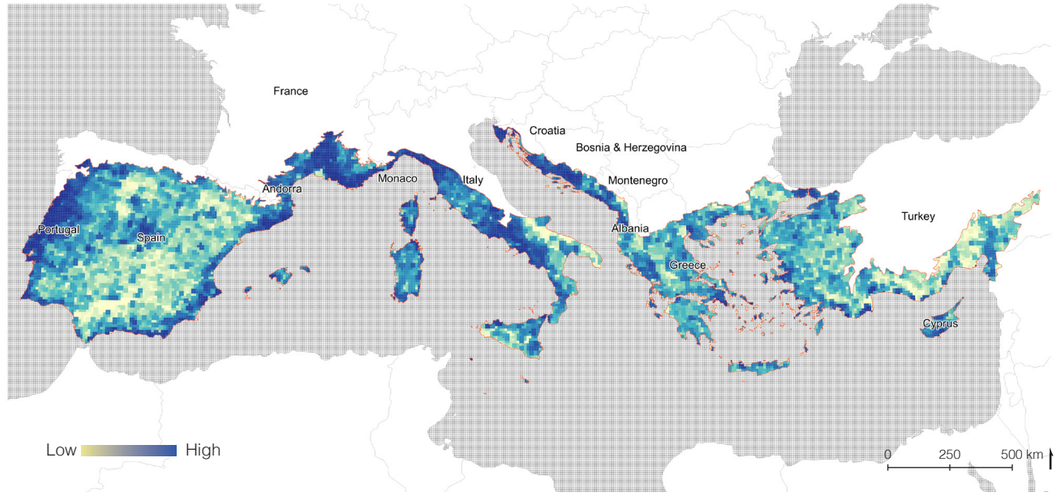


Fig. 5-18. WUI

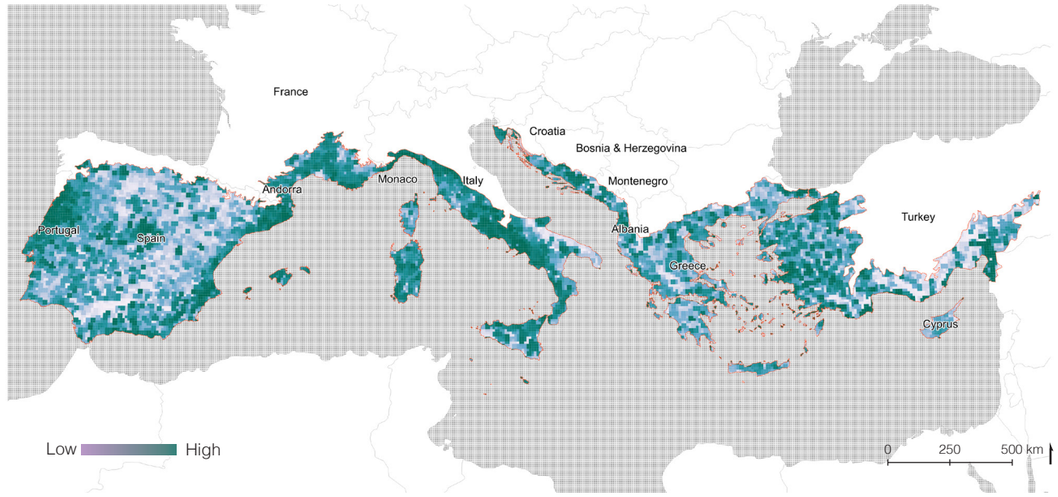


Fig. 5-19. Population density

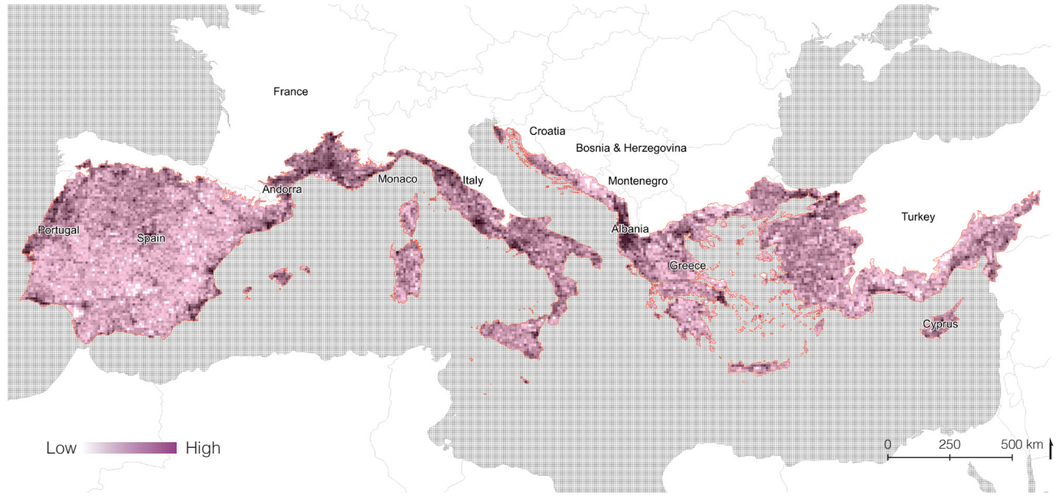


Fig. 5-20. Road density

Land-Use Change: Land-use change, particularly the conversion of natural habitats into agricultural or urban areas, can also increase the risk of wildfires. As natural landscapes are replaced with crops, buildings, and roads, the risk of fires increases due to the presence of combustible materials and the reduction in natural fire breaks. For example, in Italy, the conversion of forests and shrublands into farmland has increased the risk of wildfires, as agricultural activities can lead to the accumulation of dry plant material that can easily ignite and spread fires.

Forest Management Intensity: Finally, forest management practices can also influence wildfire risk. In the Mediterranean Basin, forests have traditionally been managed through prescribed burns and other techniques that reduce fuel loads and create natural fire breaks. However, in recent decades, there has been a trend towards more intensive forest management practices, such as clear-cutting and the removal of dead wood, which can increase the risk of fires. For example, in Portugal, the use of clear-cutting and other intensive forestry practices has led to the loss of biodiversity and increased the risk of wildfires.

In conclusion, wildfires in the Mediterranean Basin (EU part) are influenced by both natural and human factors. Human factors such as population density, land-use change, road density, and forest management intensity can increase the risk of fires by altering natural landscapes, fragmenting habitats, and increasing the potential for ignition sources. Wildland-urban interface areas, in particular, are at high risk of wildfires due to the combination of high fuel loads and the presence of people and structures. It is important for policymakers and land managers to consider these human dimensions of wildfire risk when developing strategies for fire management and prevention. This may include promoting sustainable land-use practices, reducing the risk of human-caused fires, and restoring natural fire regimes in forests and other ecosystems.

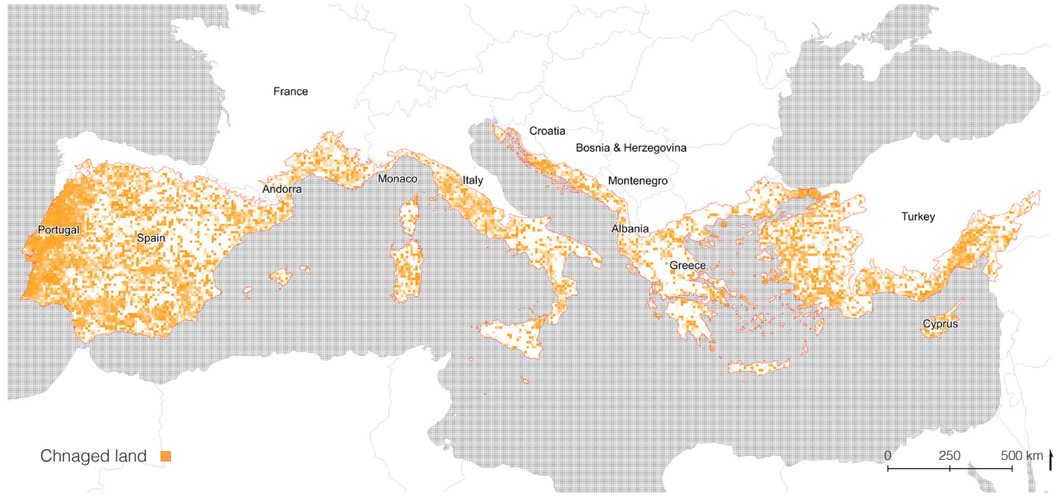


Fig. 5-21. Land-use change

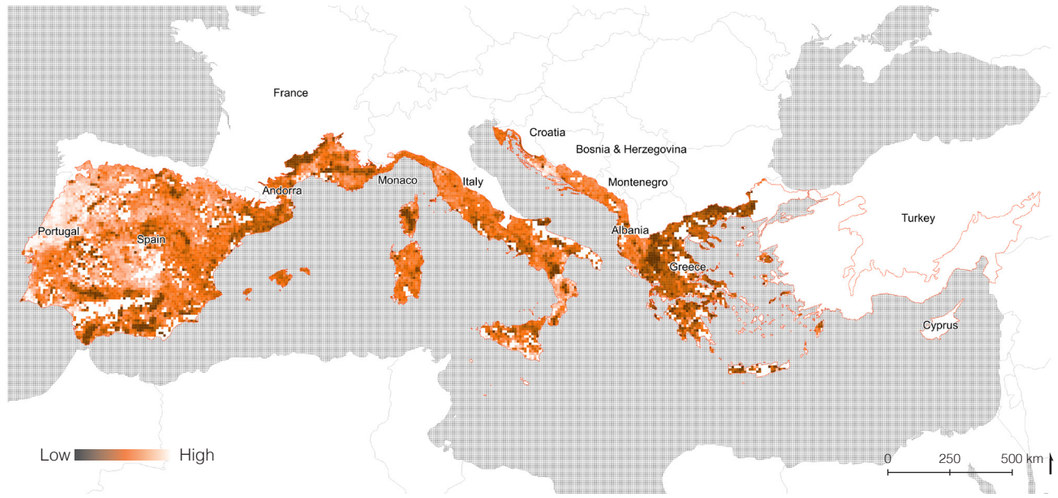


Fig. 5-22. Forest management intensity

Anthropogenic susceptibility

Humans and fuel are important parts of the system and that reciprocal effects exist between many components of the system (Riley et al., 2019). Firstly, the wildland-urban interface (WUI) in Mediterranean countries is characterized by a mix of land uses, challenging topography, and limited infrastructure and resources, which pose significant challenges for managing wildfire risk (Mitsopoulos et al., 2015). In southern Spain, the WUI is characterized by the extensive development of tourist resorts and urban areas along the coast, which are located in close proximity to natural areas. Additionally, the abandonment of agricultural production has led to a proliferation of wildland areas that are more susceptible to wildfire. Since the beginning of the 20th century, economic development has lead to a massive abandonment of agricultural land in Mediterranean regions (Nainggolan et al., 2012). In Spain and Portugal this evolution has been quite dramatic resulting in the abandonment of many marginal lands due to both heavy stocking reduction and crop abandonment. The selective abandonment of marginal agriculture land in more mountainous areas and the concentration of crop fields in valley bottoms near urban centres can lead to an increased homogeneity of (semi-) natural land use/cover types, such as shrublands and forests.

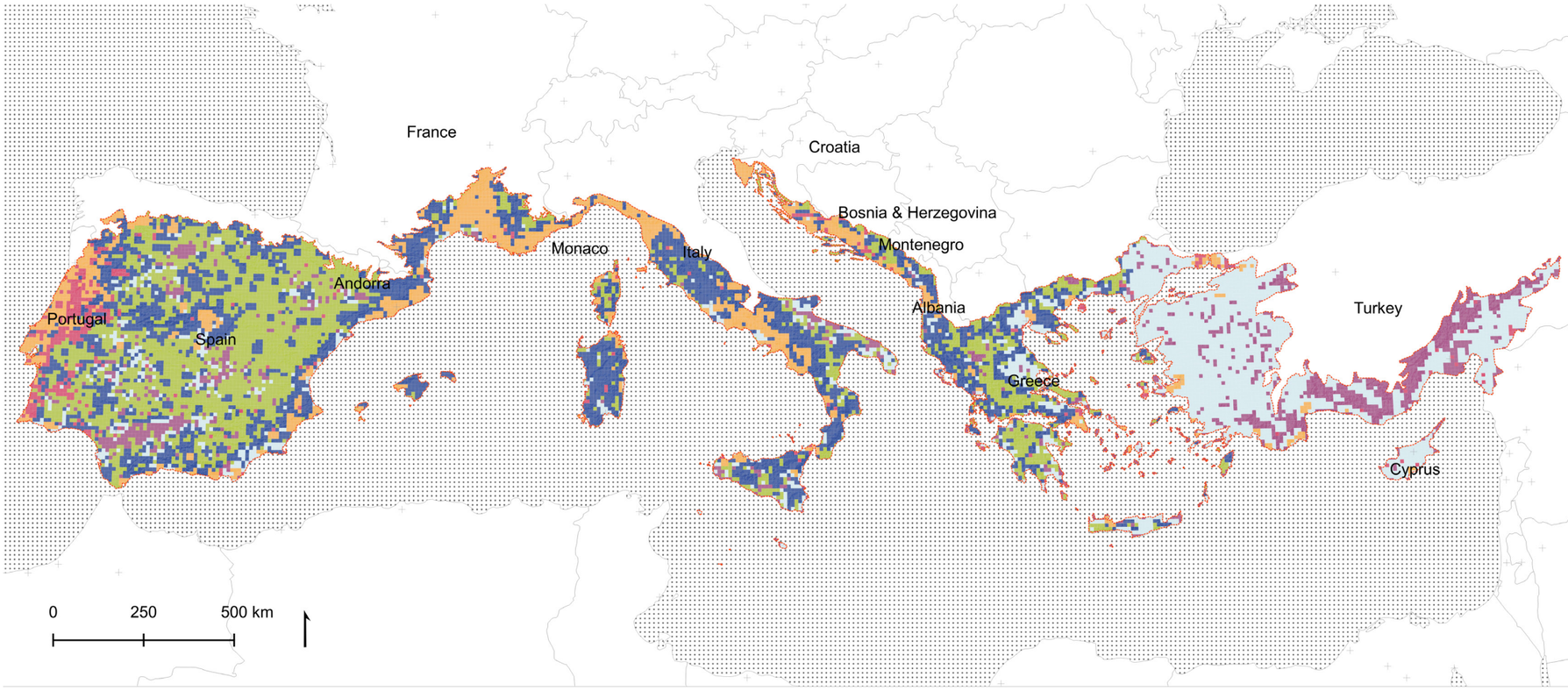


Fig. 5-23. Anthropogenic susceptibility

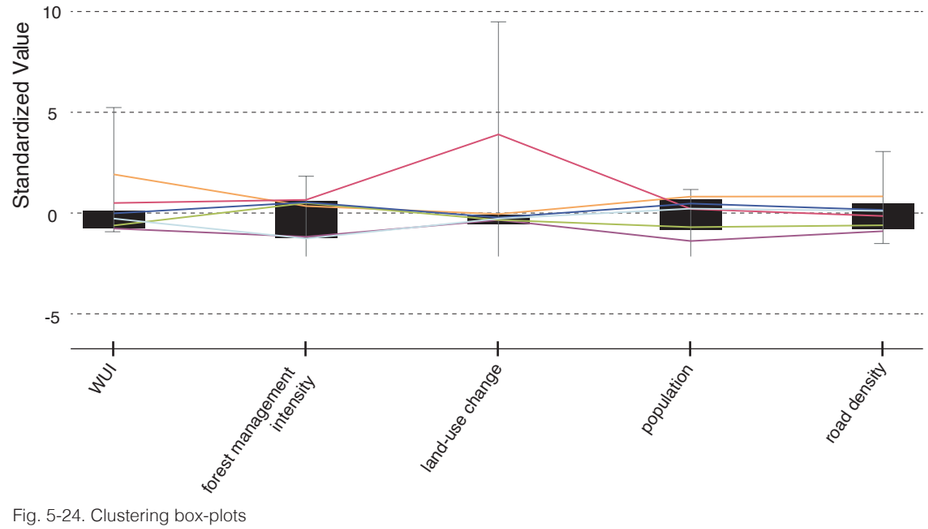


Fig. 5-24. Clustering box-plots

LANDSCAPE-BASED FIRE TYPOLOGIES

France
Monaco
Italy
Andorra
Portugal
Spain
Croatia
Bosnia & Herzegovina
Montenegro
Albania
Greece
Turkey
Cyprus

Settlement Distribution

- Urban interface mixed with unmanaged wildland
- Populated coastal land with intensive fuel cover
- Fragmented villages with multiple rainfed agricultural lowland

Land-use Dynamics

- Abandoned agricultural land with intensive fuel cover
- Extensive open dryness rangeland in high altitude

Fuel Management Differentiation

- Low intensity management woodland in humid river valley
- Multifunctional management with medium vegetative cover

Climatic & Environmental Disturbance

- Hillside in south facing with strong radiation
- Hillside in steep slope with high wind speed
- High windy propelled intensive fuel island

0 250 500 km

Fig. 5-25. Final result of fire-landscape typologies

MED ATLAS

10 Typologies

The diagnostic map of landscape-based fire typologies in terms of both composition and configuration is one of the main outputs of this research that is shown in the following figures. They illustrate the proportion of each typology in the extent of whole study area and their dominant features, which is also the basis for naming and grouping. Wildfires are produced and interact with identified ground realities among each of the landscape typologies, corresponding to part of Mediterranean land system features simultaneously (Blondel, 2006).

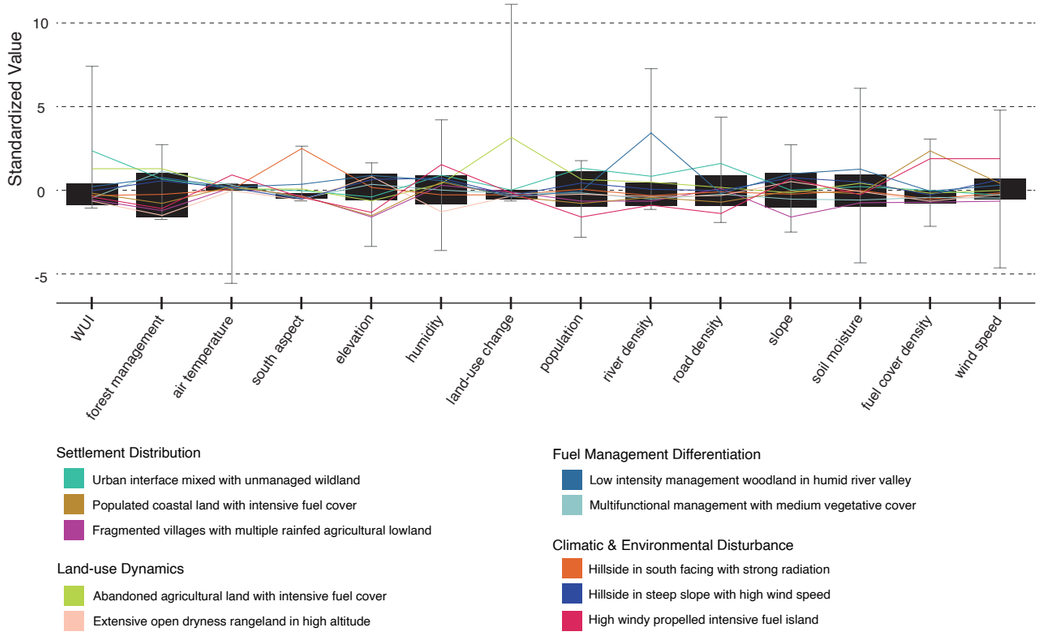


Fig. 5-26. Clustering box-plots

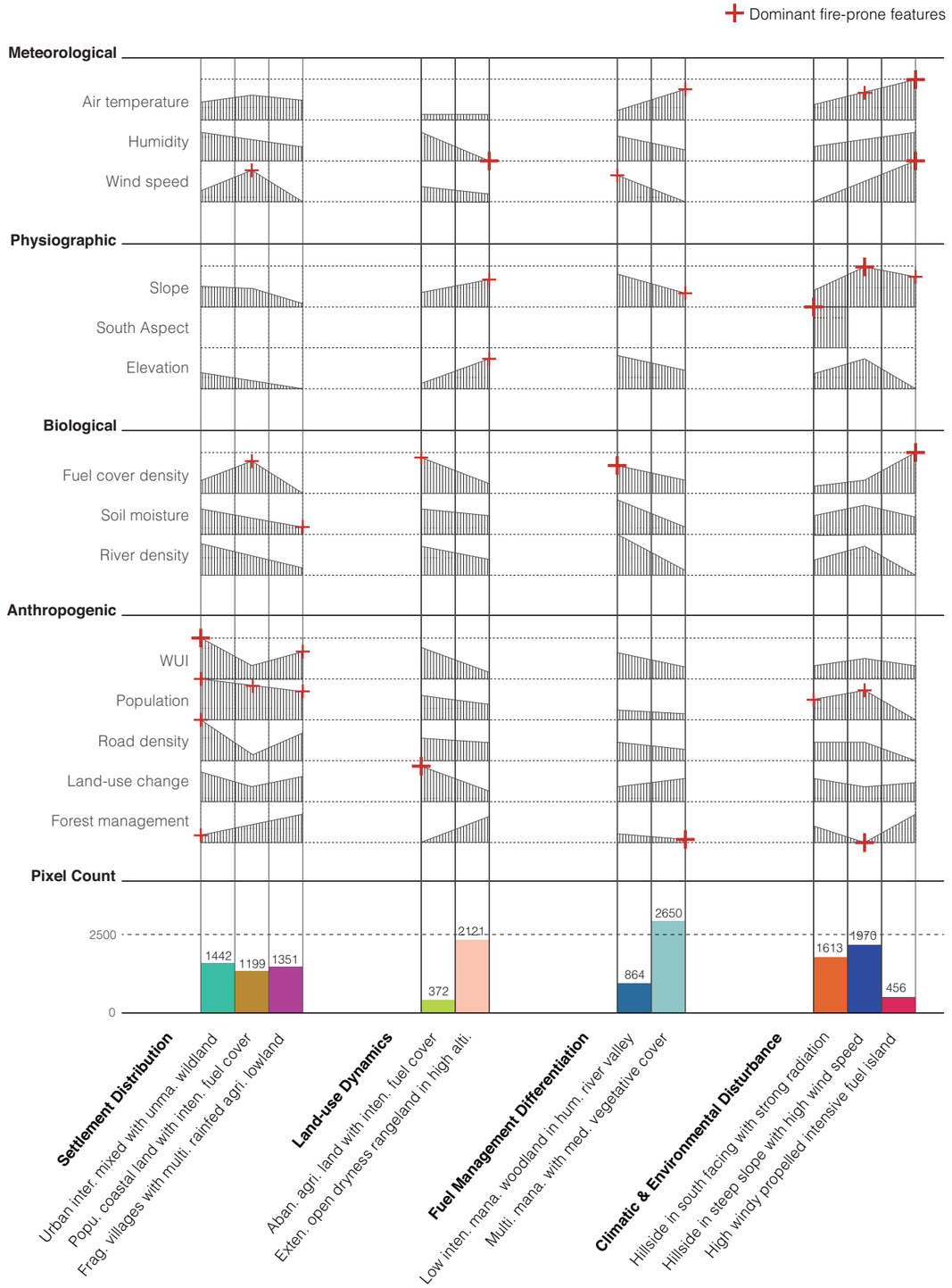


Fig. 5-27. Unpacking the dominant factors of each fire-landscape typologies

Settlement distribution

The typology of urban interface mixed with unmanaged wildland is characterized by the peri-urban areas have expanded into previously successive uninhabited wildland. Socio-economic trends in Europe towards more urban land use in rural regions and shrub encroachment are resulting to spatial change of interface (Modugno et al., 2016). The human properties are placed at high risk of woodlands and shrubs as the source of fuel for wildfires. Most of this type of landscape is often found at the foothills of south Alps and Apennine and middle Portugal. The second typology in this group is characterized by a combination of densely populated coastal areas and vegetation that is highly flammable under several transitional climate types and subtypes. The vegetation has a high concentration of oils and resins, making them highly combustible. For instance, Holm oak (Quercus ilex L.) is a climazonal species along the western Mediterranean, mostly in Croatian coast. Aleppo pine (Pinus halepensis Mill.) is a typical Mediterranean species that accounts for about 10% of all forests in the Mediterranean (Rosavec et al., 2022). The fragmented villages with multiple rainfed agricultural lowland type is basically distributed in the river basin of Guadiana and southern Tagus. The clustered villages among intensively used croplands, rangelands and seminatural lands parallel with altered fire regimes tend towards ecosystem process.

Land use dynamics

The typical Mediterranean region often shows human pressure affects the landscape characteristics through littoralisation, intensive agricultural practices, land abandonment, urban sprawl, and tourism concentration which leads soil deterioration and Land Use/Land Cover Changes (LULCCs) (Bajocco et al., 2012). This trend can be reflected in the fire typology of abandoned agricultural land with intensive fuel cover in the inland depopulation area in Spain and Portugal. This land abandonment results in unmanaged vegetation prone to fire and then, leading the soil erosion, deforestation and habitat fragmentation. In the Anatolia peninsula and Balkan regions, the next fire typology is identified as the extensive open rangelands with dry, arid conditions in remote areas with a lower population density. These areas are typically used for grazing livestock and are often located at high altitudes, where temperatures are cooler with lower potential evapotranspiration and vegetation is sparse. Wildfires in these areas tend to spread quickly due to the lack of vegetation and can be difficult to control.

Fuel management differentiation

Sustainability and multifunctionality have been the guiding European forest policy models (Aggestam & Pülzl, 2018) within which forest management with local conditions has been embedded in fire typologies definition. In this case, the river valleys of Durance in France, the Pindus Mountain ridge in Greece, and the Montenegro mountains areas are characterized as the next fire type. This close-to-nature management covers across large, interconnected areas may lead some natural wildfire ignitions. But at the same time, they are often located in a high river density context, where humid basin can help to prevent fires from spreading. The type of multifunctional management with medium vegetative cover is mainly distributed in the inland of Spain and northern Greece. The vegetation there exhibits fragmented patterns mixed with multifunctional and intensively managed forests which are aiming to more than one objective occurring e.g. timber, water production, erosion protection, biodiversity, climate mitigation and adaptation and recreation (Nabuurs et al., 2019).

Climatic and environment distribution

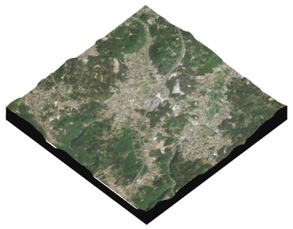
The last group of fire typologies characterization shows their specialities in hillside and archipelagos. One of the hillside types with particularly obvious landscape feature that is under the south facing hillside with strong radiation which promotes fire ignition and propagation. The pattern in dark blue represents the fire type of hillside in steep slope and canyons with high wind speed which illustrates some similarities with Mediterranean mountain system and often consistent with dense fuel configuration e.g. the Sistema Central in Spain and Portugal, the Apennines, and the Pindus Mountain in Greece. The devastating fires are associated with short episodes of severe fire weather generated by hot and dry winds (Moritz et al., 2010). Noteworthy, hillside should not be considered as the isolated landscape feature in fire typologies. The smallest proportion typology of high windy propelled intensive fuel island shows its speciality in the Aegean archipelago and Malta. Of the various types of vegetation that make up the forests and woodlands on the islands, fire statistics indicate that most of the blazes occur in the Turkish pine (Pinus brutia) forests and, to a somewhat lesser extent, in shrub lands (Ne'eman & Trabaud, 2000). Prevention of fires on the islands, including the use of prescribed burning, is relatively inadequate, and public participation in fire prevention remains limited.

REPRESENTATION OF LAND SYSTEM

Contemporary landscapes are contingent outcomes of past and present patterns, processes and decisions (Rounsevell et al., 2012). Thus, the land system is central to understand the relationship between human and environment. Some researches have previously combined territorial indicators to classify land use systems, touching less with natural crisis. The biomass in Anthropocene on global scale has been mapped by Erle C. Ellis (Ellis, 2011), which framed a systematic classification of the hybrid socio-ecological fabric associated with the long and continuous human use of the earth's surface. The result from Tomáš Václavík (Václavík et al., 2013) reveals diversity across the global land system archetypes. European scale characterizations are mapped by Christian Levers etc. (Levers et al., 2018) and reflected as the land-system archetypes and archetypical change trajectories mainly within cropland, grassland or mosaic systems.

The approach moves forward the existing classification systems by accounting for the land system conditions with their specific landscape disturbance for the Mediterranean region. The 10 typologies in the groups of settlement distribution, land-use dynamics, fuel management differentiation, climatic & environmental disturbance reinterpret the Mediterranean landscape at the first time under a novel semantic system of wildfire risk, revealing another way of understanding territorial realities (Fig.6). Considering the possible degradation of landscape value and the loss of the cultural pattern in the Mediterranean region (Čurović et al., 2019), this identification of fire-landscape system could also put the existing characteristics in a dynamic process of climate change, ecosystem evolution and settlement emigration.

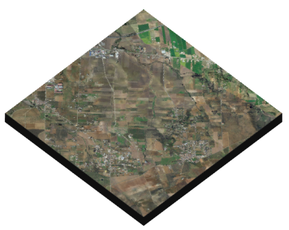
Settlement Distribution



Typology 1: Urban interface mixed with unmanaged wildland

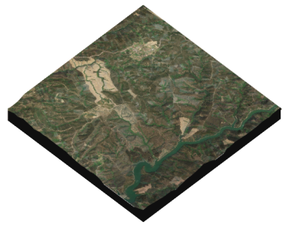


Typology 2: Populated coastal land with intensive fuel cover

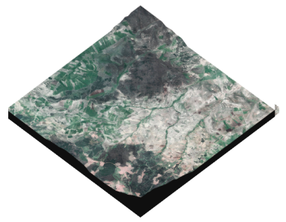


Typology 3: Fragmented villages with multiple rainfed agricultural lowland

Land-use Dynamics

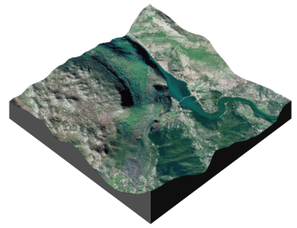


Typology 4: Abandoned agricultural land with intensive fuel cover

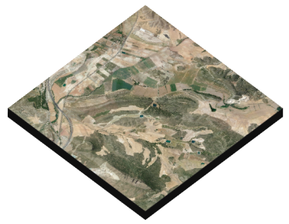


Typology 5: Extensive open dryness rangeland in high altitude

Fuel Management Differentiation

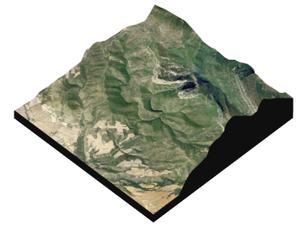


Typology 6: Low intensity management woodland in humid river valley

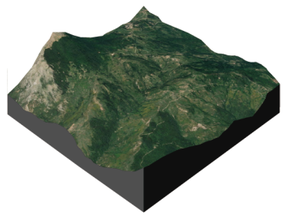


Typology 7: Multifunctional management with medium vegetative cover

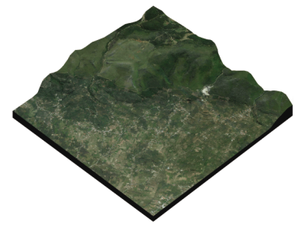
Climatic & Environmental Disturbance



Typology 8: Hillside in south facing with strong radiation



Typology 9: Hillside in steep slope with high wind speed



Typology 10: High windy propelled intensive fuel island

Fig. 5-28. Fire-landscape typologies matrix

6

TOOLKITS IN TILES

Typologies Interactivities

Preparedness

Response

Recovery

Prevention

Mitigation

From Typologies to Toolkits

Toolkits have become an increasingly popular approach to risk management, and this approach has been adopted in the fire-landscape typologies towards fire risk management. The toolkits are organized into five groups that correspond to the stages of the Risk Management Cycle: prevention, mitigation, preparedness, response, and recovery. Each toolkit visualizes one action that is tailored fire-landscape risk using a set of tiles that are arranged on a plan view.

The toolkits provide a set of landscape-based approaches that are intended to be scaleless and contextless, allowing them to be applied in a wide range of contexts. They are primarily rooted in conservation and the scienece of landscape ecology, to integrate practice for multiple land uses, within a given area, to ensure equitable and sustainable use of land while strengthening measures to mitigate and adapt to fire risk. The tiles in the toolkits are linked to each other, which allows stakeholders to develop a systemic approach to risk management. Each tile represents a specific action that can be applied individually or collectively in certain combinations.

However, it is important to note that the utilization of these tools needs to consider the local context in order to apply them more effectively. This is because the risk factors that contribute to fire-landscape risk can vary greatly from one location to another, and the strategies that are effective in one context may not be effective in another. As such, it is important to tailor the toolkits to the specific needs and circumstances of each location.

One of the key benefits of the toolkits is that they provide a systemic approach to risk management that enables stakeholders to develop place-based visions for risk reduction. This approach supports the design process by providing stakeholders with a clear understanding of the actions that can be taken to mitigate risk. Additionally, the toolkits can be used to monitor the state of fire risk and identify areas where additional action is required.

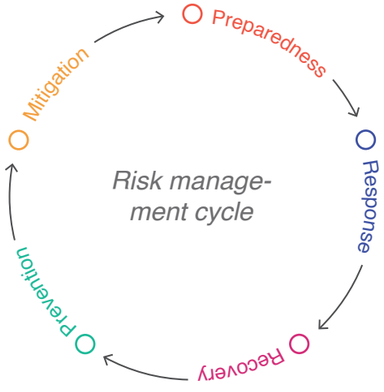


Fig. 6-1. Risk management cycle

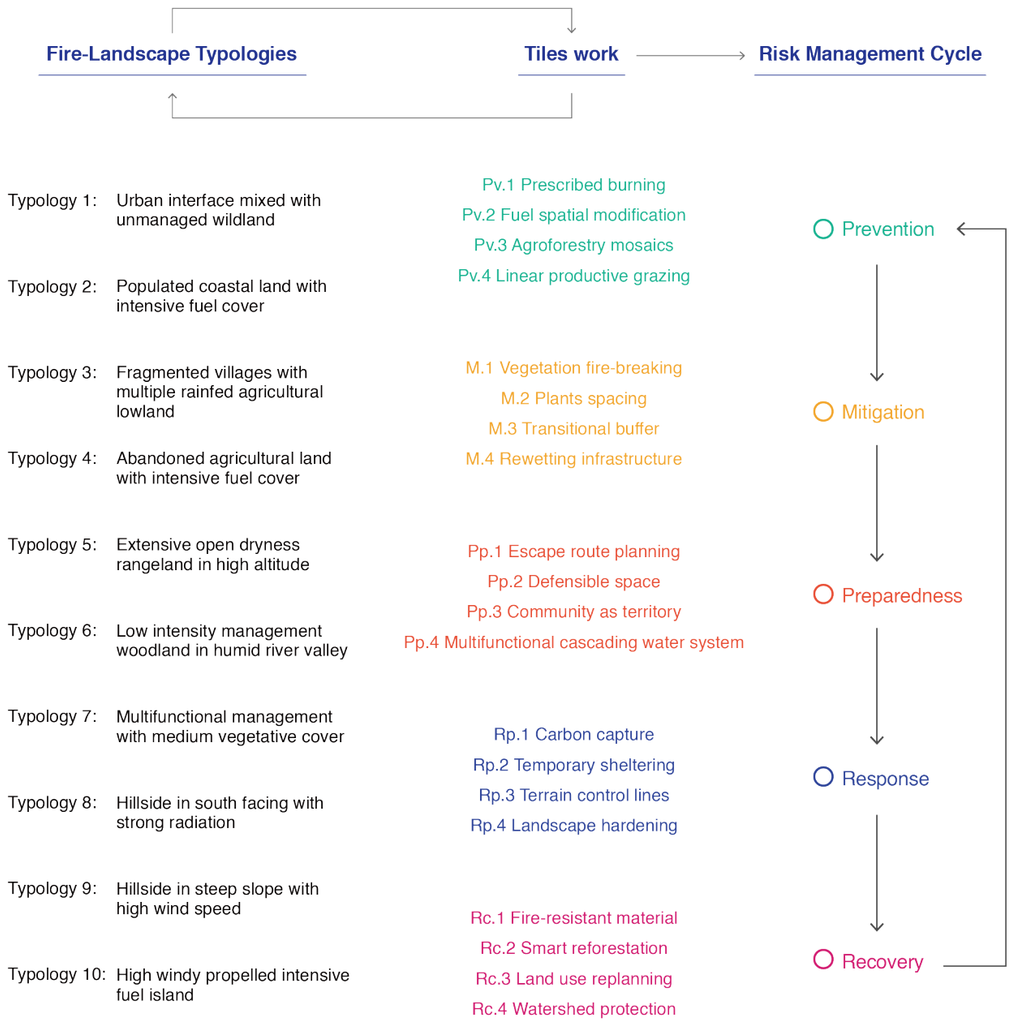


Fig. 6-2. From typologies to toolkits

PREVENTION

Prescribed burning

Prescribed burning has been introduced primarily to control fire regimes by managing fuels, counteracting the disappearance of biomass-consuming practices and reducing the fire risks inherent in highly flammable forests and shrublands. PB is a way of preservation or restoration of valued open habitat. It is also viewed as a tool for increasing structural and species diversity.

Fuel spatial modification

Fire intensity and severity in a given forest stand do not depend only on the characteristics of that stand, but also on the intensity of the fire at the time of its arrival, so that the characteristics of adjacent stands have an impact on fire effects in the given stand. Modifying the spatial distribution of fuel types across the landscape is thus one way to alter the behaviour of fire and its potential area of spread.

Agroforestry mosaics

Agroforestry landscapes with a diversity of land uses are less prone to wildfire than forests, shrublands, or grasslands, and that grazing in woodlands is effective in preventing fuel accumulation support this idea. It brings complexity and heterology of landscape simultaneously in order to improve the self-resistant ability of ecosystems.

Linear productive grazing

Sheep and goats are usually guided by a shepherd, who can ensure that high stocking rates are maintained on the fire breaks defined by forest service without the use of fences while still allowing the flock access to adequate water and feed. Involving shepherds in forest protection can have further benefits for wildfire prevention - they reduce vegetation fuel load and provide an early warning of any fires which occur and their very presence on the pasture can discourage arsonists.

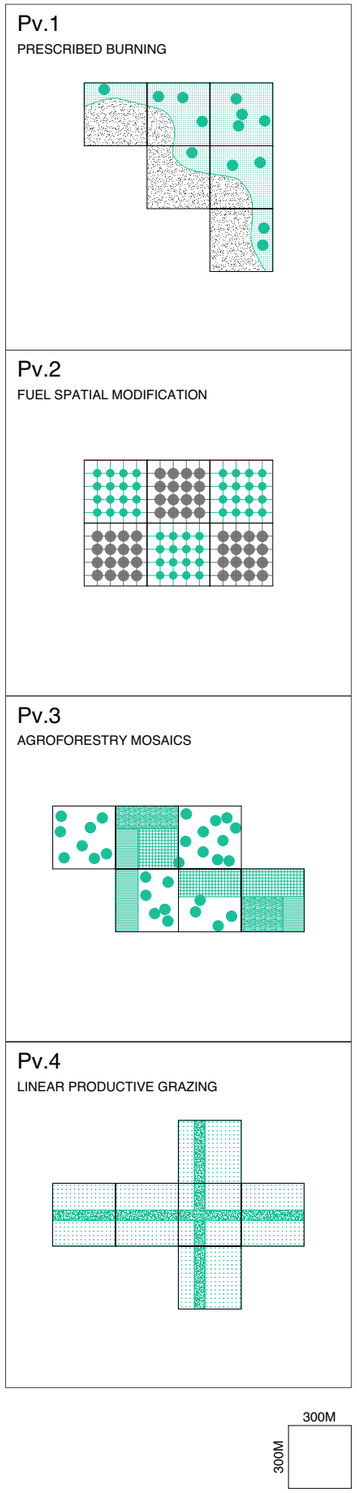


Fig. 6-3. Prevention

MITIGATION

Vegetation fire-breaking

A firebreak is an area where all vegetation and organic matter is removed down to mineral soil, thereby removing the fuel leg of the fire triangle. The purpose of a firebreak is to deny a fire any combustible material. To prevent weeds from establishing in a firebreak and to reduce future maintenance. Fire breaks must be created in the context of the landscape within which they are placed.

Plants spacing

To reduce the spread of wildfire, the amount of spacing needed is determined by the type and size as well as the slope of the land. For the vertical spacing, it is allowed extra vertical space between shrubs and trees. Lack of vertical space can allow a fire to move from the ground to the brush to the tree tops like a ladder. Horizontal spacing depends on the slope of the land and the height of the shrubs or trees.

Transitional buffer

Buffers among buildings and vegetation are planted strips of lower-flammability vegetation that are strategically placed in the landscape to reduce fire spread and minimise the risks to people, biodiversity, and assets. The aim of this approach is also to increase ecosystem resilience within fire prone landscapes under climate-shifted fire regimes.

Rewetting infrastructure

Blocking canals is built to prevent more water from escaping from the peat and maintain a wet peat condition to prevent fires from occurring. Rewetting is needed to restore the soil moisture to its near natural condition. At this stage, water can be sourced from canal blocking, backfilling, boreholes and/or water retention techniques used for rivers or canals.

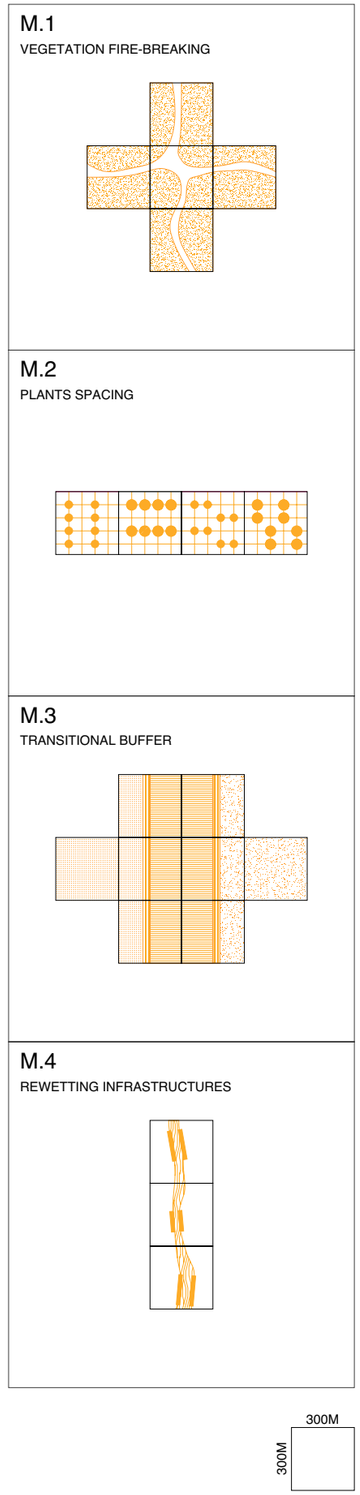


Fig. 6-4. Mitigation

PREPAREDNESS

Escape route planning

escape route planning is a critical aspect of fire risk management that can help to reduce the risk of injury or death in the event of a fire emergency. By identifying and designing effective escape routes and ensuring that all occupants are aware of them, fire safety professionals can help to ensure that everyone can evacuate quickly and safely in the event of a fire.

Defensible space

Defensible space is the required distance between properties and the surrounding area. It has three zones, including zone 0 (start to the house to be ember-resistant), zone 1 (keep it lean, clean and green), zone 2 (reduce potential fuel within specific distance). Adequate defensible space acts as a barrier and first line to slow or halt the progress of fire.

Community as territory

Considering community as an territorial unit provides better understanding of the impact of fire and fire recovery on communities. It contributes to a more general knowledge concerning fire. It is also benefitial to the developing knowledge base concerning differences both among communities and among various groups within communities about relationships to the forest and the impacts of forest management decisions in relation to fire.

Multifunctional cascading water system

Multifunctional cascading water system is designed to provide a reliable and efficient source of water for firefighting purposes. It consists of a series of interconnected water sources, such as reservoirs, tanks, and hydrants, that are strategically located following local topographic conditions. In rural areas where there are no fire hydrants, the system can draw water from nearby lakes, ponds, or other bodies of water to supply firefighting efforts.

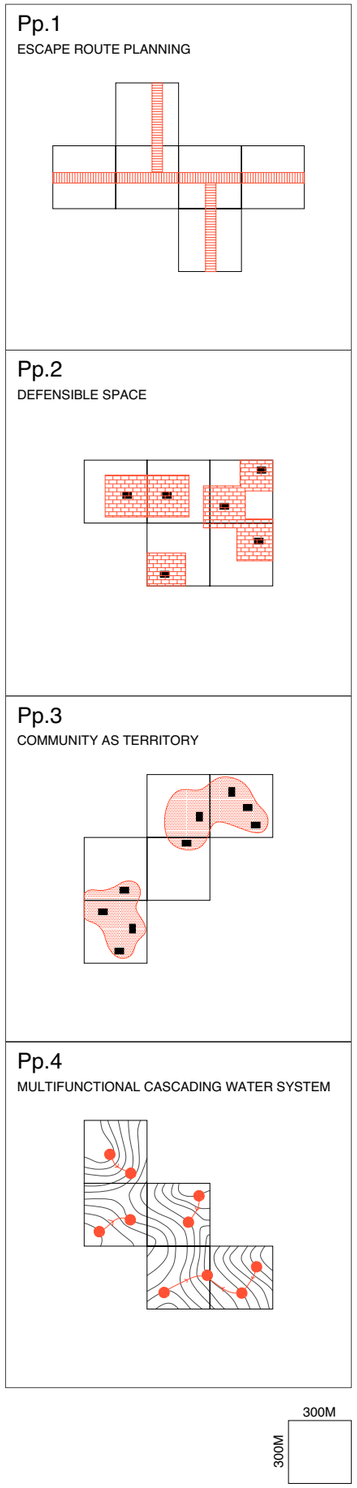


Fig. 6-5. Preparedness

RESPONSE

Carbon capture

Carbon capture infrastructure during a fire disaster refers to the technology and equipment that is used to capture and contain carbon emissions that are generated during a wildfire. An example is the use of carbon capture and storage (CCS) technology which involves capturing carbon emissions and storing them in a secure location, such as underground storage reservoirs or depleted oil and gas reservoirs.

Temporary sheltering

Temporary sheltering in fire-prone areas provides immediate relief and support to people. Temporary sheltering can take many forms, depending on the specific needs of the affected community. The provision of it is often a collaborative effort between government agencies, non-profit organizations, and community groups. It can help to build community resilience by providing a sense of support and solidarity during a time of crisis.

Terrain control lines

In especially fireprone areas, people are often encouraged to design fire lines around their homes, so that they will be safer in the event of a fire. These lines can be deliberately built into landscaping, in the form of an artfully curved driveway, a strategic series of gravel paths, or a well-placed pond. It is also a good idea to keep the vegetation close to a property well trimmed.

Landscape hardening

"Zero" combustible material is widely used in the landscape hardening surface to stop fire propagation. Use only noncombustible materials in this zone: concrete, pavers, bricks, gravel, etc. (NO organic mulch material) Maintenance is key: Clean out all dead or decaying plant material from this area: dead leaves, weeds, branches, grass, etc. This includes removing dead material and debris. Any plants in this zone must be fire-resistant: nonwoody, well watered, and low-growing.

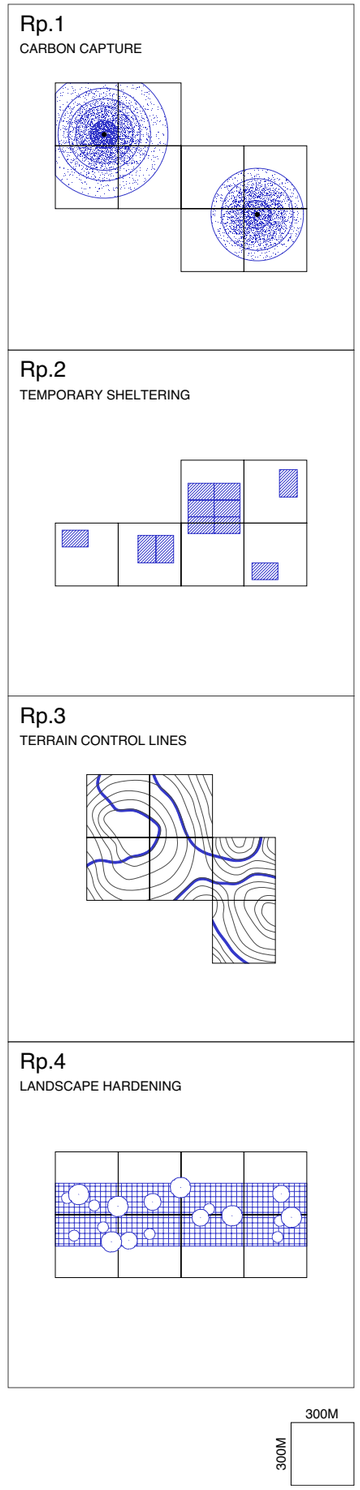


Fig. 6-6. Response

Fire-resistant material

Using fire-resistant building materials and designs include using non-combustible roofing, double-paned windows, and vents that can resist ember intrusion. It may also involve designing structures to be more resistant to fire, such as using materials that are less flammable or incorporating fire-resistant landscaping features.

Smart reforestation

The smart reforestation needs combination of planting and managing natural vegetation which is successful in the reintroduction of native resprouting species in the short term. Planting within the shrubland in the planting hole would create a more suitable environment for seedling establishment and growth, changing the successional trajectories of early postfire stages to fit ones toward later successional stages dominated by species that are more resilient.

Land-use replanning

Land-use replanning can reduce wildfire risk by helping communities grow and develop with wildfire in mind. It measures are diverse and can be customized to fit the needs of the neighborhood, community, or county. For example, the regulations can require defensible space in ignition zone, adequate water supply, road widths and access. Land-use replanning tools can also restrict development in areas of highest hazard.

Watershed protection

The after effects of a wildfire on watershed can be drastic causing immediate issues and long term effects. Rates of erosion and runoff can increase to dangerous levels. Normally trees, shrubs, grass and other protective groundcover help prevent soil detachment and allow rainfall to infiltrate into the soil. After a wildfire the extreme heat can bake the soil to the point that water is unable to penetrate and can cause excessive run off in a post wildfire area.

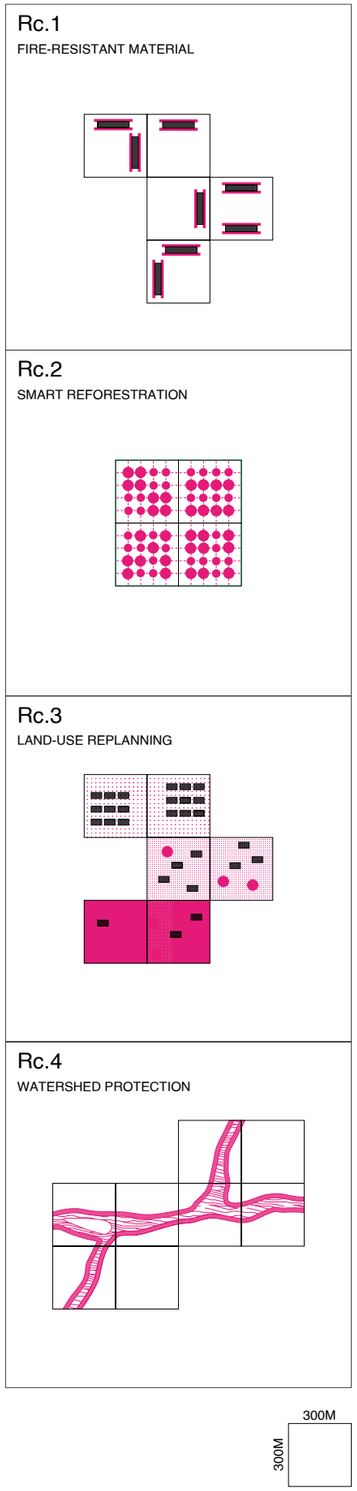


Fig. 6-7. Recovery

Supplementary

In case to support the landscape-based appraoches, the supplements are needed to balance competing demands on land through the implementation of adaptive and integrated management system. These include all of the internal and external socio-ecnomic , socio-political and culturaldrivers that affect land use.

Pp.5
RISK FUNDING TRANSFER

Pp.6
DEMOCRATIZING WILDFIRE STRATEGIES

Pp.7
ALL-IN-ONE PLATFORM

Rp.5
RAPID DAMAGE ASSESSMENT

Rp.6
REAL-TIME COMMUNICATIONS

Rp.7
EMERGENCY SUPPLY KIT

Pv.5
CULTURAL REGIMES RESTORATION

Pv.6
MULTISTAKEHOLDER PROCESSES

Pv.7
COUPLED-FIRE-ATMOSPHERE MODELING

Rc.5
PSYCHOSOCIAL WELL-BEING HEALING

Rc.6
FORESTRY INDUSTRIES CHAIN IMPROVEMENT

Rc.7
RECOVERY FOUNDATION COLLABORATION

M.5
FOREST MONITOR

M.6
EDUCATION AND OUTREACH PORTAL

M.7
SUBDIVISION REVIEW

Fig. 6-8. Supplementary toolkits

7

DESIGN FOR DUALITY

Reanalysis of the Iberian Peninsula

Selection of Two Sites

Design Methodology

The Typologies of the Iberian Peninsula

Towards design and strategic perspective, downscaling works are needed. So the next step of the project will focus on the Iberian peninsula where the same methodology is applied. The fire-prone landscape data are again group in meteology, physiography, biology and anthropology but clustered in 1km*1km grids.

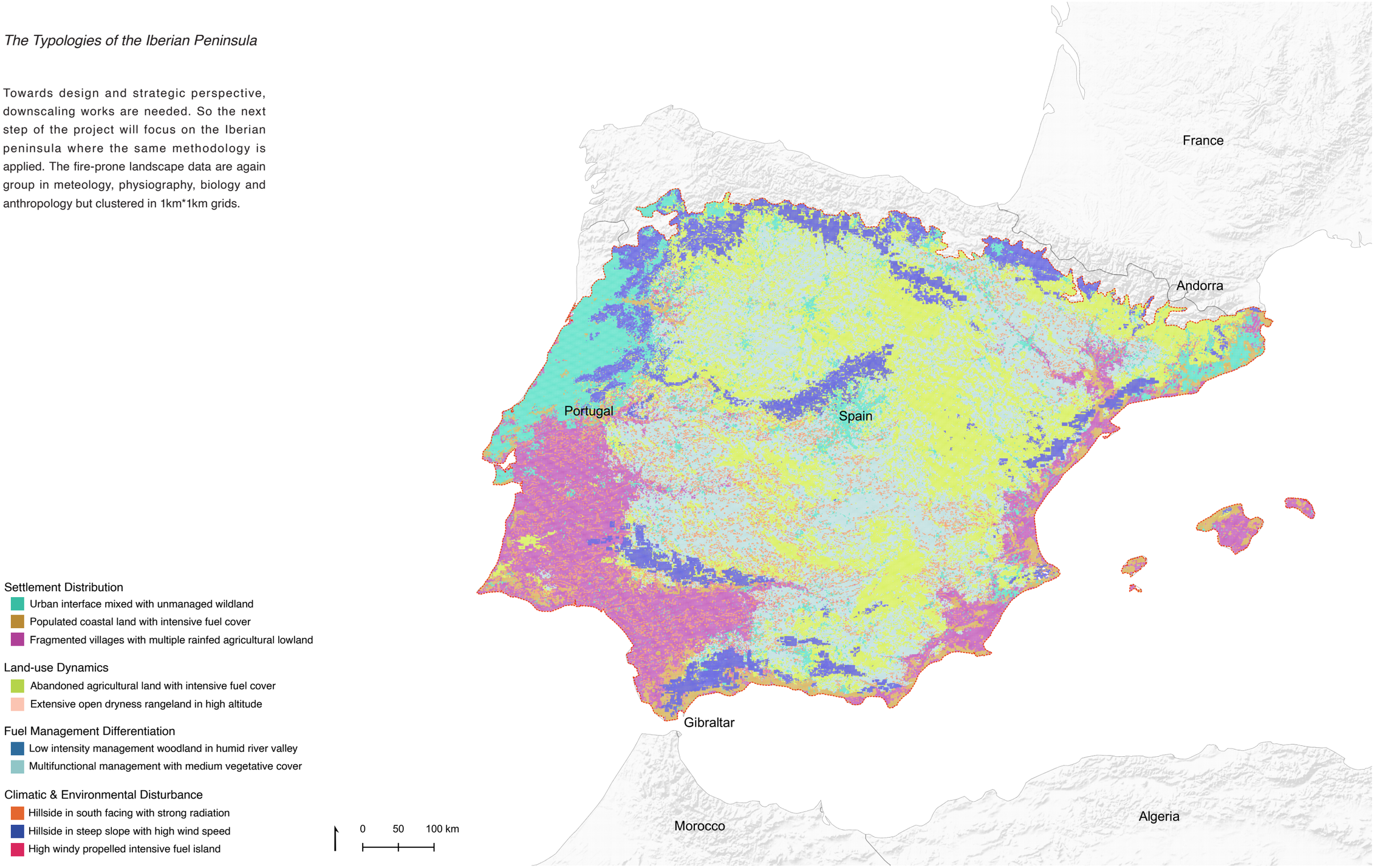


Fig. 7-1. Identifying fire-landscape typologies in the Iberian peninsula in 1km grids

SELECTION OF TWO SITES

Design for Duality

To better apply the combination utilization of the toolkits strategies, three of typical sites are selected in the middle transect of the Iberian peninsula. Following the definition of fire-landscape typologies in the Mediterranean scale in the previous chapter, these three sites are dominanted by three different fire-landscape typologies, and at the same time, composed by some sub-typologies as well. Here are the main features of these three sites:

• The first site would be the **wildland and urban interface** under the agricultural abandonment pressure in Coimbra, Portugal.

• The second one is located in a tourist attraction in Marina Alta (a coastal comarca of the autonomous community of Valencia, Spain) which the fire risk will be mitigate in the dense **populated coastal areas**.

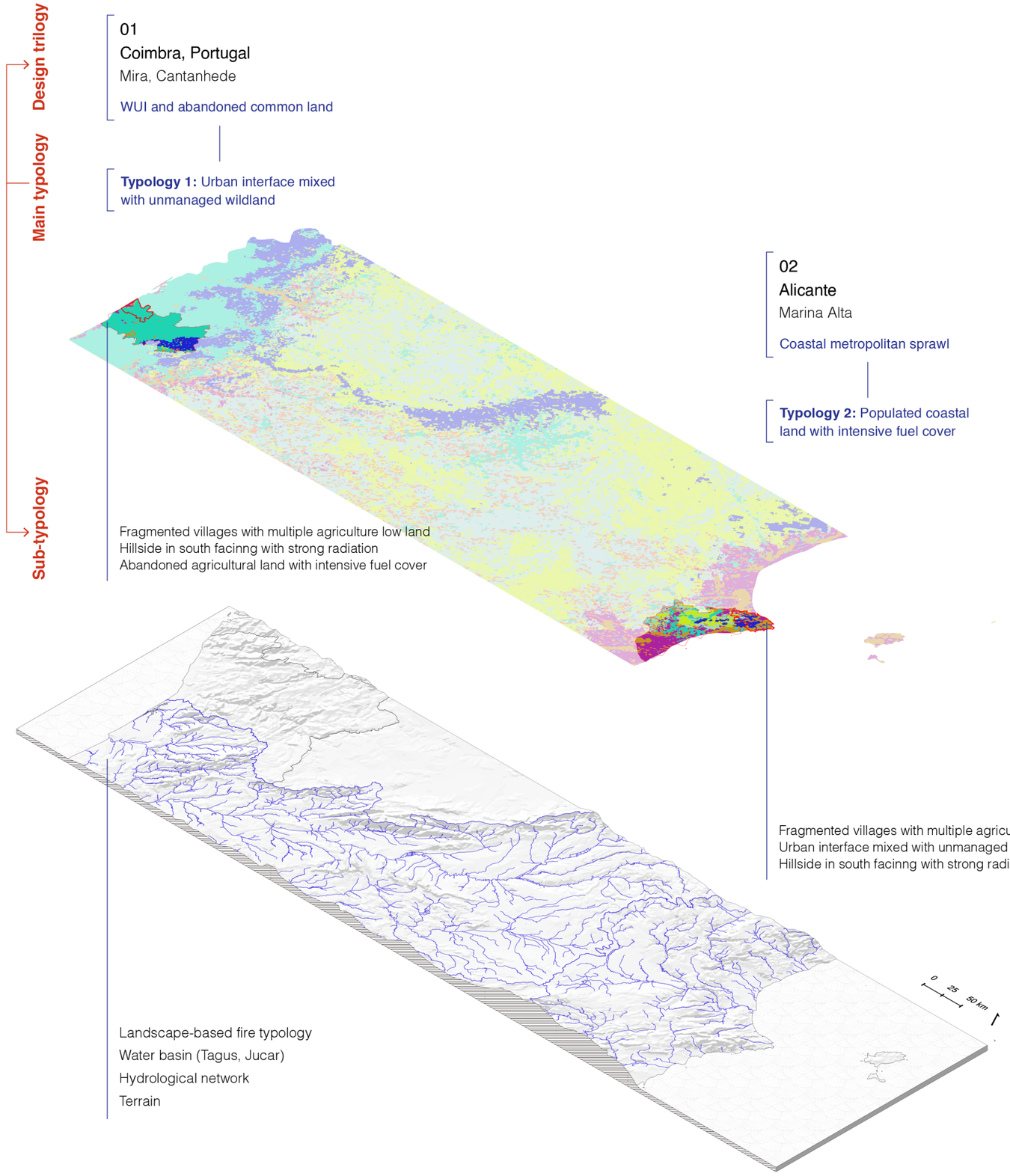


Fig. 7-2. Site selections

Take Landscape as Entity

The proposed design methodology for creating fire-resilient landscapes in the three sites of the Iberian Peninsula integrates the principles of fire ecology and landscape design. The methodology focuses on identifying the fire-landscape typologies present in each site and developing tailored toolkits to address the specific challenges of each typology.

The first step in this methodology involves a thorough assessment of the landscape features to identify the different fire-landscape typologies that exist within each site. This assessment will guide the design process and help to develop tailored toolkits for each typology. The identified typologies will also inform the selection of landscape entities for each site, taking into account the local context and understanding of the stakeholders.

Once the fire-landscape typologies have been identified, a toolkit is selected for each typology to bridge the gap between research and design. The toolkits are tailored to the specific needs and characteristics of each typology, and provide design with the necessary information and resources to address the unique challenges of each site.

Each of the selected sites represents a different fire-landscape typology. A specific landscape entity is identified to apply the toolkit and design principles, that are, community, mountain, and settlement. By identifying these landscape entities, the design process can ensure that it is contextually appropriate and considers the unique cultural and ecological conditions of each site.

Ultimately, the goal of this methodology is to create fire-resilient landscapes that balance the ecological needs of natural systems and the human needs for safety and economic prosperity. Through the integration of local context and fire smart landscaping principles, this methodology aims to create landscapes that are both resilient to fire and integrated into the human-natural system. By achieving this vision of fire-resilient landscapes, we can preserve the natural and cultural values of these landscapes while minimizing the risk of catastrophic wildfires.

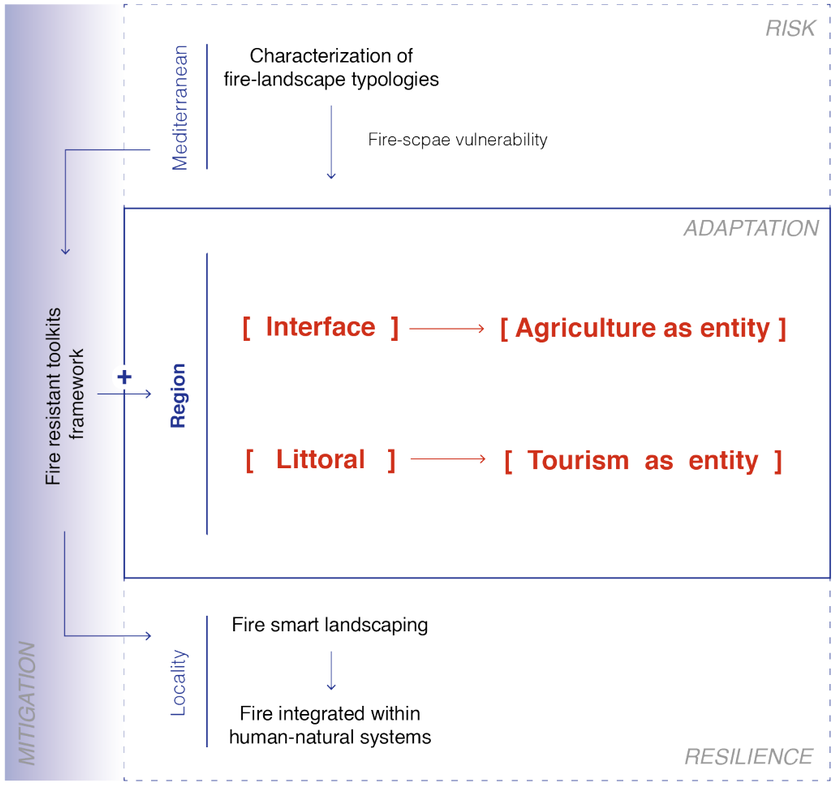


Fig. 7-3. Design methodology

8

WILDFIRE ALTERNATIVES_SITE 01

Fire-landscape Typologies

Fire Evolution

Climatic & Ecological Structure

Forest Dynamics

Forest Situation

Mobility Network

Interface Patterns

Flow of Community Units

Strategies Application

Strategy 01_Fire Break Network

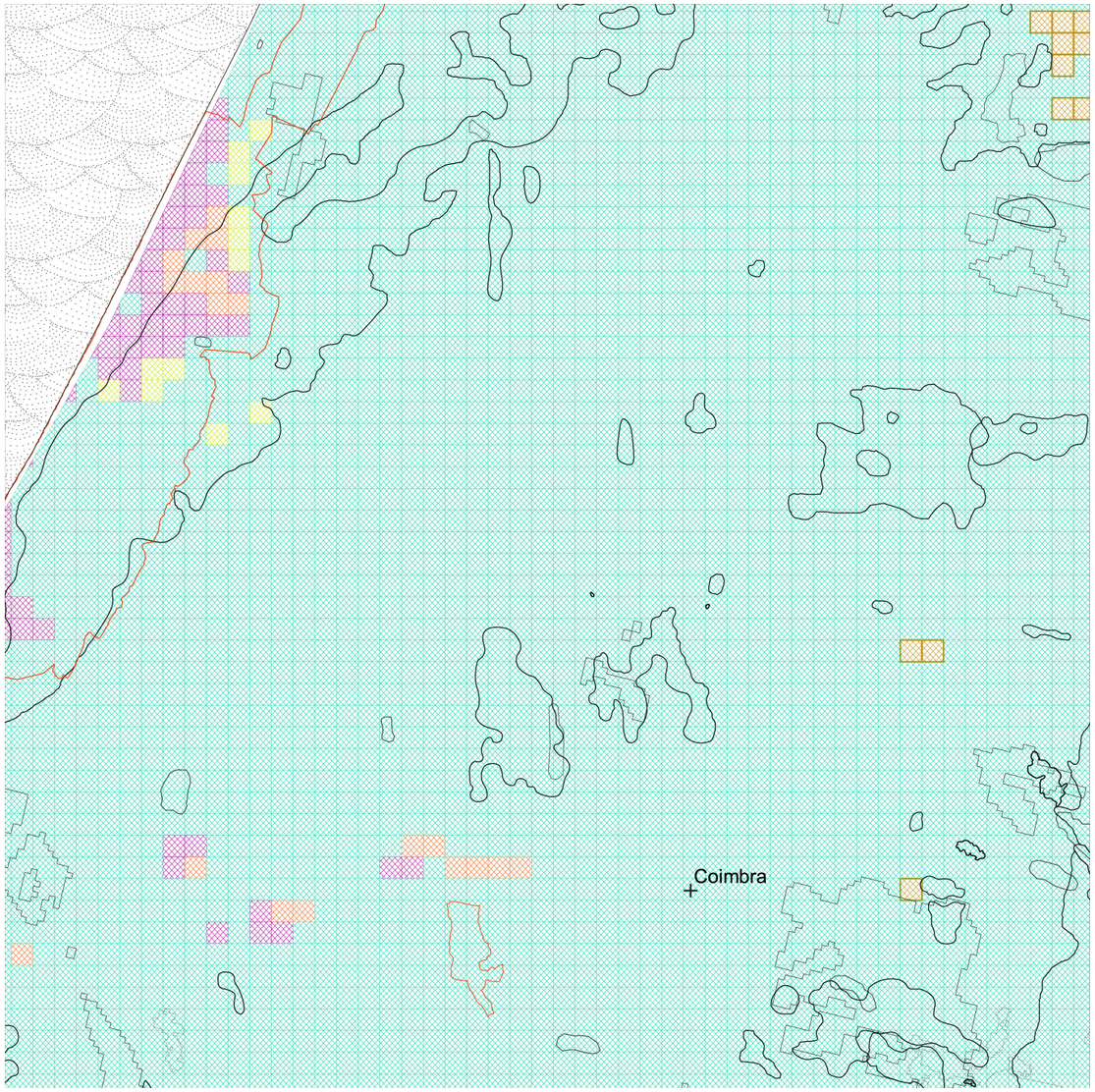
Strategy 02_Fuel Modification

Strategy 03_Community-based Management

Stakeholders Engagement

Long-term Fire Resilience

FIRE-LANDSCAPE TYPOLOGIES



Burnt areas
- 2020-2022
- 2015-2019
- 2010-2014
- 2005-2009
- 2000-2004

Fire typologies
- Urban interface mixed with unmanaged wildland
- Fragmented villages with multiple rainfed agricultural lowland
- Abandoned agricultural land with intensive fuel cover
- Hillside in south facing with strong radiation
- Populated coastal land with intensive fuel cover

- Natura 2000

FIRE EVOLUTION

1880s-1960s

Before 19th	Not many written documents regarding large forest fires
1859	National Wood of Leiria was affected by several fires, about 5000ha
1880s	A fire in the Estrela mountain range
1950-60s	A few large forest fires (mentioned by the National Plan for the Defence of Forests Against Fires (APIF)
1960s	The beginning of **seasonal scourge** of large forest fire, **relationship changed** between local communities and surrounding forests

1966s-1990s

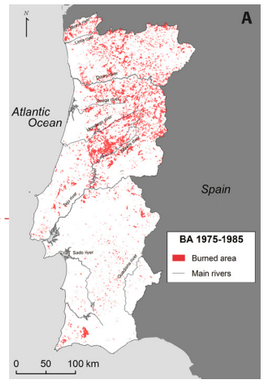
1966	A healthy coexistence between rural populations and fire --> a serious threat (lack of territory planning)
1970s	Not a crucial problem for Portuguese forests
1986	First time **reached 10,000 ha** of burned area in a single occurence
1987	Arganil, Oliveira do Hospital and Pampilhosa da Serra in Sept. 10,900ha forest land and pine trees
1990s	Recent reality: **Mega-fires**
2001-2010	Average burned area per year: 672 ha

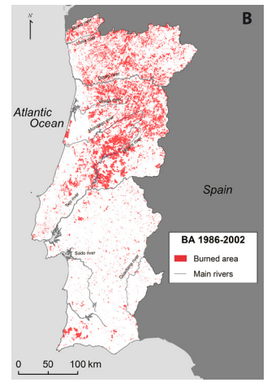
2003-2012

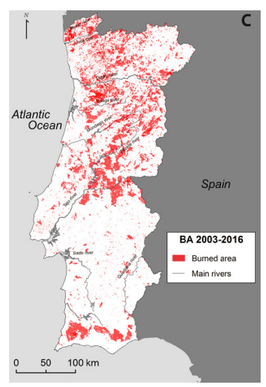
2003	Contiguous mega-fires started, e.g. Monchique mountain range and the Nisa region, in excess of 40,000ha
2005	Weather conditions were extremely unfavourable for a period of 18 consecutive days. 35,824 occurrences and destroyed 339, 089 ha in all municipalities
2005 Aug.	First time fire impacts one of the largest cities in Coimbra(within **urban perimeter**)
2012	First time fire burned **more than 20,000ha** (Tavira and São Brás de Alportel), extreme dry weather and water levels in the ground below 10%

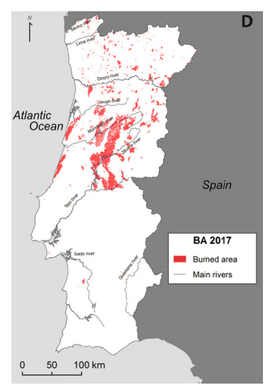
2017 - Present

2017	**A series of wildfires** under an intense heat wave (in excess of 40°C) -dry thunderstorms and arsonists -estimated 50,000 burned area, 111 deaths, 204 injuries -500 houses were desdroyed -Castanheira de Pera and Pedrógão Grande, Leiria

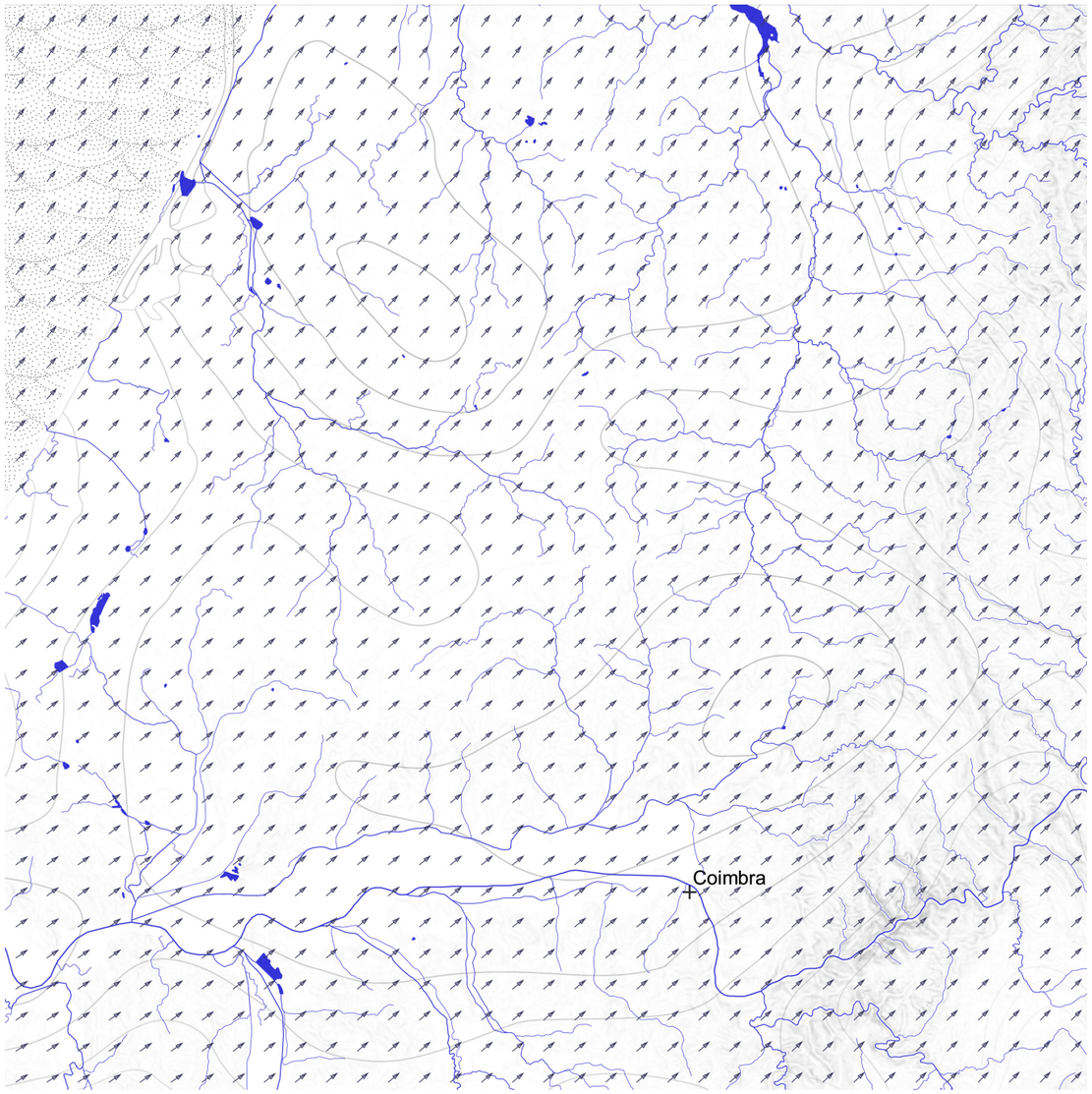






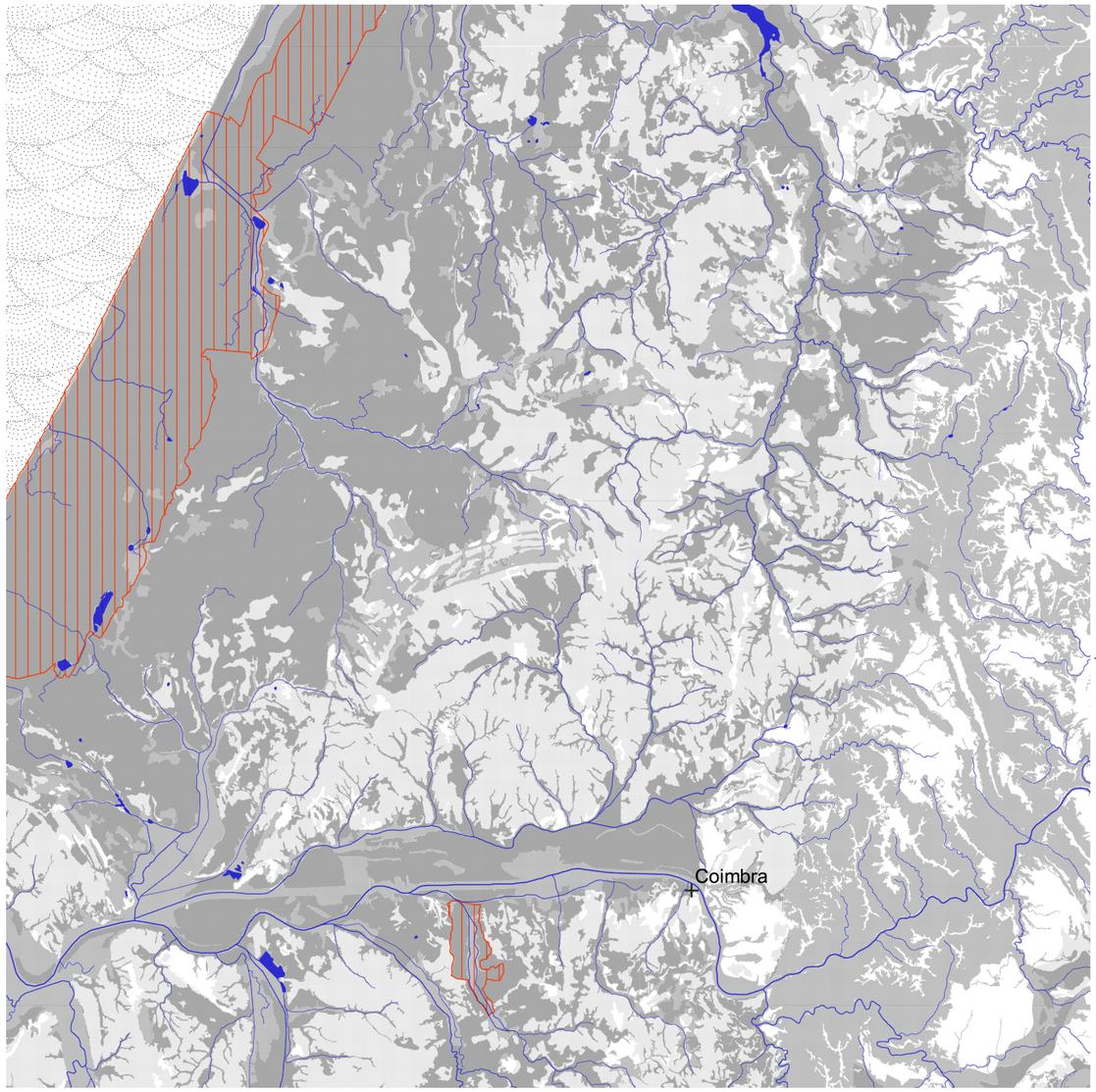


CLIMATIC & ECOLOGICAL STRUCTURE



- Wind direction and intensity (on average of summer)
- Hydrographic system
- Waterways
- Mean annual precipitation (1969-2019)
- Slope

0 2,5 5 km



- EEN 1+2 (National ecological structure)
- EEN 1
- EEN 2
- Hydrographic system
- Waterways
- Nature 2000

0 2,5 5 km

19th: Increasing of forest

The Liberal Revolution of 1820 stimulated agrarian capitalism and reinforced the land structure that still exists in Portugal today: large properties in the south and fragmentation in the north, with private property dominating and the State. The liberalization of property gave rise to a market economy that encouraged the private sector to expand and thicken the cork forests (previously dedicated only to the production of acorns, as pig feed) and to plant pine forests, an objective strongly promoted by the Forest Services, both in public and private areas. The forest was the main source of fuel and raw materials, which is why public policies were adopted aimed at reducing the area of uncultivated land, which occupied most of the territory.



Fig. 8-1, 8-2. From left to right: Tree planting in Serra do Soajo; Sowing in the dunes of Ovar (1933); Sowing in the National Bear Forest (1907-1908). Source: “About forestry services”, by José Mateus de Almeida Mendia (1945)

The privatization of common lands to reduce the uncultivated area and increase forestry and agriculture is promoted between 1869 and 1932.

Privatization

Provoked a strong reaction on the part of the local populations , who found themselves deprived of the spaces that served the tradition of “landless grazing”,

Conclusion

- Increasing of maritime pine, reduction of hardwood because of increased vines, olive trees and corn.
- Regeneration of the cork oak forest (cork and cattlle as income alternatives) due to the devaluation of the price of cereals.
- Progression of maritime pine stands from the coast to the interior, forming mixed stands with oak and chestnut trees occupying deforested areas.

20th: Dynamics between forest, agrarian and uncultivated land

- The increasing cropland leads the pollution and erosion of soil
- Rural exodus, depopulation

This breakdown in the structural, social and economic viability of many farms, along with the decline in population in rural areas and the abandonment of traditional practices, also led to an increase in the abandoned area of uncultivated land.

rural abandonment

The Development Plans named the maritime pine as a pioneer species, capable of growing in skeletal and poor soils, of improving the level of organic matter in the soil, of being used in the first years for the production of biomass, of promoting new sawmills in the interior and, from the “waste” of these, to generate opportunities for the wood agglomerate industries.

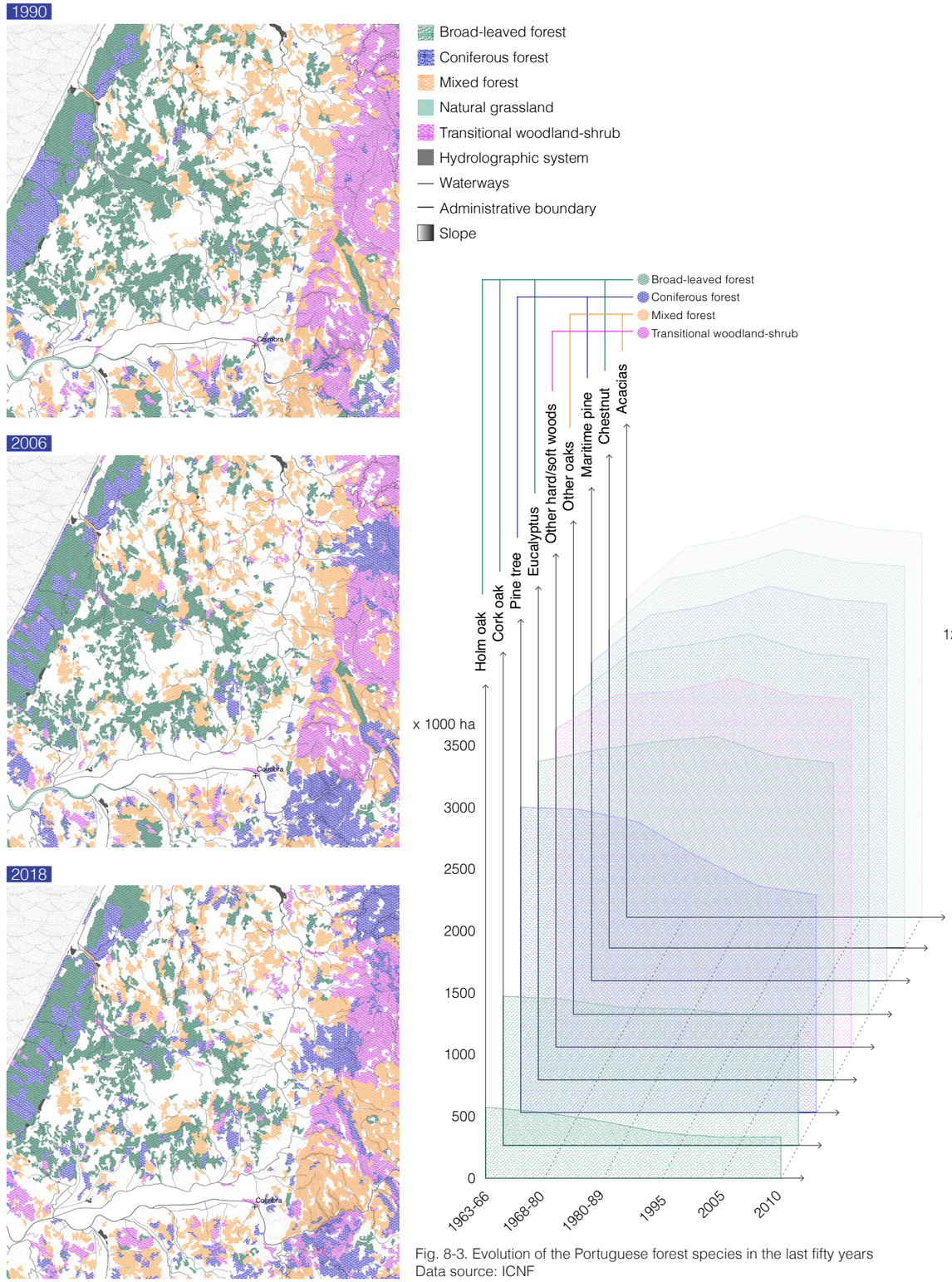


Fig. 8-3. Evolution of the Portuguese forest species in the last fifty years
Data source: ICNF

Flammable Forests

The forests are mainly composed of two tree species: the Maritime Pine (Pinus pinaster) and the Eucalyptus (Eucalyptus globulus).

The Maritime Pine is a fast-growing tree that can reach up to 30 meters in height. It is a fire-adapted species, meaning that it has evolved to withstand and even benefit from forest fires. The heat of the fire opens the pine cones and releases the seeds, allowing for the next generation of trees to grow. However, when these fires occur too frequently, they can destroy the entire forest, making way for invasive species and reducing the biodiversity of the ecosystem.

The Eucalyptus, on the other hand, is a non-native species that was introduced to Portugal in the 19th century for pulp industriall and commercial purposes. It has become one of the most widely planted tree species in the country, due to its fast growth and high productivity. However, it is also highly flammable, due to its high oil content and tendency to shed its bark, which accumulates as dry, highly combustible material on the forest floor.



Fig. 8-4. Eucalyptus forest (Source: The Portugal News)



Fig. 8-5. Eucalyptus forest fire (Source: Portugal's 'killer forest')

Portugal: 28 years ago a village fought against eucalyptus. The land never burned again

WRM Bulletin 238 9 July 2018

In 1989, there was a war in the valley of Lila, Portugal. Hundreds of people gathered to destroy 200 hectares of eucalyptus, fearing that the trees would rob them of their water and bring fire.

Issues: Seeds of Hope / Seeds of Hope / Large-Scale Tree Plantations / Timber / Struggles Against Tree Monocultures

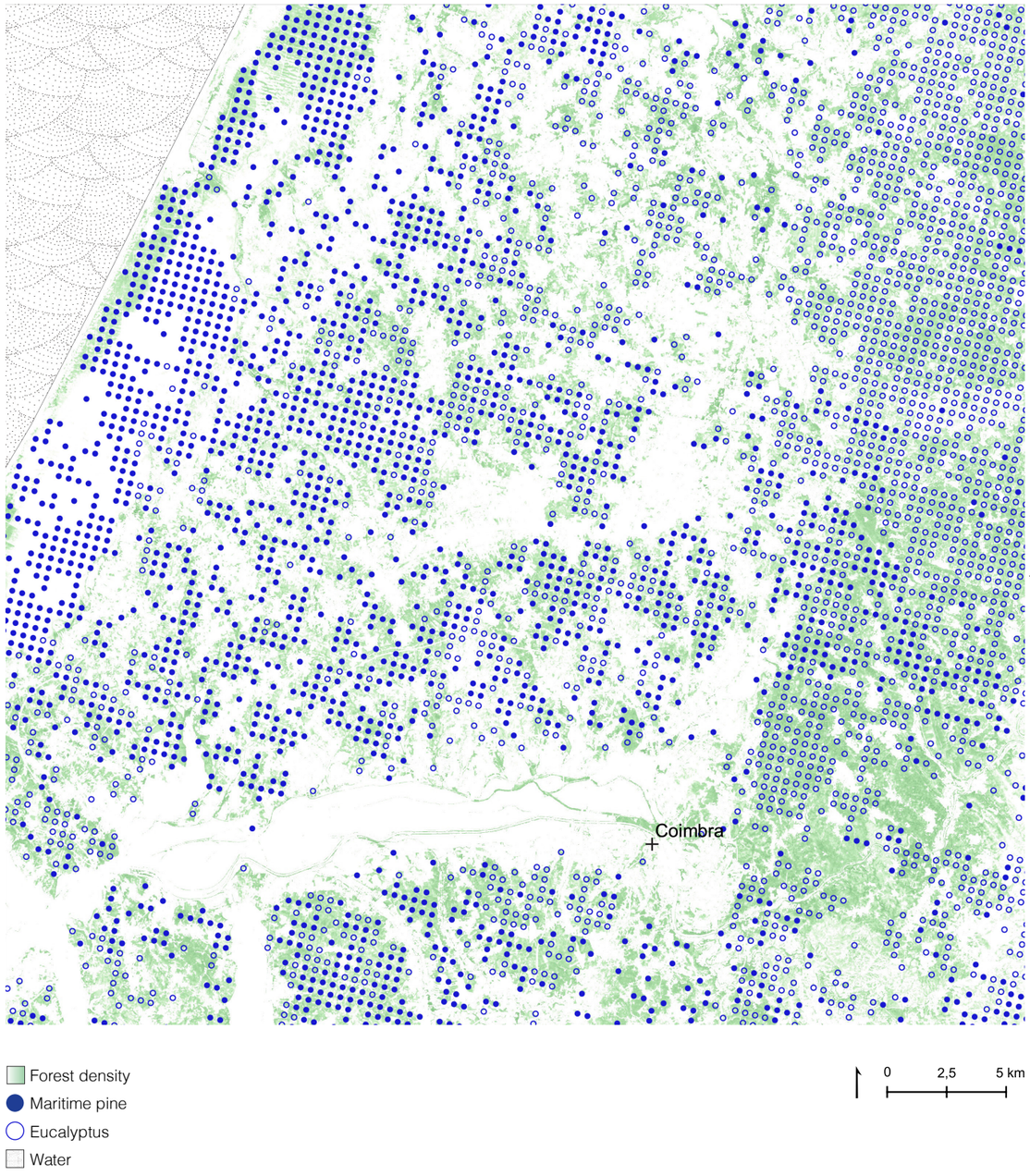
Countries: Portugal

Special section: 21/09/2018

Languages: English / Español / Français / Português



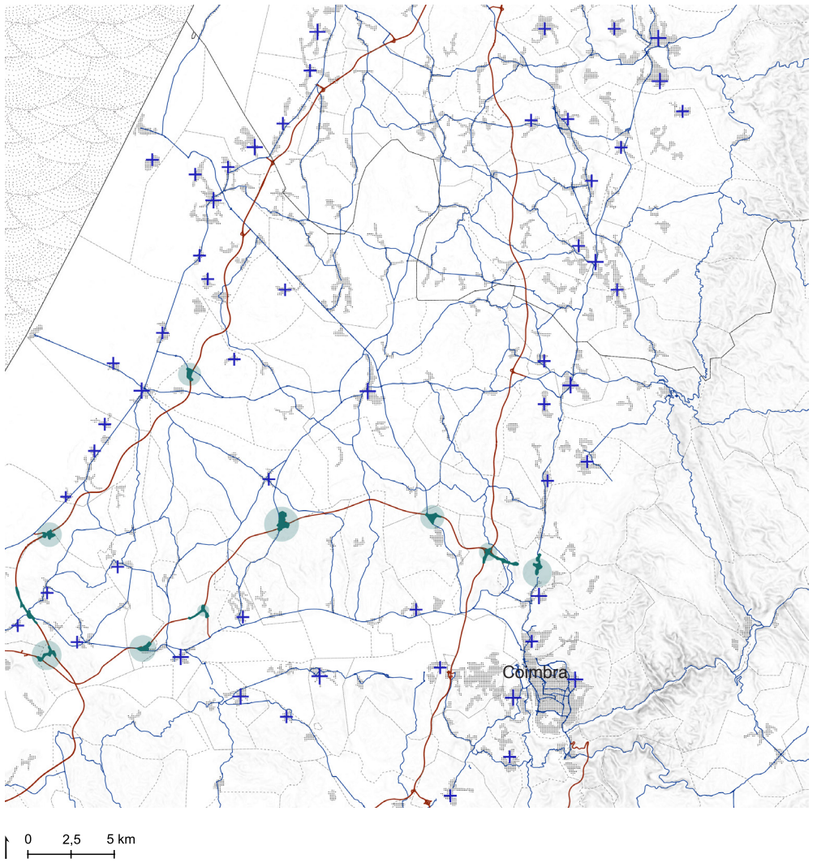
Fig. 8-6. "Violent" afforestation (Source: World Rainforest Movement)

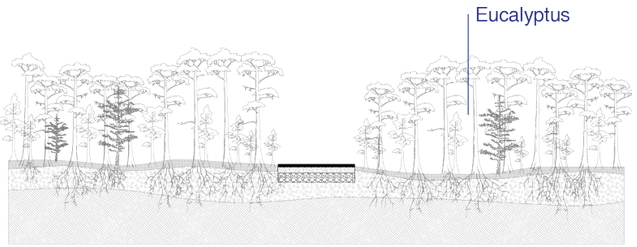


Settlement and Mobility Growth Patterns

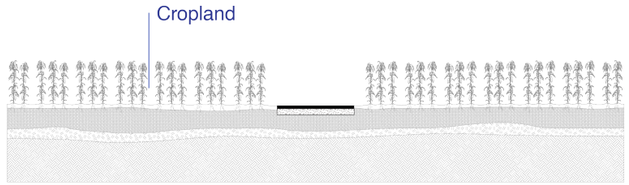
There is an obvious trend that the growth of both continuous and discontinuous settlements follows the mobility network (mainly primary and secondary roads). The surroundings on the two sides of the roads are really diverse. The sections AA'-FF' are distributed in an almost flat terrain, where the flammable and mixed forests, cropland, burnt scars and fragmented settlement are nearby. Section GG'-HH' are located in the montain hills, where the rural orchards and wildland are surrounded. The mobility network shows a strong potential to convert into the fire break network.

- Primary road
- Secondary road
- Settlement
- Settlement along the mobility network
- Mobility associated land
- Community boundary
- EU NUTS 3

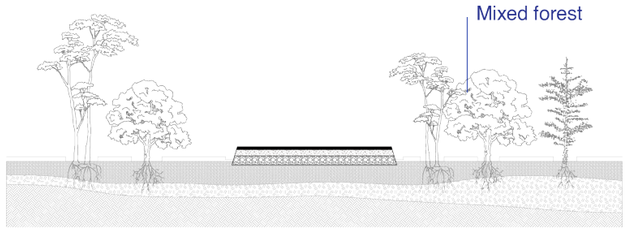




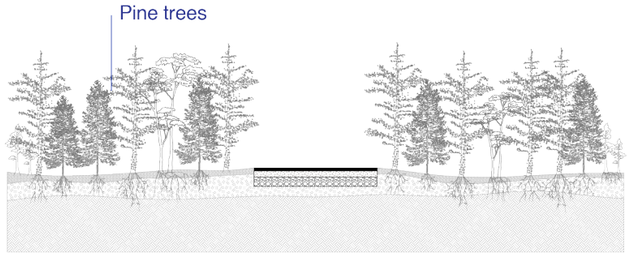
Section AA'



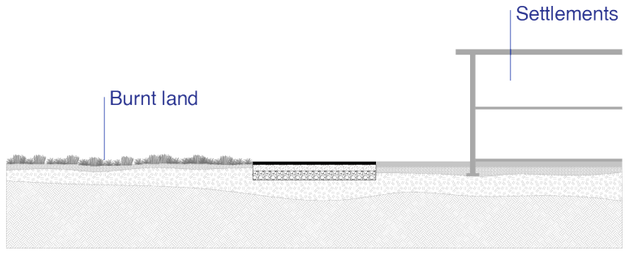
Section EE'



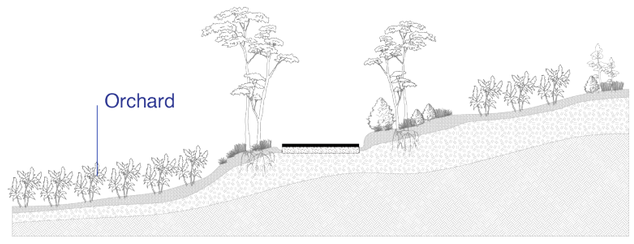
Section BB'



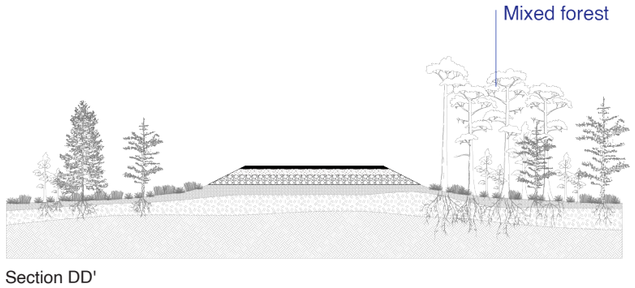
Section FF'



Section CC'



Section GG'



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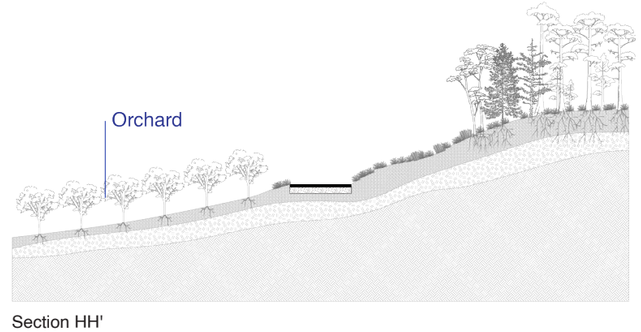


Section HH'

INTERFACE PATTERNS

Identifying WUI Typologies of the Region

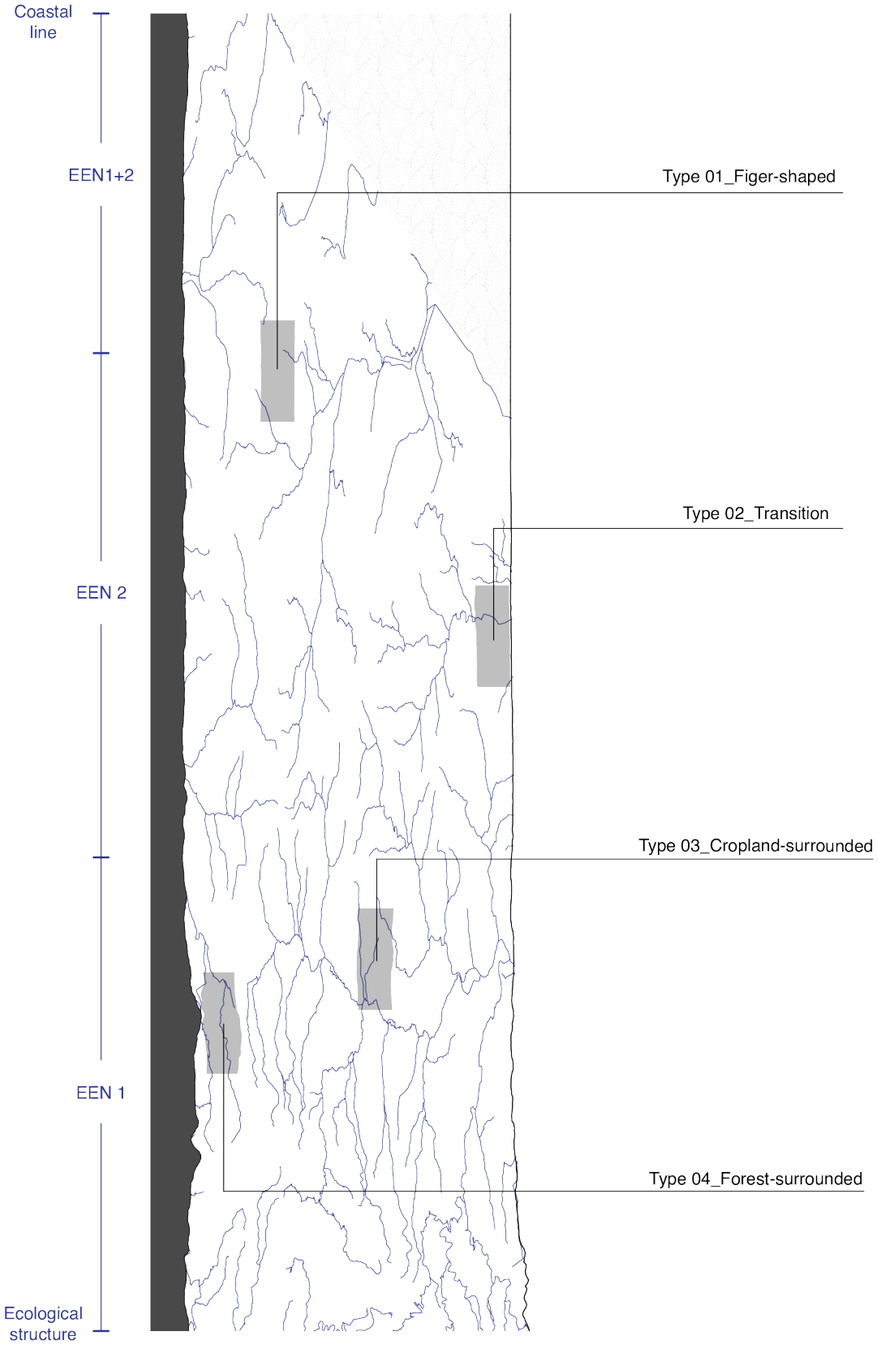
The urban and wildland interface (WUI) in the region exhibits distinct spatial patterns shaped by village settlements, croplands, forests, and burned scars. Four types of interface patterns can be identified.

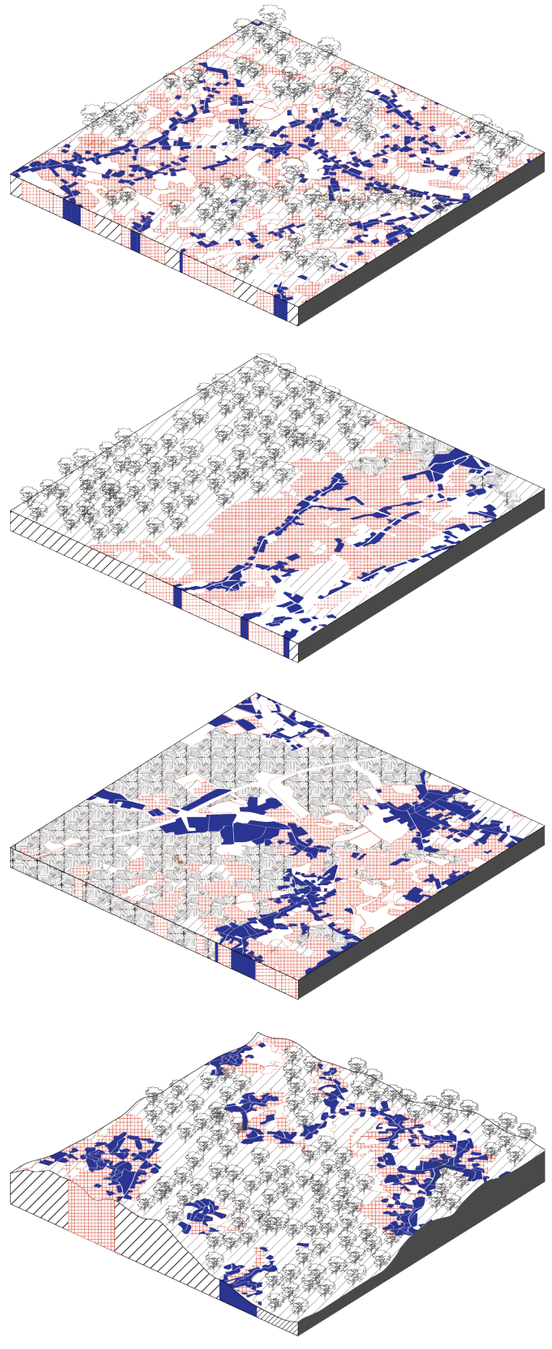
Finger-shaped interface: This pattern features a built surface as the central axis, with croplands and wild forests growing along the development of settlements. Unmanaged forests and abandoned agricultural lands are extensively mixed within this pattern.

Transition type: Primarily located in the coastal zone, this pattern shows linear growth extending from south to north. It includes burnt scars, pine forests, and villages along the coastal side. The recovery of burnt areas is an urgent priority in this type.

Cropland-surrounded type: This pattern is found in close proximity to densely populated villages and is characterized by high-quality irrigated croplands. Although these areas are well-managed, they still face the risk of wildfires due to scattered wild forests.

Forest-surrounded type: This type is distinguished by complex topographies. The slopes are covered with dense maritime pine trees, creating a highly vulnerable environment for settlements and arable land.





a



b



Image sources: (a) https://florestas.pt/conhecer/o-uso-do-fogo-em-portugal-da-tradicao-a-tecnica/
(b) https://florestas.pt/valorizar/baldios-o-passado-e-o-presente-das-terras-comuns/
(c)(d) https://issuu.com/gsdharvard/docs/canary-in-the-mine/s/16382651

c



d



External Rural-Urban Flows

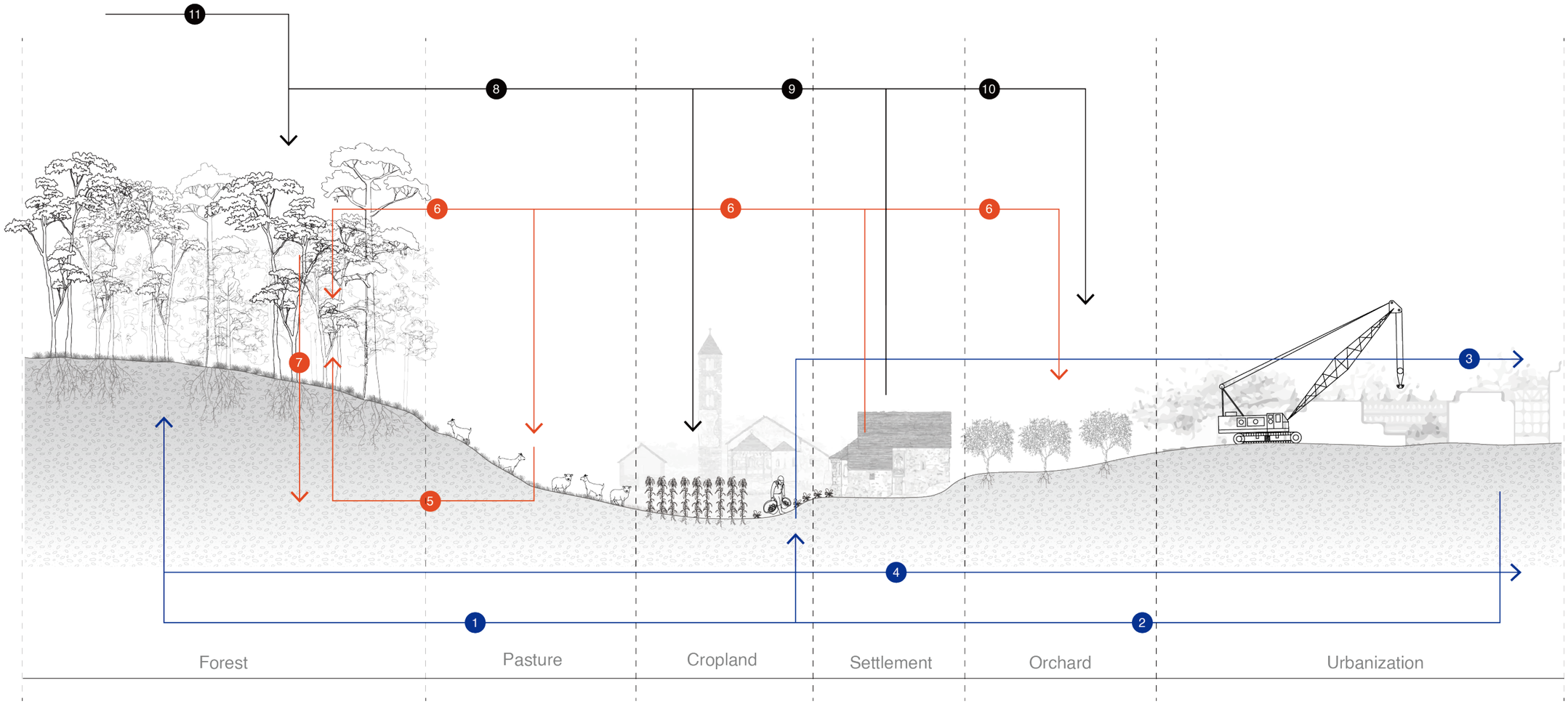
1. Utilization of forests by villagers
2. Urban techinique support
3. Depopulation of villages
4. Wood production transport

Internal Flows of Village

5. Fuel consumption from grazing
6. Operations on silviculture, grazing and agricultural planting
7. Nutrient exchange with soil

Flow of Forest and Agriculture Management

8. Management on cropland from urban agency
9. Management on cropland from rural agency
10. Orchard management
11. Forest management

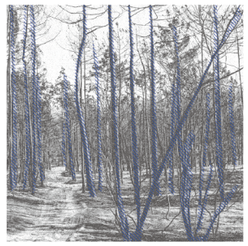


LANDSCAPE CRITERIA → TOOLKITS APPLICATION → FIRE ADAPTIVE RESILIENCE

Agro-silvo-pastoralism (Montado)



Violence of forestation



Common land resto-ration (Baldio)



Recreation place



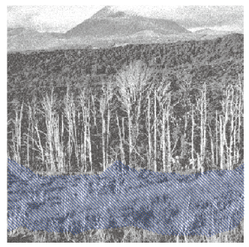
Mobility construction



Rural community



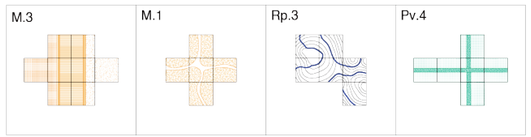
Unmanaged wildland



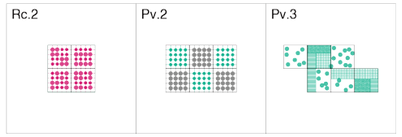
Burned scar



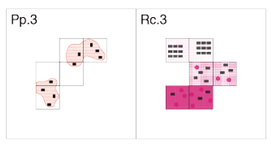
M.3 Transitional buffer
M.1 Vegetation fire-breaking
Rp.3 Terrain control lines
Pv.4 Linear productive grazing



Rc.2 Smart reforestration
Pv.2 Fuel spatial modification
Pv.3 Agroforestry mosaics



Pp.3 Community as territory
Rc.3 Land use replanning



STRATEGY 01 Regional fire break network

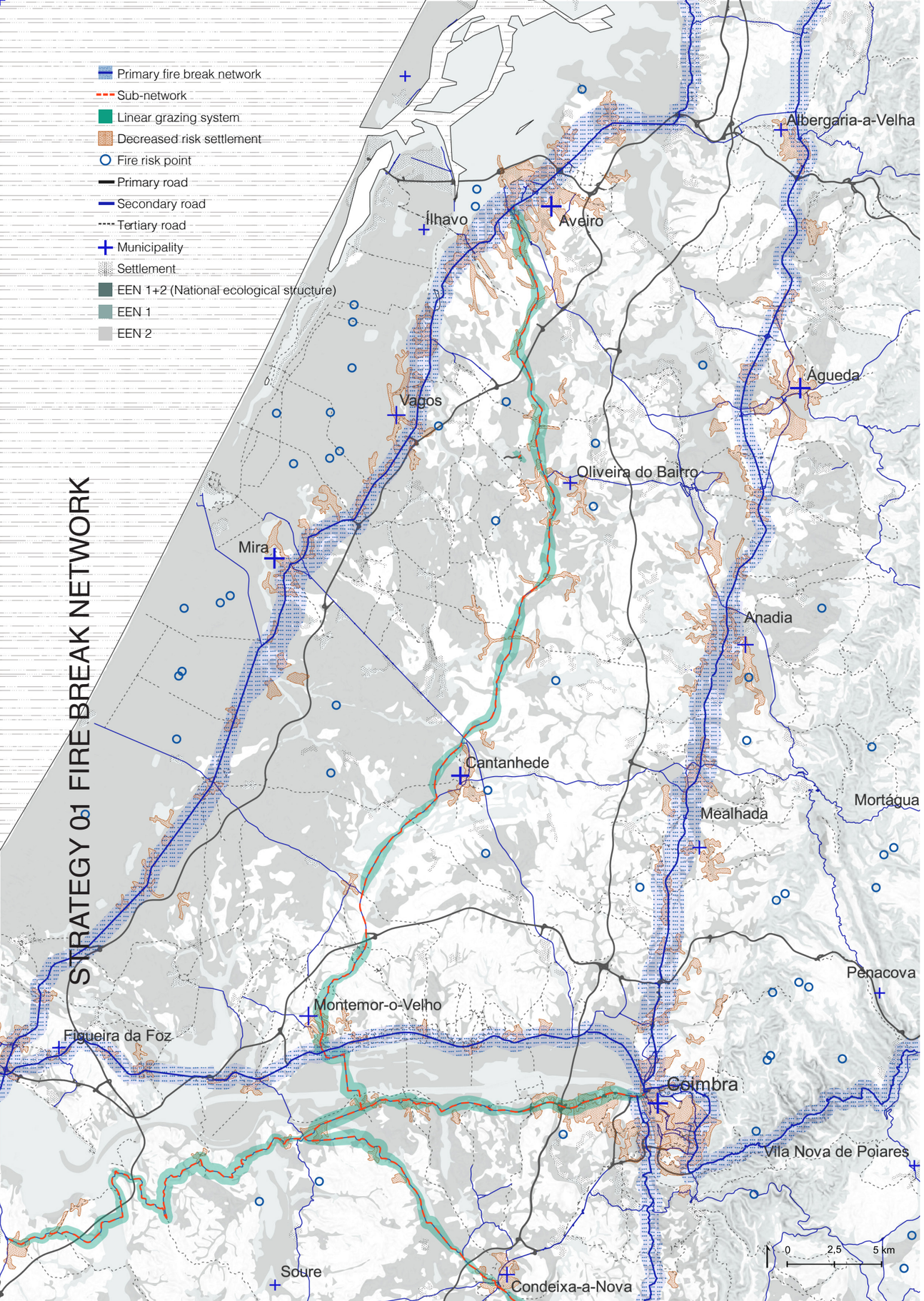
The mobility network in Coimbra exhibits a high degree of relevance to the settlement growth pattern, which presents a significant opportunity to establish an effective fire break network. The secondary roads in the area have been built with high-quality foundations that lend themselves to the construction of four types of linear fire breaks: fire-resistant species belts, linear grazing areas, hill control lines, and raising-up foundations. These fire breaks adhere to the national ecological structure and provide comprehensive coverage from the western coastal region to the hilly terrain in the east, thus providing robust protection against wildfires.

STRATEGY 02 Fuel spatial modification

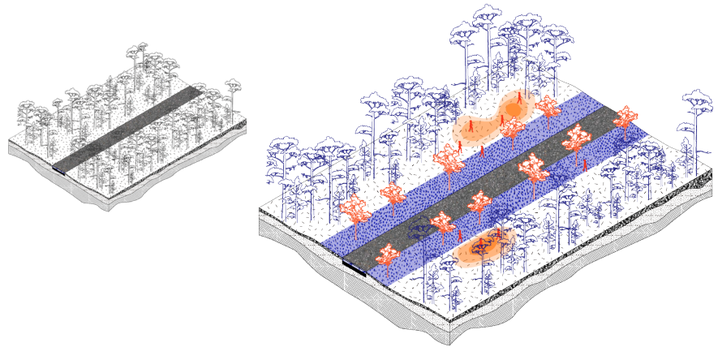
The historical violence of afforestations have led huge amount of flammable coniferous and eucalyptus forest which is needed to shift towards sptial modification. The strategic intervention proposed there forest modification models—recovery succession, productive estabishment, ecological estabishment. This well-established structure respected the national ecological structure in order to solve the diverse interface forest issues towards wildfire on the regional scale.

STRATEGY 03 Community-based management

The gradual return of common lands ("baldios") to rural communities in Portugal has created an opportunity for collaborative management that holds significant potential for creating adaptive fire-scape on the land. Traditional pastoralism, which is a hybrid human-animal community with extended sociality grounded in the territory, offers a promising framework for achieving this goal. By viewing the community as a unit, a compartmentalized landscape organization is promoted. This involves distributing the various land uses according to ecological aptitude, establishing discontinuities, and making the agrosilvo-pastoral mosaic more complex in order to mitigate the risk of wildfires.

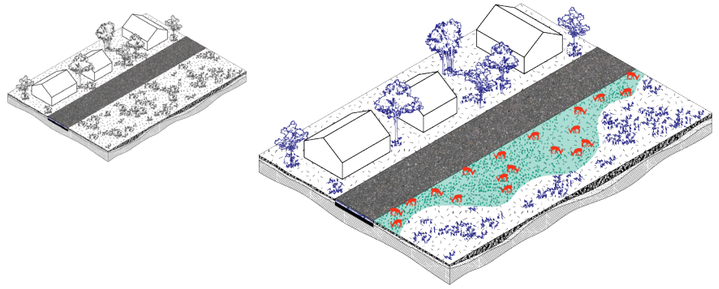


Thining operation in the dense conifer and eucalyptus forest



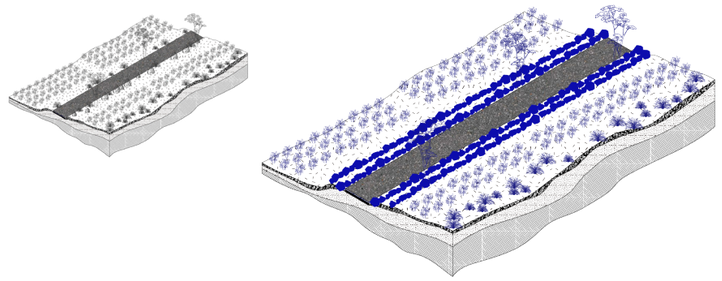
The thining operation can be applied along the secondary roads which are surrounded by dense maritime pine (coastal dune) and eucalyptus forest (hill land). By removing lines of trees to get access to national ecological structure and remain trees spaced to stop fire ignition and propagation.It is also viewed as an investment in forests which can optimise the periodic returns from the matures and improve the biodiversity.

Linear grazing along the settlement mobility network



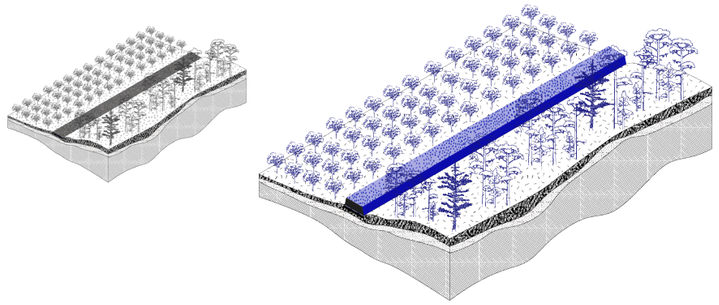
A transformation for the available space near the village settlement involves converting it into a linear grazing belt that aligns with the existing mobility network. The presence of farm animals grazing in this linear space reduces the fuel load, thereby establishing a firebreak corridor that effectively halts the spread of fires. Moreover, through regular and seasonal grazing activities, it ensures the ecological continuity of the firebreak itself.

Fire control line along roadbed in the hill cropland



Within the context of cropland situated on a hill, the mobility network serves as a natural boundary with the potential to impede the spread of fires along the slope. By constructing a fire control line using stones, the road itself is fortified, providing enhanced protection for agricultural resources.

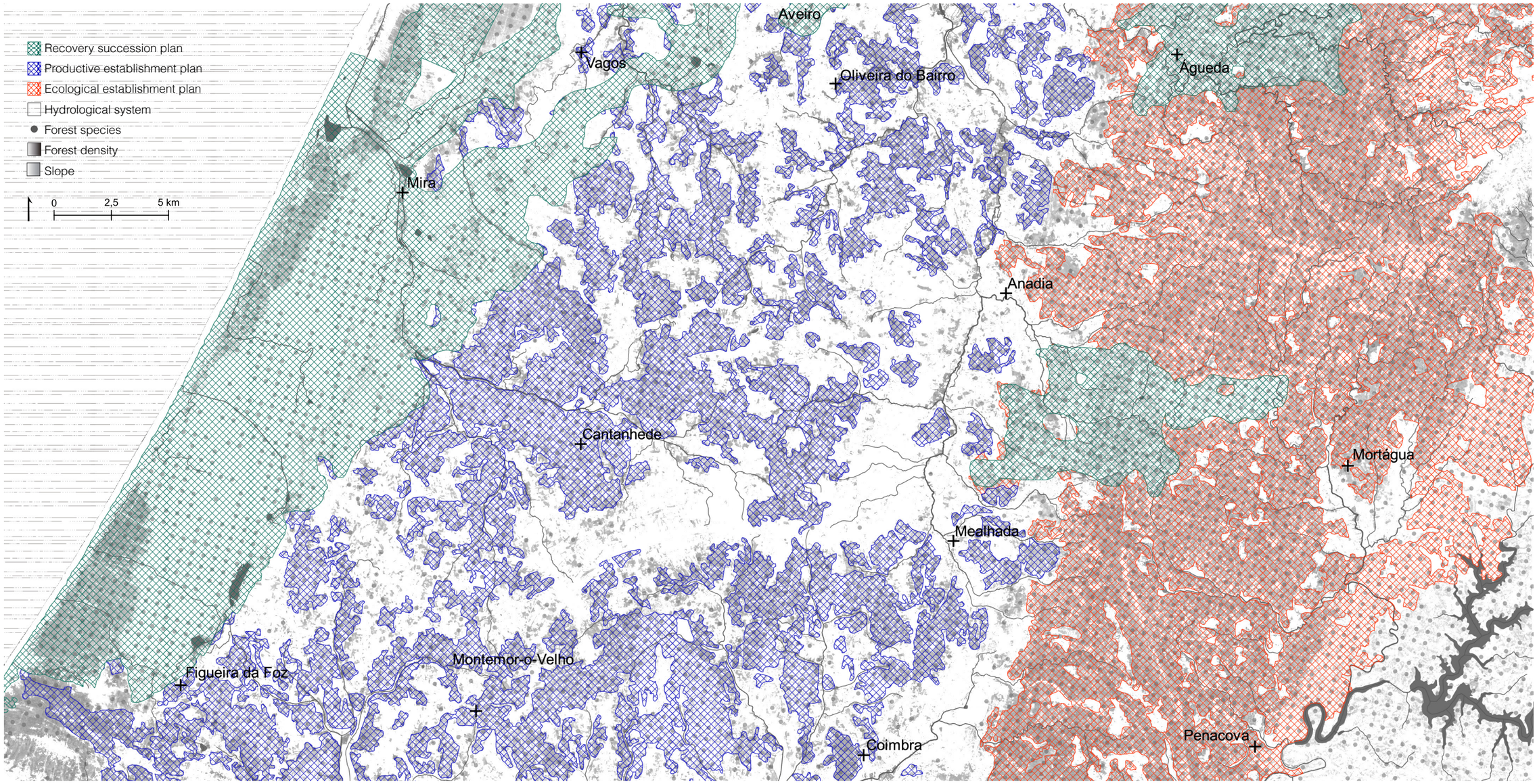
Raised hill roadbed between wild forest and orchards



To safeguard the higher crops and orchards located on the slope, an effective approach is to implement a raised roadbed system. This elevated roadbed fortifies the structural integrity of the road and functions as a protective barrier, preventing the spread of fires and ensuring the safety of the surrounding agricultural areas.

WILDFIRE ALTERNATIVES

STRATEGY 02 FUEL MODIFICATION



Recovery Succession

5-10 Year

- Establish a **protective buffer zone** along the coastal path
- **Remove and restore areas** affected by burning
- Introduce oak trees to create a visual and **ecological boundary** between coniferous areas

30-50 Year

- Implement **periodic harvesting** to sustainably manage the resource
- Use **silvicultural techniques** to encourage growth and minimize the risk of fire

>100 Year

- **New species** are rapidly growing to nearly reach the full height of a **well-established structure**

Productive Establishment

5-10 Year

- **Remove highly flammable bushes** located near settlements
- Implement a **linear grazing system** to decrease fuel load by reintroducing wild or semi-wild herbivores

30-50 Year

- **Introduce pro-forested bushes** that have a broad texture and lower combustibility
- Restore **former croplands and orchards** to their former diverse state

>100 Year

- **Farming activities** remain vital for supporting **sustainable development** in rural areas, while also helping to manage fire hazards

Ecological Establishment

5-10 Year

- Reduce **fuel load along hill ridges**
- Install fire **risk assessment infrastructure**
- Introduce new species to protect against **soil erosion** and **increase water flow**
- Reintroduce orchards into wildland areas among mountain ranges

30-50 Year

- Introduce fire-resistant species to **connect ridges**
- New species can aid in soil protection and the **restoration of biological diversity**

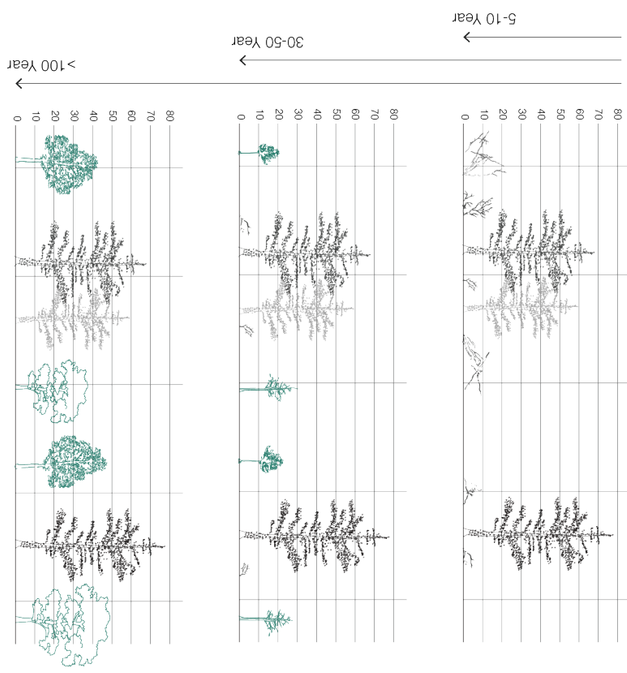
>100 Year

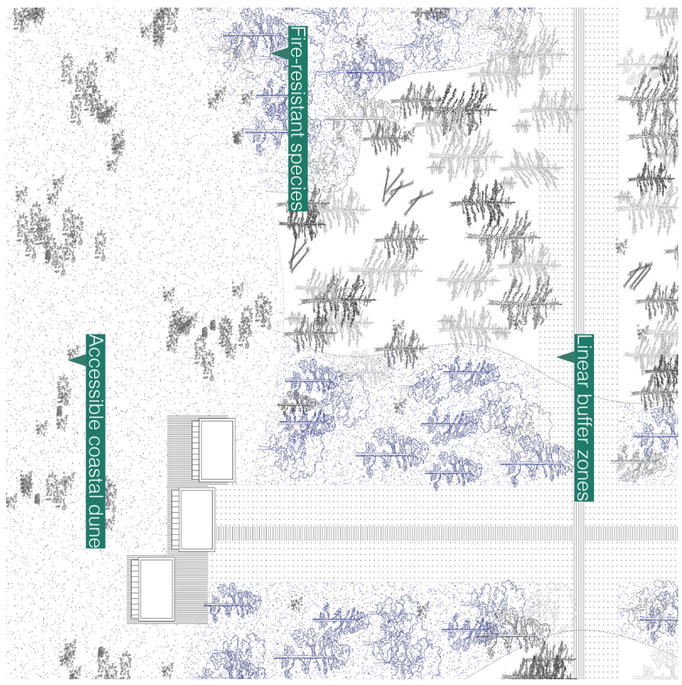
- **Mature orchards management** and related industries
- Improve **carbon sequestration** under management scenarios
- **A mix of native and fire-resistant species** shape a biological protection paradigm

WILDFIRE ALTERNATIVES

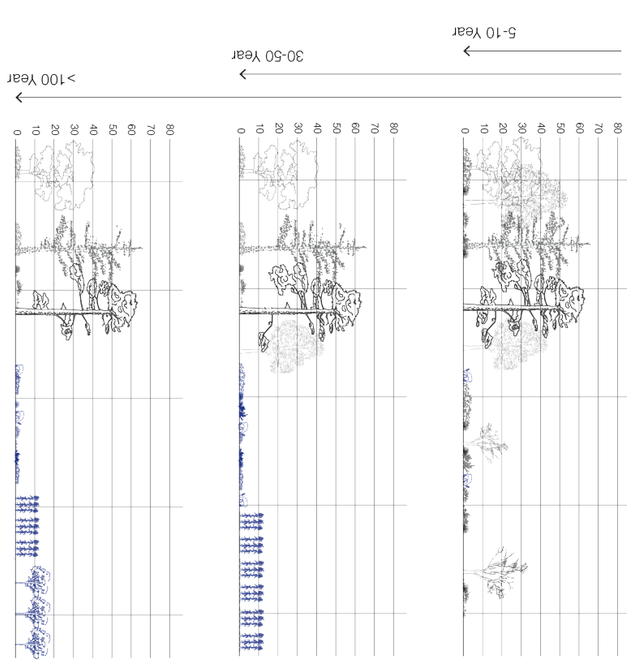
STRATEGY 02 FUEL MODIFICATION CATALOG

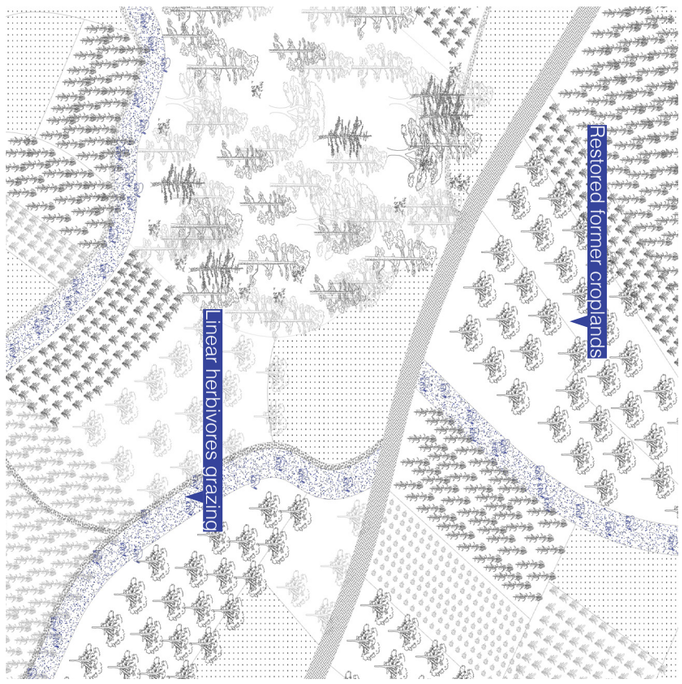
Recovery Succession



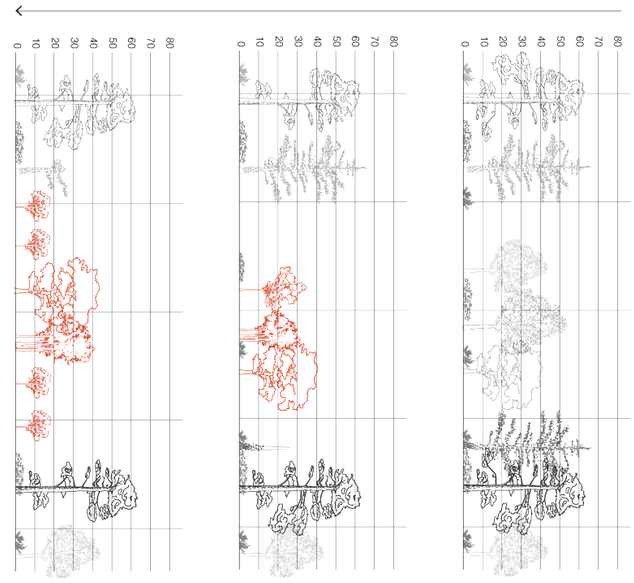


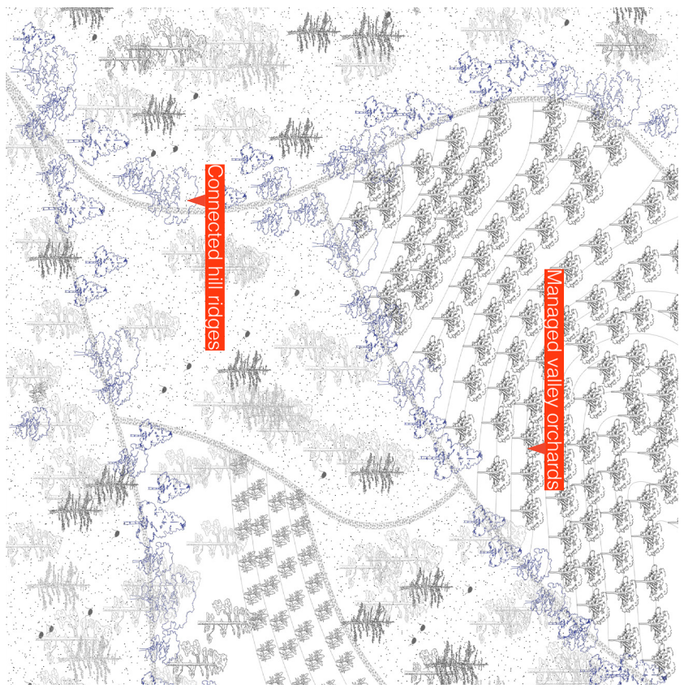
Prodctive Establishment





Ecological Establishment





Community-based Management

The factors influencing wildfire risks need to consider the effect of the ownership type and management modalities in forest areas, referred to as "baldios" (common land) in Portugal. Afforestation under the Forest Regime drastically changed the traditional use of baldio areas. After the revolution of 1974, more and more baldios have been given back to the rural communities. Earlier, they were used by commoners to provide pastures and agricultural fields, while the existing forests were used to harvest firewood. This traditional method of managing land in villages helps to promote a compartmentalized landscape organization in the most fire-prone areas, distributing the various uses according to ecological aptitude, establishing discontinuities and making the agro-silvo-pastoral mosaic more complex.

To strength and revival the way of managing common land and its fuel load, rural communities are considered as the basic unit to co-management with national Forest Services or local technique hubs. The enlarge of baldios is needed to the inland areas within communities. The protection status of the flammable forests was also considered. Under this new management model, private/common forest owners and labors will be involved. Fuel reduction and complexity of the land could be improved through the development of new bioeconomic activities in community forests.

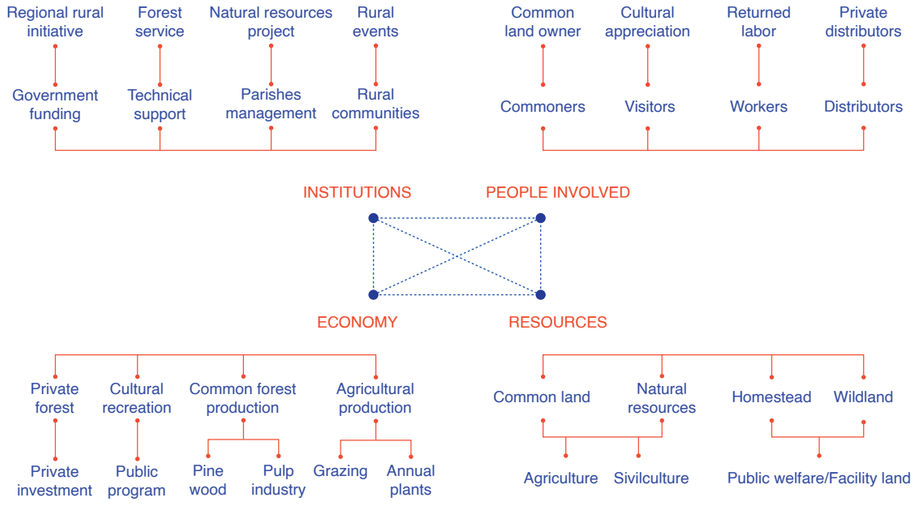
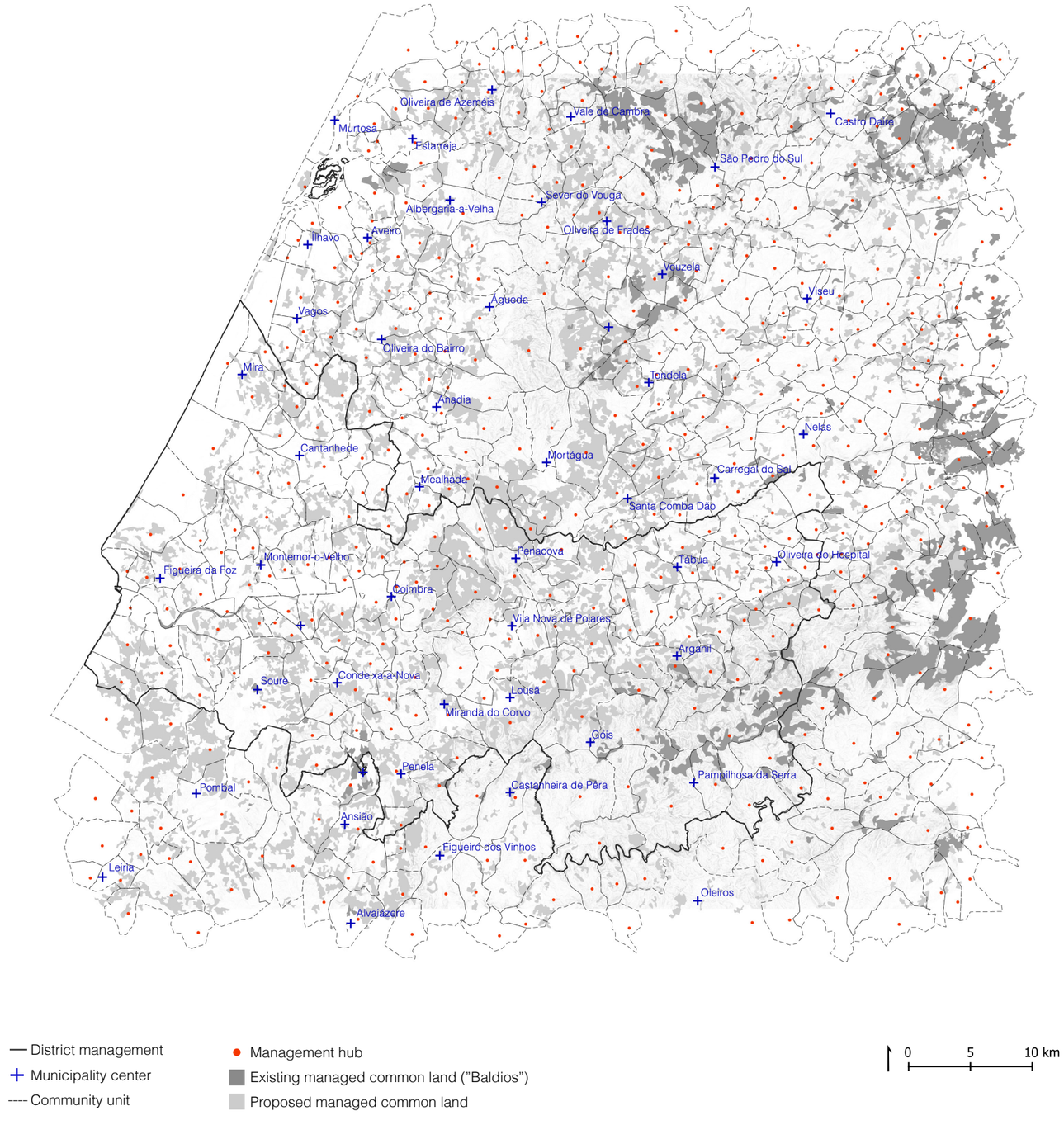


Fig. 8-7. Co-management model of "baldios" (common land)



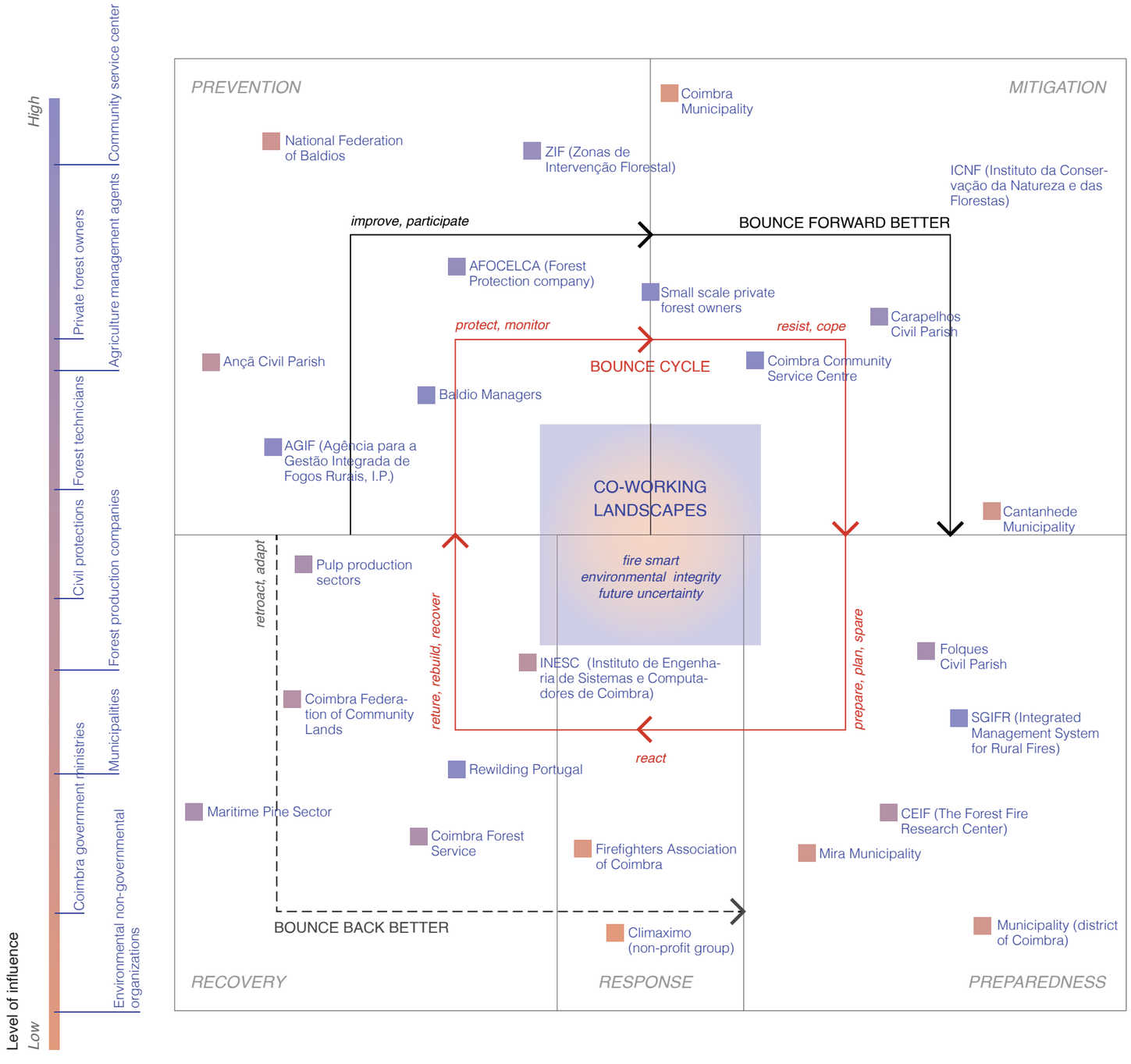
The Goal of Co-working Landscapes

Collaboration and Partnership: Addressing fire risk requires the active participation and cooperation of all stakeholders, including government agencies, local communities, emergency services, research institutions, NGOs, and private entities. By fostering partnerships, we can leverage collective expertise, resources, and knowledge to develop comprehensive and sustainable solutions.

Knowledge Sharing and Innovation: By encouraging research, data collection, and the exchange of best practices, we can enhance our understanding of fire risk factors, prevention measures, and response strategies. We will foster an environment that encourages creativity and embraces new technologies and approaches to improve fire safety.

Proactive Risk Management: By identifying and assessing potential hazards, vulnerabilities, and ignition sources, we can develop risk reduction strategies and implement appropriate preventive measures. This includes land management practices, early warning systems, community education programs, and the establishment of fire-safe infrastructure and zones.

Effective Communication and Engagement: By recognize that effective communication is vital in building trust, raising awareness, and mobilizing stakeholders, the framework will ensure transparent and timely dissemination of information related to fire risk, prevention measures, and emergency procedures. We will actively engage stakeholders through public consultations, workshops, forums, and education campaigns, enabling them to actively participate in decision-making processes.



Villages in nomalcy, Coimbra



Fig. 8-8. Traditional "Baldios"(common land) in Coimbra
Source: https://florestas.pt/valorizar/baldios-o-passado-e-o-presente-das-terras-comuns/

The village is nestled in a landscape that's composed of a forest hill in the distance, followed by cropland, linear grazing, a rural settlement, and an orchard. The landscape elements in the village work together to create a harmonious and complex ecosystem that's both beautiful and resilient to wildfires.

The thinned forest surrounding the village reduces the risk of wildfire ignition, as there are fire-resistant species mixed in the Eucalyptus forest. The agrarian mosaics in the cropland and linear grazing belt bring complexity to the local ecosystem, creating a natural barrier that helps slow down the spread of fire. The linear grazing belt, which follows the mobility network, serves as a firebreak that can help stop the spread of fires.

The rural settlement is home to a small community of people who live in charming houses and buildings clustered together. They have access to fire assessment infrastructure that helps assess the risk of fire and collect data. This infrastructure ensures that the village is always prepared to deal with any potential fire outbreaks.



Villages in emergency, Coimbra



Fig. 8-9. Burning in Eucalyptus forest, Coimbra.
Source: https://www.cbc.ca/news/world/portugal-awaits-foreign-help-to-fight-deadly-wildfires-1.4166899

The village is in a state of emergency due to a serious wildfire outbreak. The landscape elements that were once working together to mitigate fire risk are now being put to the test. The thinned forest surrounding the village is burning seriously, but thankfully, the fire-resistant forest area is reducing the spreading areas of the fire. The linear grazing belt is also playing a crucial role in stopping the fire propagation immediately. This belt, which follows the mobility network, acts as a barrier that can help to contain the fire.

In this emergency state, the fire mitigation infrastructure and devices are being put to use. They help to monitor the fire and collect data that can be used to build a communication platform for different departments to work together. The rural settlement has an emergency response team that is working tirelessly to combat the fire outbreak and keep the community safe. The orchard is now serving as a refuge for the villagers, as it provides a safe area where they can take shelter from the fire. The cropland and grazing belt are also providing a natural barrier that's helping to slow down the spread of the fire.



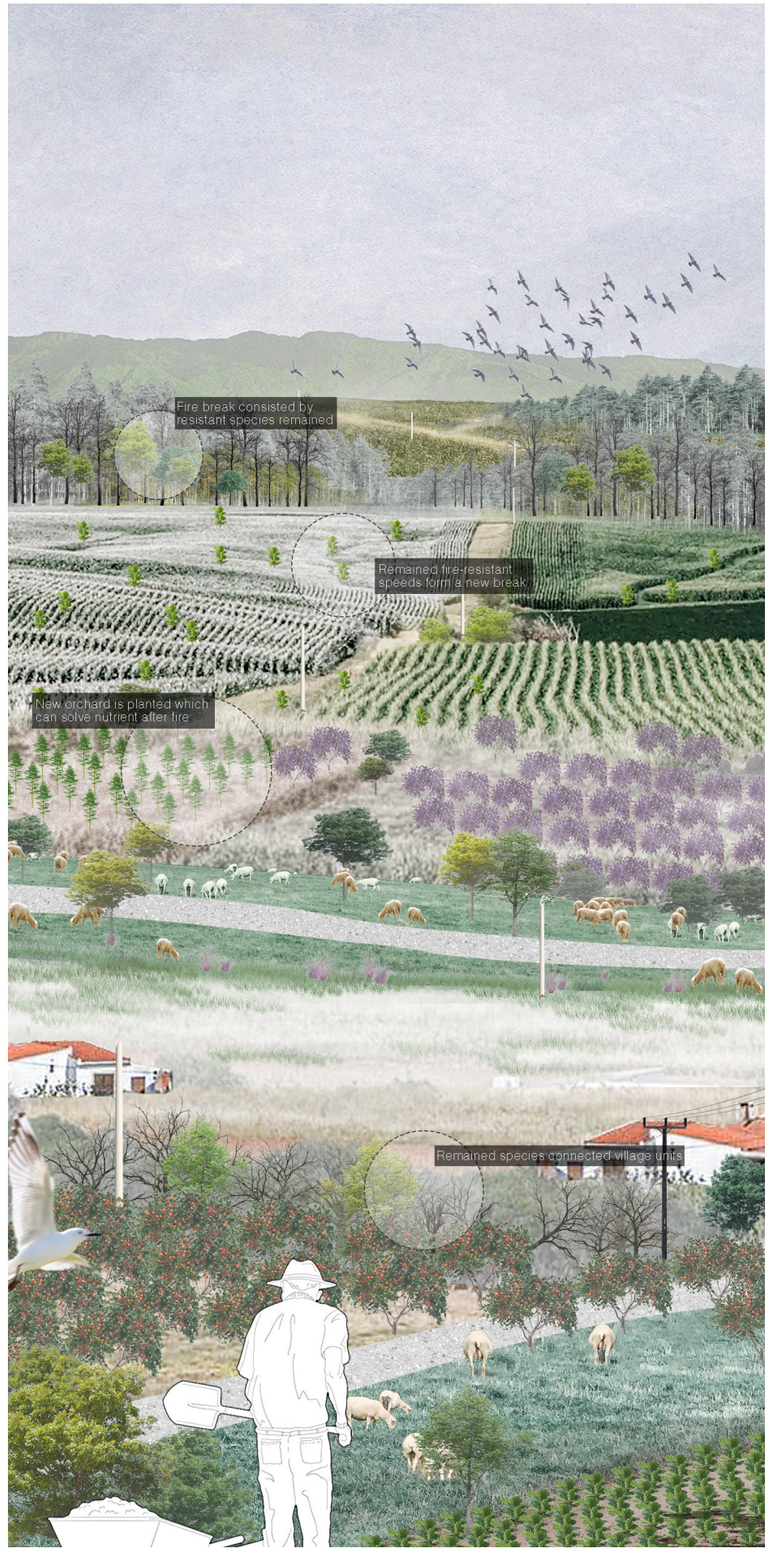
Villages in recovery, Coimbra



Fig. 8-10. Remained pattern in burned scar
Source: https://www.bbc.com/news/science-environment-34116491

In the aftermath of the devastating fire, the village in Coimbra begins the process of recovery with the help of its fire mitigation and recovery landscape elements. The view of the landscape appears different now, with the forest hill showing the scars of the fire. However, the thinned forest, which had helped reduce the spread of the fire, is still there and has become a source of inspiration for the new forest evolution trajectory. The village has begun to plant new trees that are more resilient to fire and to implement strategies to protect the forest from future fires.

The cropland, which had saved some fire-resistant seeds, is also being used to regenerate the land. The ash from the burned land has helped to fertilize the soil, providing nutrients for new orchards. The orchards, in turn, are being replanted with fire-resistant species to ensure their survival in the event of future fires. The linear grazing belt, which had acted as a barrier to stop the spread of the fire, is still intact. The fire-resistant species that remained have helped to connect the bio-diversity of the village and maintain the integrity of the landscape.



9

WILDFIRE ALTERNATIVES_SITE 02

Fire-landscape Typologies

Fire Category

Hydrological Network

Vegetation

Littoralisation Process

Urban Planning & Tourism Development

Climate Change

Water Challenges

Strategies Application

Strategy 01_Hydrography-based Fire Mitigation

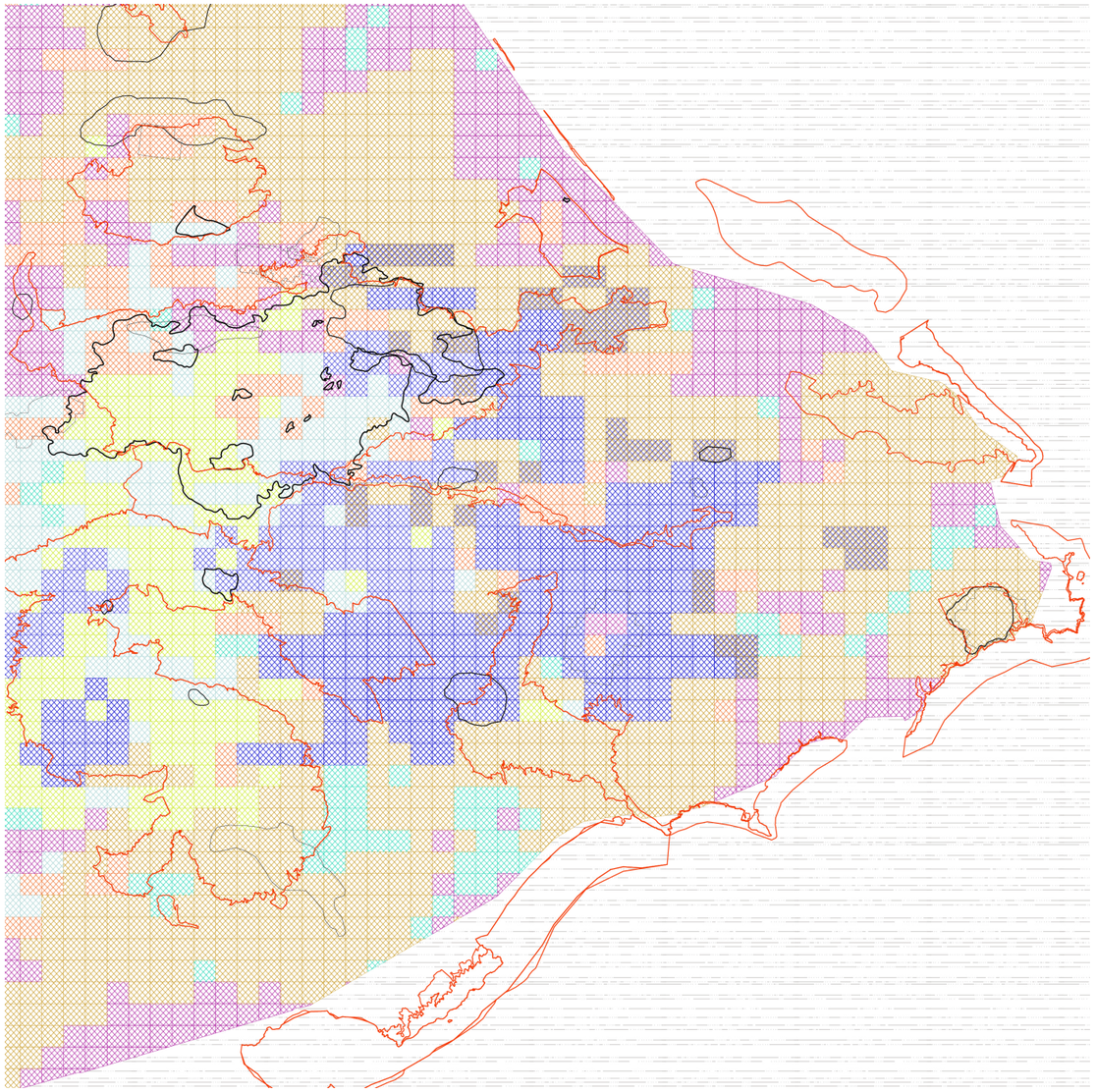
Strategy 02_Urban Emergency Model

Strategy 03_Seasonal Tourism Management

Stakeholders Engagement

Long-term Fire Resilience

FIRE-LANDSCAPE TYPOLOGIES

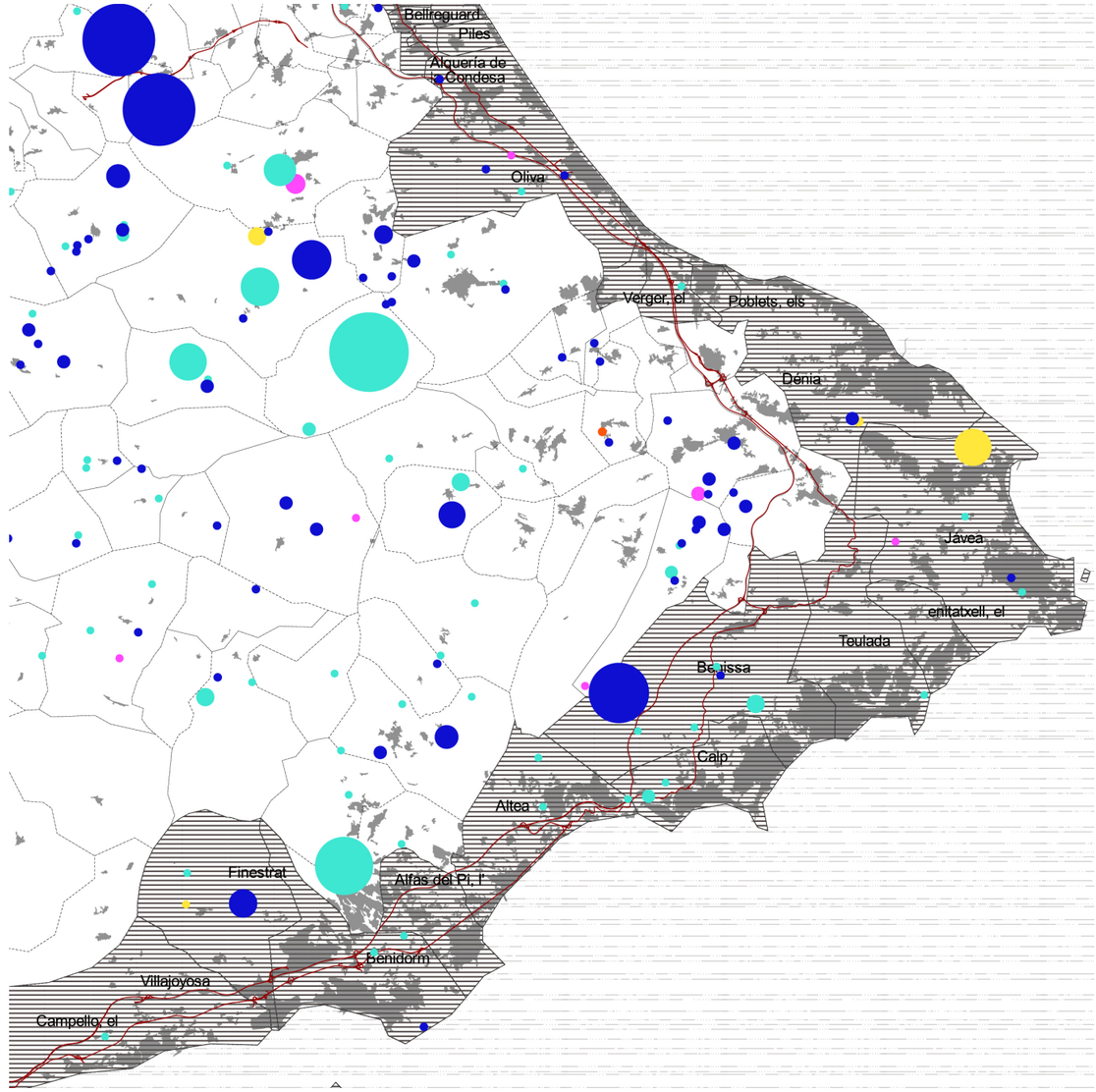


Burnt areas
- 2020-2022
- 2015-2019
- 2010-2014
- 2005-2009
- 2000-2004

Fire typologies
- Populated coastal land with intensive fuel cover
- Fragmented villages with multiple agriculture low land
- Urban interface mixed with unmanaged wildland
- Hillside in south facinng with strong radiation
- Multifunctional management with medium vegetative cover
- Natura 2000

0 2,5 5 km

FIRE CATEGORY



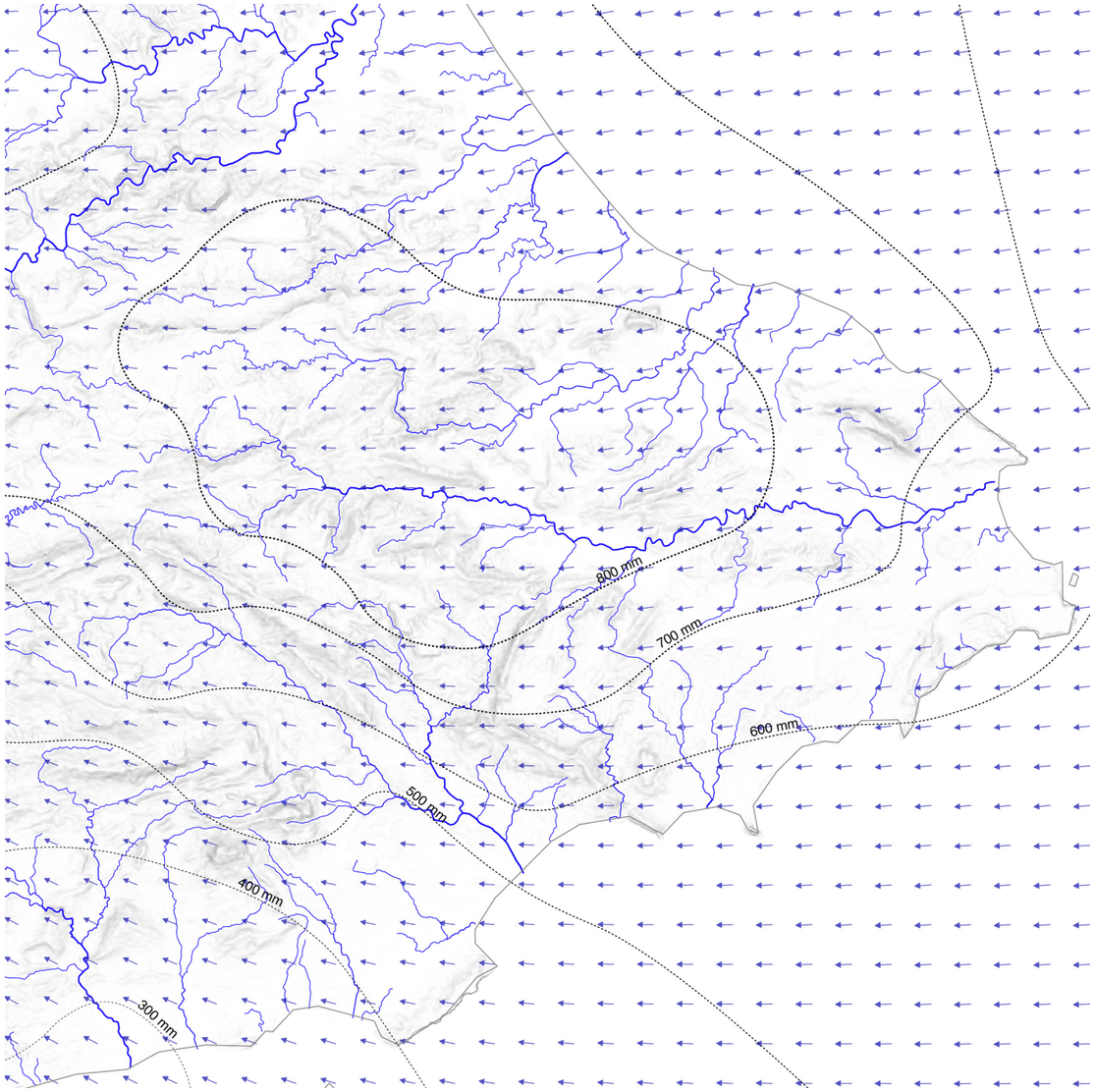
Urbanization
- Artificial surface
- Coastal community

Fire categories
- Intentional fire
- Fire caused by accident or negligence
- Fire caused by lighting
- Reproduced fire
- Fire caused by unknown reasons

0 2,5 5 km

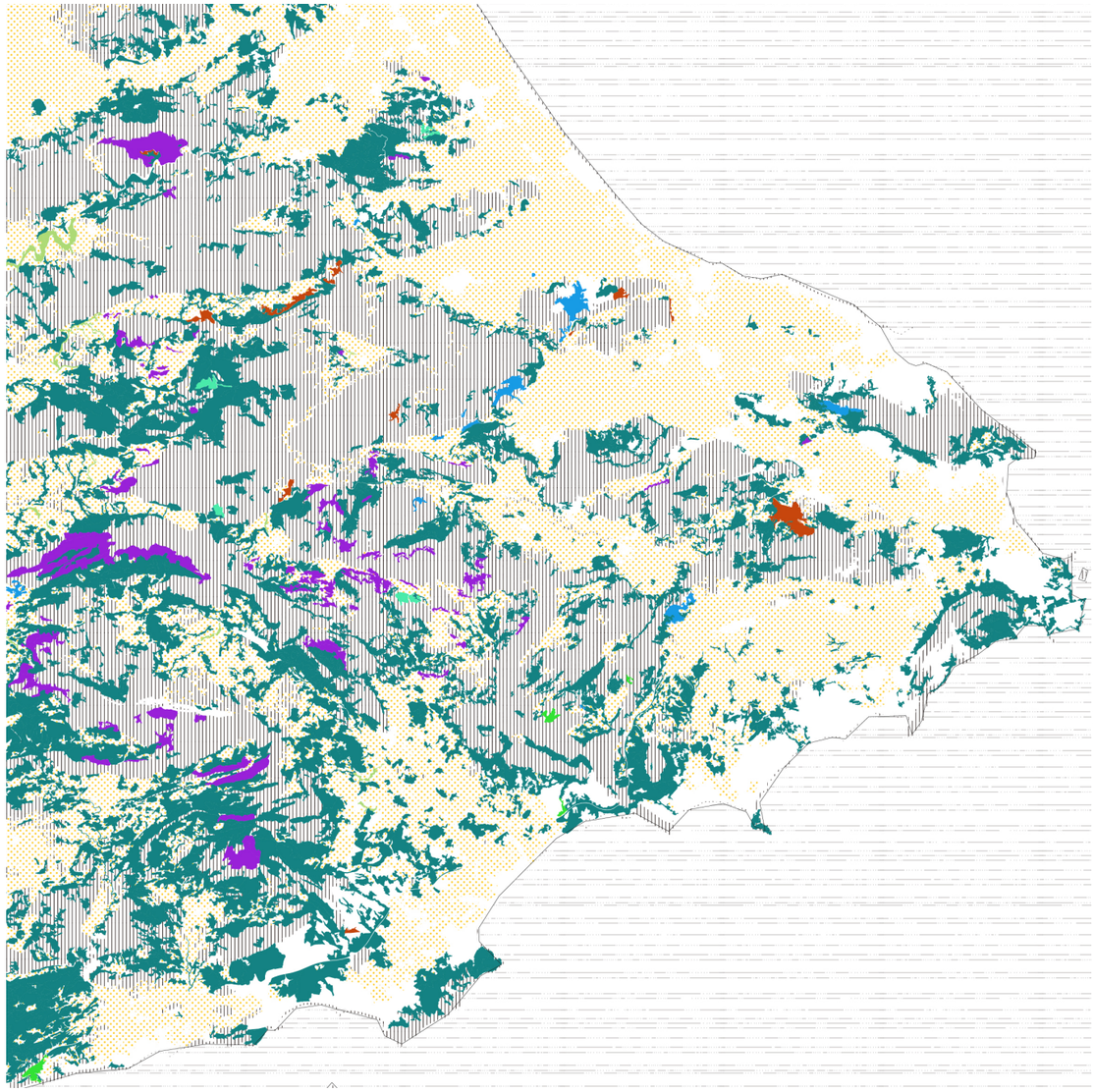
The size of the bubbles is the actual size of surface area burned:
408 fires
10.177 Ha burned
2 deaths
6 injuries
Data source: CIVIO

HYDROLOGICAL NETWORK



Accumulated precipitation (mm, average annual and in the period 1981-2010)
- 800 mm
- 700 mm
- 600 mm
- 500 mm
- 400 mm
- 300 mm
- Wind direction and intensity (on average of July)
- Hydrographic system
- Waterways
- Slope

VEGETATION



Forest species
- Pine (mainly Maritime pine)
- Oak
- Poplar
- European oils
- Juniperus
- Ceratonia siliqua
- Mosaic grassland-scrub

- Cropland
- Treeless

LITTORALISATION PROCESS

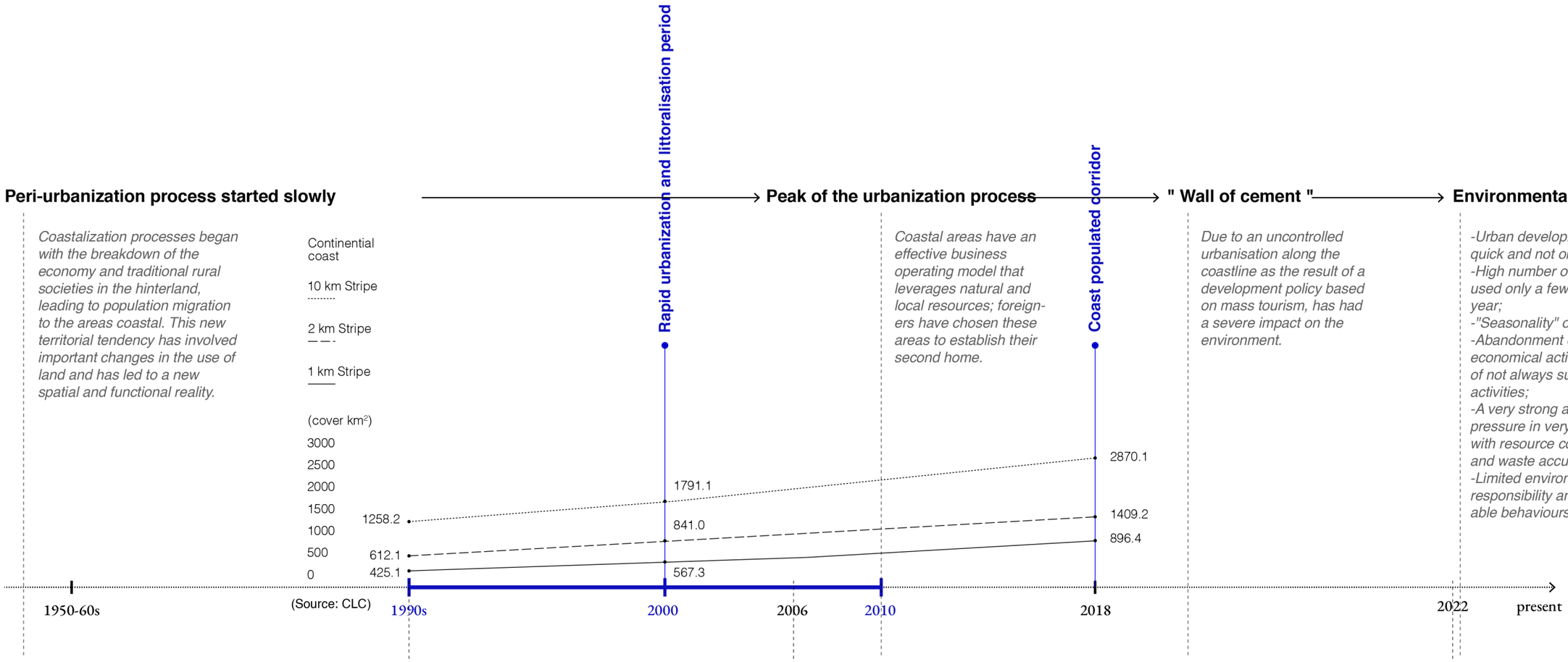
Peri-urbanization process started slowly → **Peak of the urbanization process** → **" Wall of cement "** → **Environmental degradation**

Coastalization processes began with the breakdown of the economy and traditional rural societies in the hinterland, leading to population migration to the areas coastal. This new territorial tendency has involved important changes in the use of land and has led to a new spatial and functional reality.

Coastal areas have an effective business operating model that leverages natural and local resources; foreigners have chosen these areas to establish their second home.

Due to an uncontrolled urbanisation along the coastline as the result of a development policy based on mass tourism, has had a severe impact on the environment.

-Urban development often quick and not ordered;
-High number of buildings used only a few month per year;
-"Seasonality" of services;
-Abandonment of traditional economical activities to favour of not always sustainable activities;
-A very strong anthropical pressure in very narrow areas with resource consumption and waste accumulation;
-Limited environmental responsibility and not sustainable behaviours of tourists.





WILDFIRE ALTERNATIVES





WILDFIRE ALTERNATIVES

Benidorm as an Example

Benidorm is a popular coastal city located in the province of Alicante, on the eastern coast of Spain. The urbanization of Benidorm encompasses the growth of residential, commercial, and infrastructure sectors, leading to a remarkable transformation from a small fishing village to a major tourist hub. This urbanization was primarily driven by the city's strategic coastal location, favorable climate, and the rising popularity of tourism in the region.

In the 1960s, Benidorm experienced a surge in littoralization as it became a sought-after destination for domestic and international tourists. The city witnessed a construction boom, with high-rise buildings and hotels dominating its skyline. These tall structures, often referred to as "skyscrapers," became defining features of Benidorm's urban landscape. The vertical growth was necessary to accommodate the increasing number of visitors seeking sun, sand, and entertainment.

However, while urbanization and littoralization have brought economic prosperity and employment opportunities to Benidorm, they have also posed environmental challenges, including an increased risk of wildfires.

The surge in human activity associated with urbanization and tourism development in Benidorm can contribute to a higher likelihood of human-caused wildfires. Activities such as discarded cigarettes, campfires, or accidental sparks from machinery or equipment can act as ignition sources for fires. Furthermore, the presence of infrastructure, electrical systems, and increased human activity in urbanized areas can introduce additional sources of ignition. Malfunctioning power lines, equipment, or machinery can spark wildfires. Additionally, the dense concentration of buildings and infrastructure can facilitate the rapid spread of fires in urbanized areas.

To address these challenges, it is important for local authorities and stakeholders to implement effective landscape-based fire management strategies. By prioritizing fire prevention and implementing appropriate mitigation measures, Benidorm can continue to thrive as a popular tourist destination while ensuring the safety of its residents and preserving its unique urban landscape.



Fig. 9-1. The location of Benidorm city

Fig. 9-5. Benidormcoastal urbanization in 2022, Sonneil

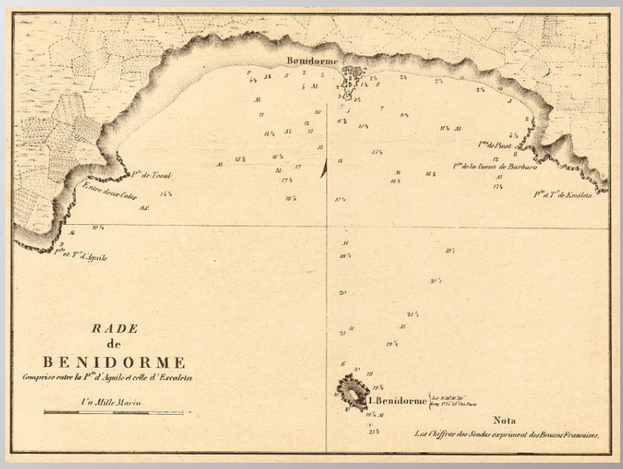


Fig. 9-2. Benidorm Bay, 'Rade De Benidorme', Gauttier 1851, Posted by Old antique map chart



Fig. 9-3. Before "tourism boom", Benidorm in 1950s, Posted by cbts on 4 December, 2020



Fig. 9-4. Benidorm in 1960, 'History of Benidorm', Posted by Iberianature 2009

[Regional tourism events]

1954 - Customs facilities are granted for tourism *(Jimenez & Joyanes, 2013)*

1956 - The first Land Act was adopted in Spain *(Spainish Government, 1956)*

This Act obliged every municipality over 50,000 inhabitants to adopt a Masterplan designed to regulate urban growth during the industrialisation period following the zoning principles of the Modern Movement. (Mancuso,1980)

1963 - British European Airway flew 30,000 tourists from the UK to Valencia and their main destination was Benidorm.

1967 - Liberalisation of foreign investment in the hotel sector *(Jimenez & Joyanes, 2013)*

1974 - 1975 - Aministry of Tourism and Commerce was founded in Spain and the World Tourism Organization set up headquarters in Madird *(Jimenez & Joyanes, 2013)*

1990 - 1994 - Spain exceeds 60 million visitors per year

2005 - 2011 - A Rregional strategy is approved for Land Planning in thr Valencia Comunity

2011 - Openning of a new airport terminal in the Alicante-Elche Airport with capacity for 20 million passengers

2017 - 2013 - Openning of a high speed train line Madrid-Alicante

present

[Benidorm's tourist and urban evolution]

1954 - 1954 - Benidorm attracts summer visitors

A colony of 12,516 people from Madrid and Alcoy - a nearby town in the industial zone of the Alicante province (Vera, 1987) was settled in bungalows and small hotels along the Levante beach area. (Zaragoza, 1955)

1956 - 1956 - First Benidorm masterpaln (the first masterplan approved in Spain)

1963 - 1963 - A modification to the 1956 masterplan are approved by the Local Council

Removal of the building height restrictions maintaining the original plot size among other conditions in the Levante and Poniente Beach areas.

1967 - 1967 - A new international airport, located 58 km from Benidorm, was opened with a capacity to handle a million passengers per year.

1974 - Tour operators aleardy working from Manises airport began to operate with large aricraft and charter flights generating greater demand for short-term accommodation.

1974 - Benidor, coastline was planned in detail despite half the land zoned in the masterplan of 1956 remained undeveloped yet.

1990 - 1988 - Registered overnight stays reached 8.4 million *(Spainish Statistics Institute, 2018)*

2005 - 2005 - Registered overnight stays reached 10.7 million *(Spainish Statistics Institute, 2018)*

2005 - Sierra Helada area was granted natural park reserve status

2017 - 2015 - Registered overnight stays reached 11.01 million *(Spainish Statistics Institute, 2018)*

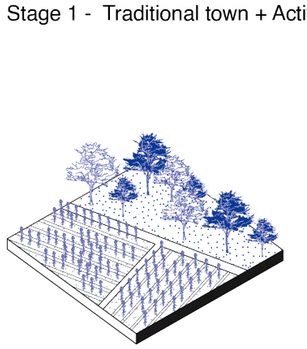
2017 - Up to 21 modificatons to the 1990 masterplan have been approved.

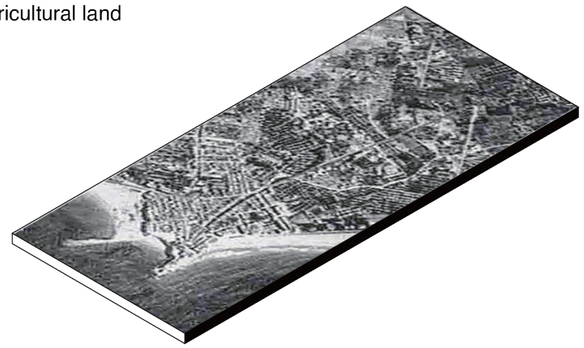
The specific regulations do not change the concept of the urban model nor the masterplan's guildlines, but they facilitate the application of increasingly complex regulations, such as the construction of new big commercial areas (Benidorm Townhall, 2016); or the creation of new non-residential uses. (Benidorm Townhall, 2017)

present

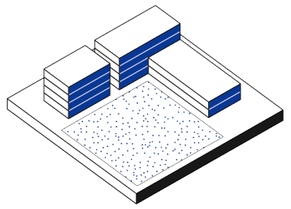
[Spatial transition]

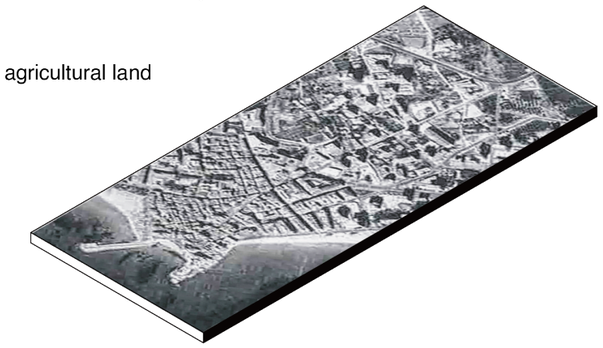
1954 - Stage 1 - Traditional town + Active agricultural land



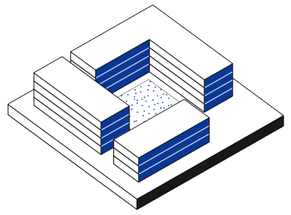


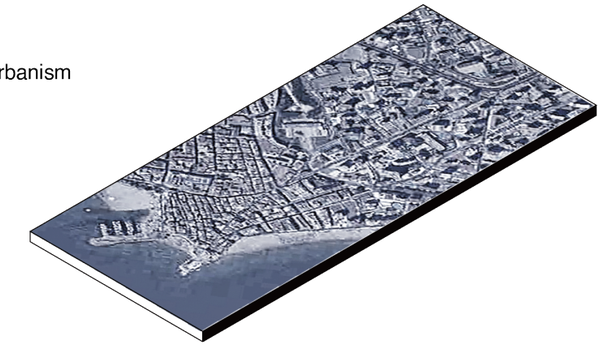
1967 - Stage 2 - Leisure area + Abandoned agricultural land



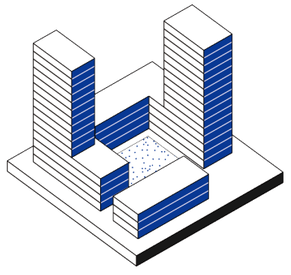


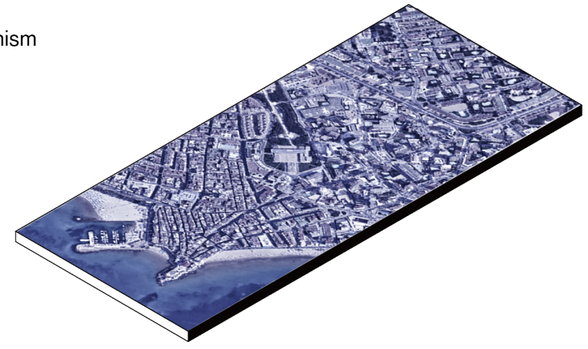
1990 - Stage 3 - Low density + Horizontal urbanism





2017 - Stage 4 - High density + Vertical urbanism





present

Spatial and Temporal Patterns of Fire and Climate Change

The images presented depict the temporal and spatial distribution of the number of fires and the area affected by fires in the eastern Iberian Peninsula, specifically the Mediterranean coastline of Valencia, over the past few decades. These patterns of fire occurrence align with the summer rainfall and summer temperature in this coastal area, which is known for its "blue economy" activities. Most fires in this region tend to occur during the summer season.

The maps provided in the images analyze meteorological data from 350 weather stations that cover the eastern Iberian Peninsula from 1950 to 2000. The findings of this analysis indicate a slight tendency towards decreasing summer rainfall and a clear pattern of increasing summer temperatures during the last few decades. Moreover, the maps reveal that the meteorological stations located in warmer areas exhibited a higher rate of summer temperature increase.

Considering the prevalence of the "blue economy" activities, which encompass various economic sectors related to the coastal and marine environment, it becomes crucial to incorporates both ecological and socioeconomic factors, taking into account the changing climate patterns identified in the meteorological data.

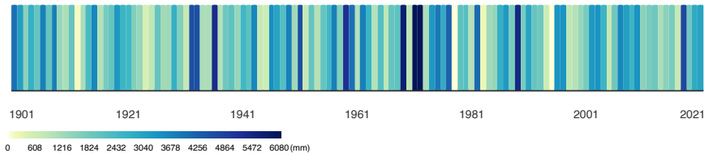


Fig. 9-6. Annual Precipitation, 1901-2021
Data source: Climate Change Knowledge Portal (CCKP), World Bank

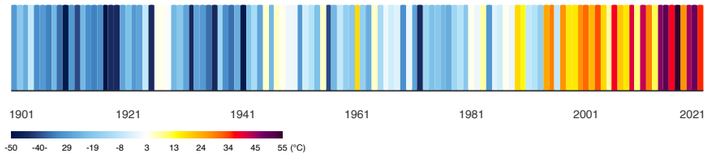


Fig. 9-7. Annual Max-Temperature, 1901-2021
Data source: Climate Change Knowledge Portal (CCKP), World Bank

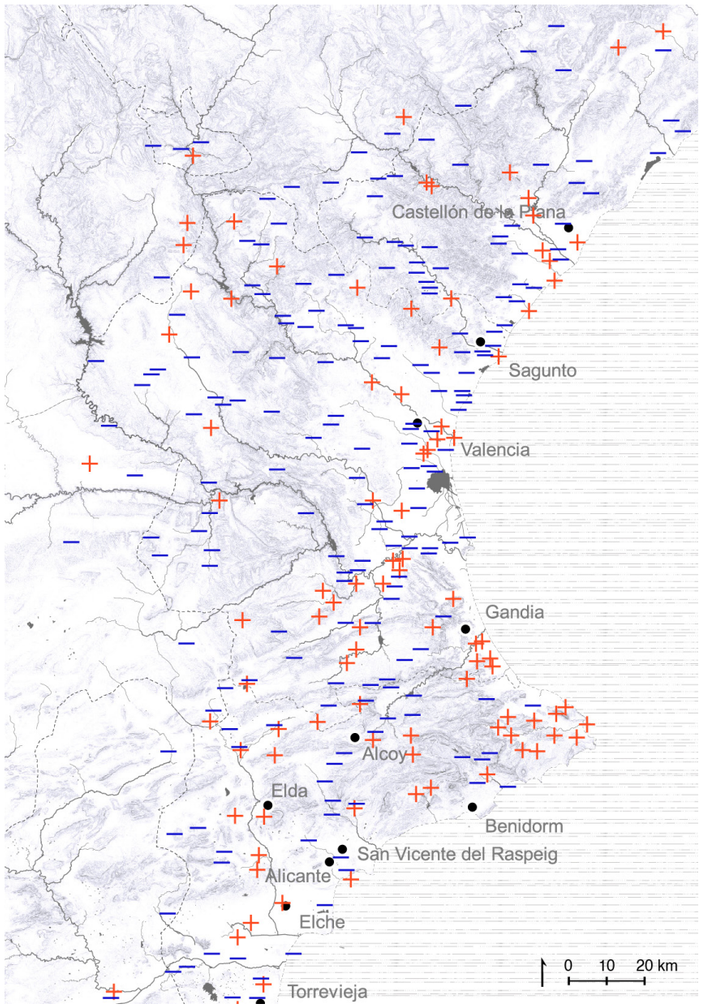


Fig. 9-8. Summer rainfall
Trends of increase + and decrease − (1950-2000)
Data source: Climatic data from 350 meteorological stations, National Meteorological Service

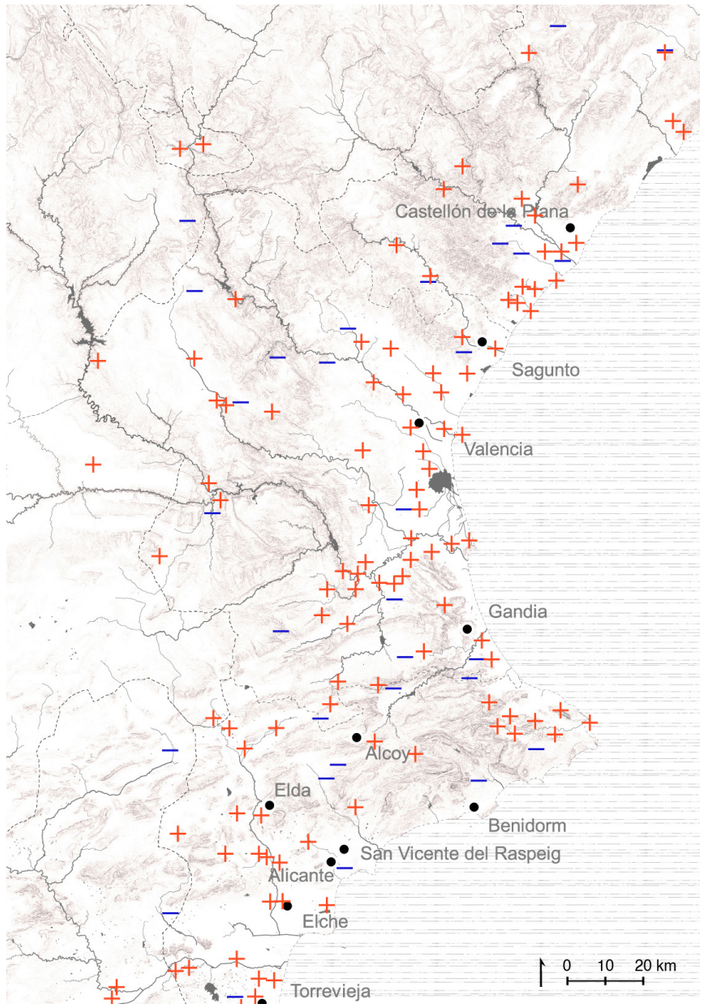


Fig. 9-9. Summer temperature

WILDFIRE ALTERNATIVES

Urban Water Scarcity

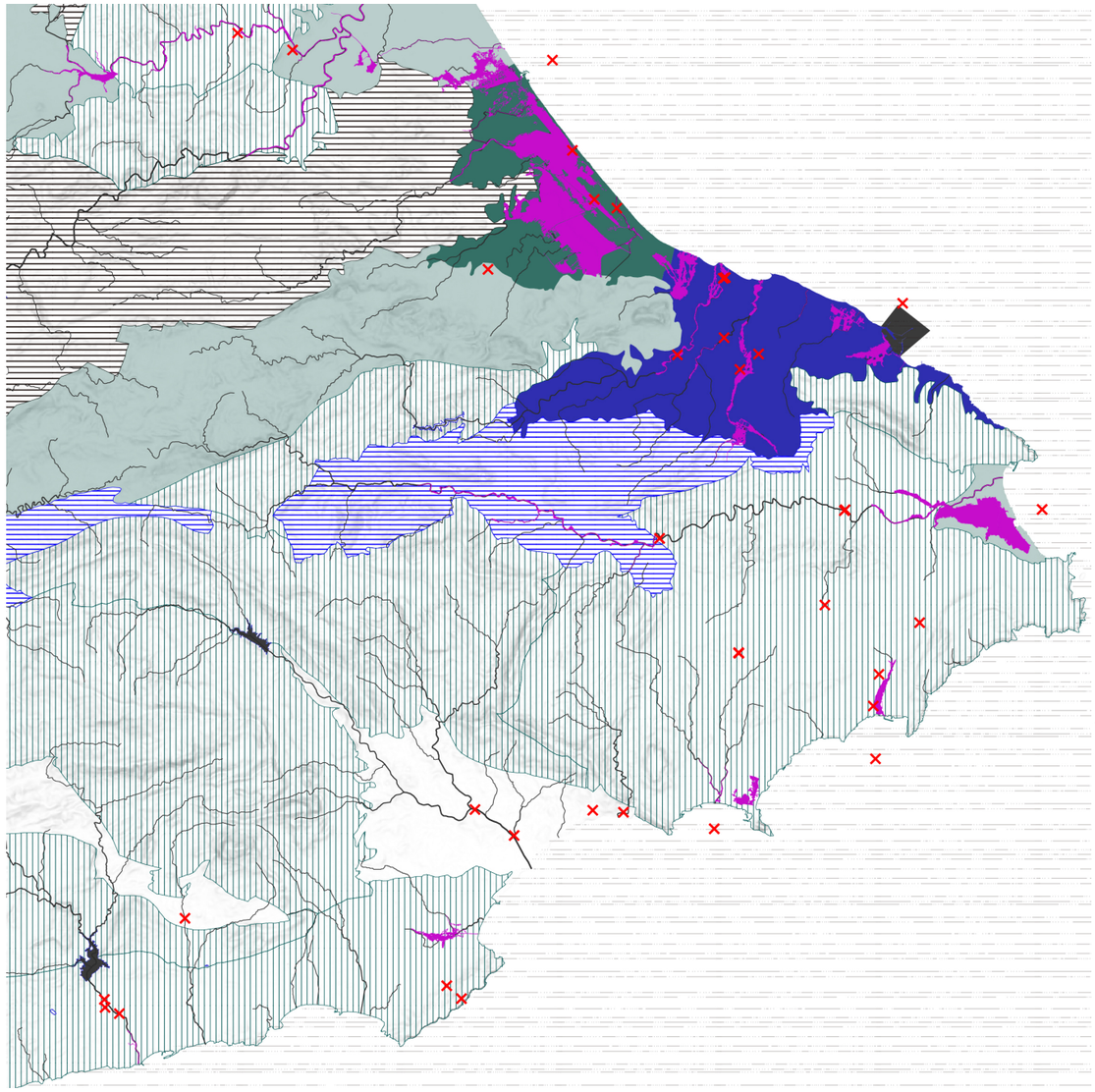
The analysis comarca (an intermediate level of administrative subdivision between municipalities and provinces) of Marina Alta, being situated in a semi-arid region, faces multiple challenges related to water scarcity, wildfires, and dry river conditions. The region limited water resources and periodic water scarcity stem from prolonged periods of drought and increased water demand due to population growth, urbanization, and tourism. To ensure water security, they relies on various water sources, such as reservoirs, underground aquifers, and desalination plants. Implementing water conservation measures, water recycling, and desalination technologies are crucial in addressing water scarcity and managing the water needs of the local population, agriculture, and the tourism industry.

Marina Alta also experiences intermittent or seasonal rivers known as ramblas, which may run dry for a significant part of the year due to the region's aridity. These dry riverbeds typically have rocky terrain and sparse vegetation. However, during heavy rainfall, they can transform into fast-flowing torrents, potentially causing flash floods that pose risks to nearby settlements and infrastructure. Adequate infrastructure and flood management measures are in place to mitigate the impact of these occasional but intense rainfall events. The management of dry river conditions involves land-use planning, floodplain mapping, and infrastructure development to ensure safety and minimize damage during flash flood events.

By addressing water scarcity through sustainable practices, implementing effective wildfire prevention and management strategies, and managing occasional flash flood risks, the region of Marina Alta aims to enhance resilience, ensure the well-being of its residents, and protect its natural environments. These efforts are vital for the long-term sustainability and adaptability of the city in the face of these challenges.



Fig. 9-10. Dry River Bed in the gorge at Gata de Gorges in the Province of Alicante, Spain
Image source : Keith Skingle / Alamy Stock Photo, 2019

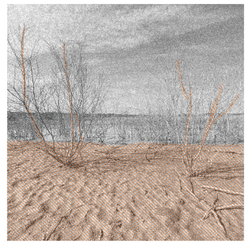


LANDSCAPE CRITERIA → TOOLKITS APPLICATION → FIRE ADAPTIVE RESILIENCE

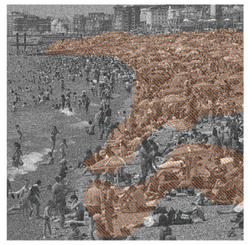
Hydrological system



Water scarcity



Extreme heatwave



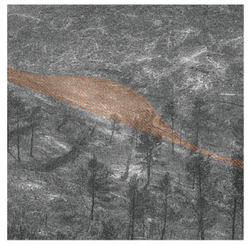
Urbanization (Littoral-ization) process



Coastal leisure area



Burned infrastructure scars



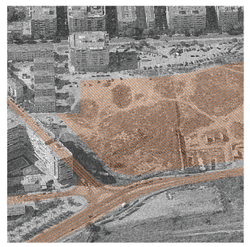
Coastal community



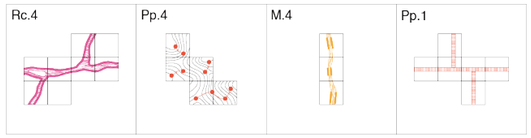
Seasonal tourism service



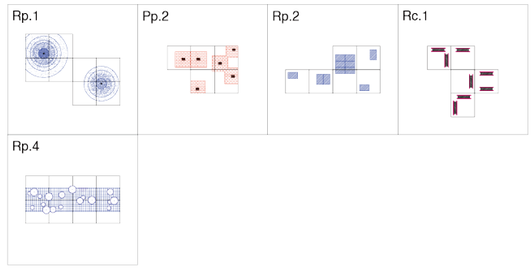
Urban planning & regulations



Rc.4 Watershed protection
Pp.4 Multifunctional cascading water system
M.4 Rewetting infrastructure
Pp.1 Escape route planning



Rp.1 Carbon capture
Pp.2 Defensible space
Rp.2 Temporary sheltering
Rc.1 Fire-resistant material
Rp.4 Landscape hardening



Pv.1 Prescribed burning
Rc.3 Land-use replanning



STRATEGY 01 Hydrography-based fire mitigation

Recognizing the untapped potential of existing waterways, a groundbreaking concept has emerged – channeling these water bodies into navigable pathways to provide a lifeline during emergencies. The constant flow of water provides a dynamic line of defense, minimizing the risks associated with fire and allowing for the safe passage of people and animals. More than perceiving rivers solely as replenishment or recreational areas, this endeavor seeks to elevate their purpose by integrating them into the very fabric of resilient urban design. The objective is to create a demonstrative model for new cities that can effectively utilize abundant water resources and ensure that waterways can contribute to the overall sustainability and livability of the urban environment.

STRATEGY 02 Urban emergency model

The new urban design idea integrates carbon capture, defensible space planning, temporary sheltering, fire-resistant building materials, and landscape hardening as "plug-ins" to prepare and mitigate wildfire risks in both normal times and emergencies. For instance, by incorporating carbon capture technology, settlements contribute to reducing emissions and improving air quality. Deployable structures with fire-resistant materials provide safe havens during emergencies and multifunctional spaces during normal times. This comprehensive approach ensures the safety, resilience, and sustainability of populated coastal settlements in different seasons.

STRATEGY 03 Seasonal tourism management

The proposed strategy for wildfire risk reduction in tourist popular coastal areas involves a seasonal management approach. During non-tourist seasons, prescribed burning is utilized to reduce fuel loads and create defensible spaces in preparation for the peak of fire ignition. In contrast, the management of coastal areas becomes more intense during the tourist season, with increased monitoring, rapid response systems, and strict enforcement of fire safety regulations. This comprehensive approach ensures the safety of tourists and the preservation of coastal ecosystems.

WILDFIRE ALTERNATIVES

STRATEGY 01 HYDROGRAPHY-BASED FIRE MITIGATION

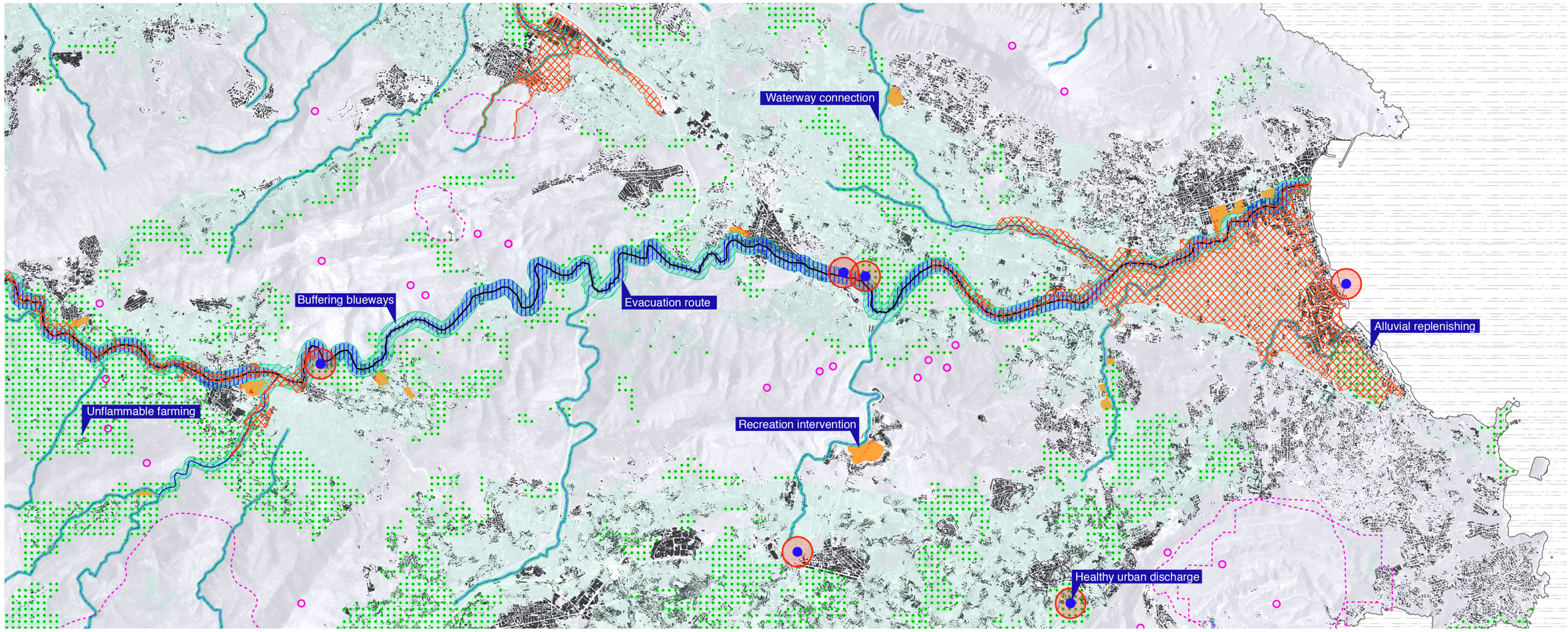


Fig. 9-11. Masterplan of hydrography-based fire mitigation strategies

RIver Gorgos Potentials

The torrential autumn rains usually cause frequent floods, especially in the middle course of the river; however, in summer it remains practically dry under the heatwave. Another characteristic of this river is the great permeability of its bed, which means that its flow serves to feed many sources due to the effect of underground filtration.

Recognizing the untapped potential of existing waterways, a groundbreaking concept has emerged – channeling these water bodies into navigable pathways to provide a lifeline during emergencies. This innovative approach, known as the water-led concept, aims to leverage the versatility of water and unveil its hidden gifts in the fight against devastating bushfires. The focus lies in harnessing the inherent capabilities of rivers and transforming them into robust evacuation routes. The presence of water acts as a binding agent, bridging the gap between everyday routines and the urgency of fire emergencies.

More than perceiving rivers solely as water sources or recreational areas, this endeavor seeks to elevate their purpose by integrating them into the very fabric of resilient design. The objective is to create a demonstrative model for new cities that can effectively utilize abundant water resources to address the challenges posed by wildfires.

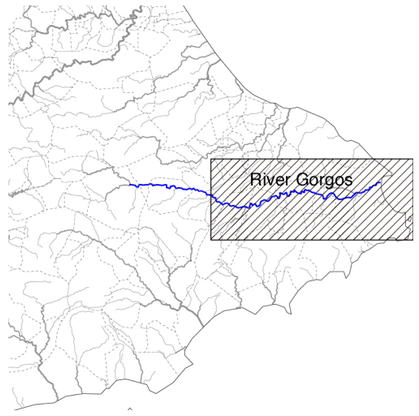
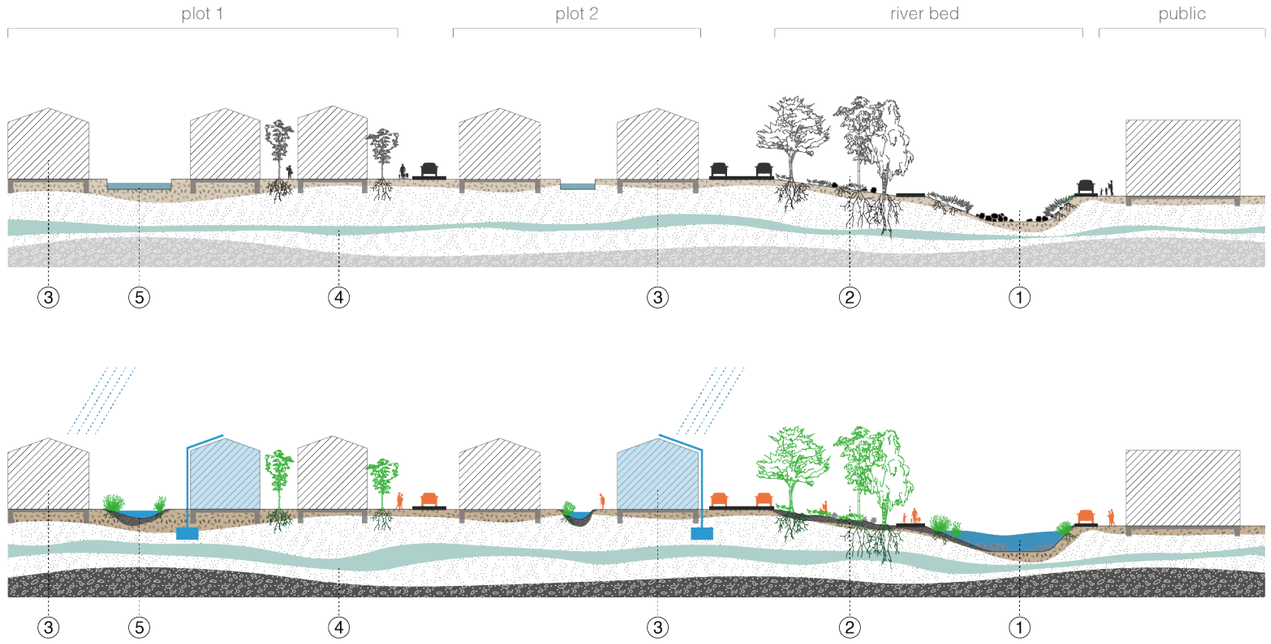


Fig. 9-12. Location of the design site

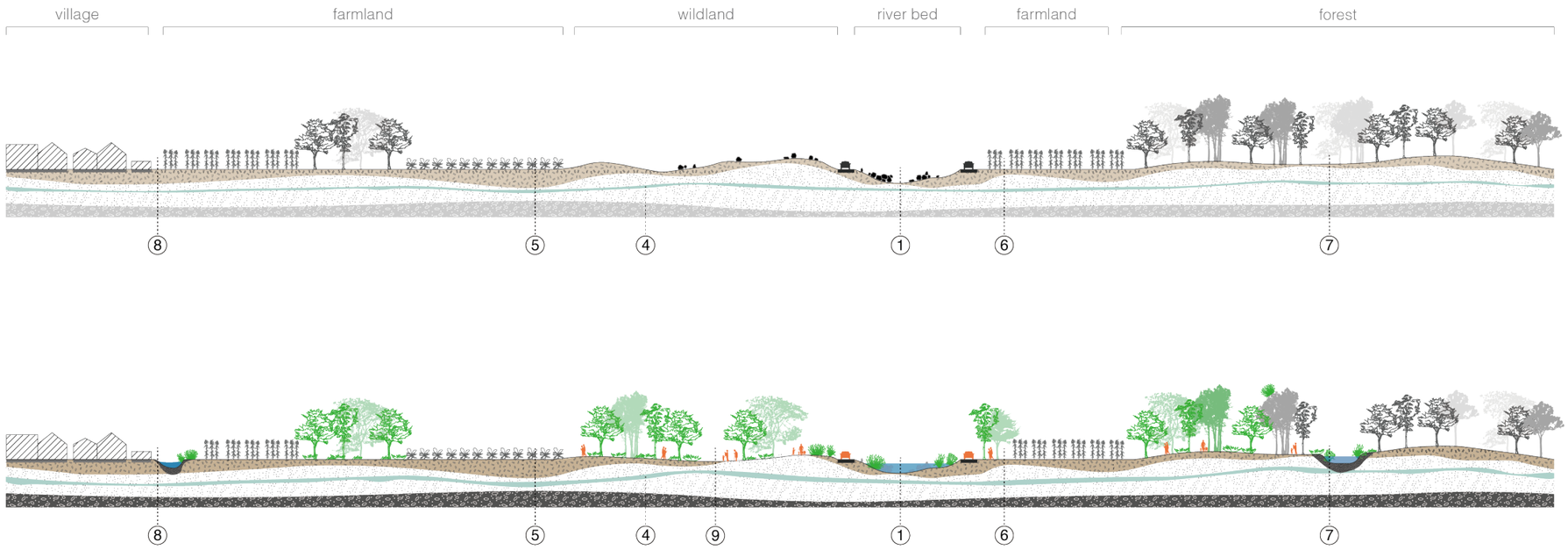
STRATEGY 01 HYDROGRAPHY-BASED FIRE MITIGATION



Section A



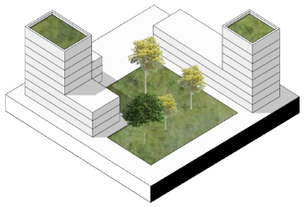
Section B



(Before / After)

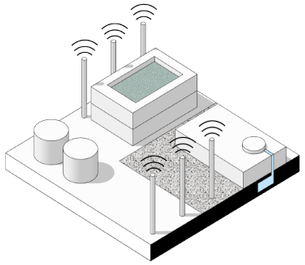
① Dry river bed / Water evacuation route
② Riverside wildland / Bank restoration
③ Urban block / Fire-resistant roof and water collection
④ Aquifer / High productive aquifer
⑤ Swimming pool / Pool and rain garden
⑥ Farmland / Unflammable farming buffer
⑦ Forest / Forest moisture ponds
⑧ Village / Village rain garden and stream
⑨ Riverside wildland / Recreation intervention

Low occupancy of buildings on plots



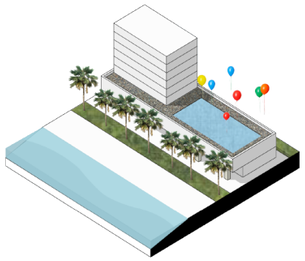
Low occupancy can create more public space for tourist and private use. It also create more space for evacuation and firefighting in the urban areas, especially along the coastal corridor.

Carbon capture and monitor infrastructure



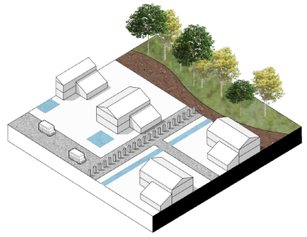
The infrastructure of CO2 capture works as a monitoring facility at normal time. It can evaluate on the climate conditions.

Fire-resistant material for highly densed coastal areas



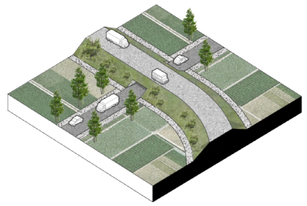
Fire-resistant material can be used in the new property constructions along the boulevards. Roof swimming pool can be built with these materials to support firefighting.

Landscape hardening for interface settlements



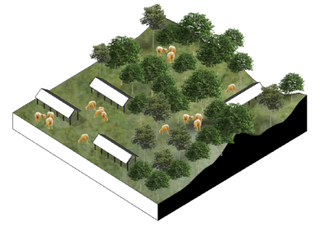
The interface of urbanization has high risk of wildfire. The hardening landscape along the settlements is needed to create a buffer to stop fire spreading and avoid damages of properties.

Landscape hardening for infrastructure



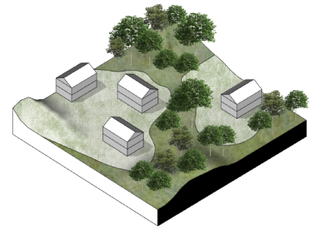
Landscape hardening can be used in the suburban areas in another way, which creates fire breaks to protect the mobility, industrial space and farmland.

Temporary sheltering nearby the high risk areas



Temporary shelters are built with recyclable and degradable materials that can be use at the normal time for grazing, but at the same time, it creates safe space for wild species.

Defensible space for isolated villages

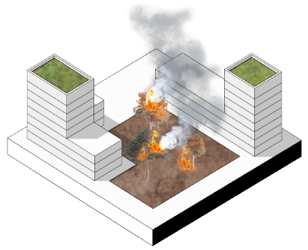


Defensible space around the buildings creates a fire-resistant buffer in the context of flammable hills. They are planted by some non-combusted species to create recreational space at the normal time.

Fig. 9-13. Urbanization transect in Benidorm city, normal state

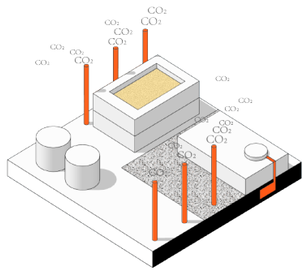
Low occupancy of buildings on plots

When low severity urban fire happens during the tourist seasons, larger public space can response quickly on the risk for evacuation and firefighters. Roof green remains.



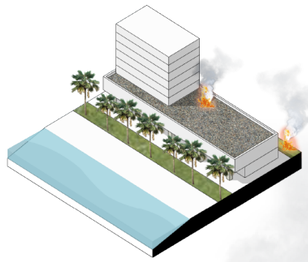
Carbon capture and monitor infrastructure

The capture facility can absorb carbon dioxide through smoke, transforming and storing them at the same time. It also helps collect data about fire severity.



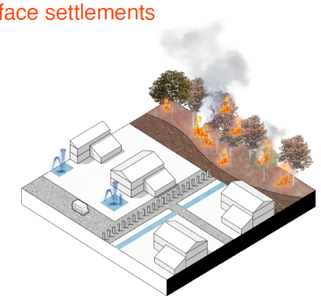
Fire-resistant material for highly densed coastal areas

Fire-resistant material protects densified coastal areas during the busy tourist season. The non-burning roof can stop the propagation of fire.



Landscape hardening for interface settlements

When the urbanization interface are suffered by the wildfire, the harden surface help protect the properties. Water pools and creeks can work on fire mitigation and provide escaping route.



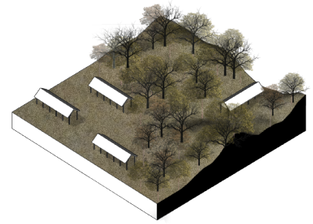
Landscape hardening for infrastructure

The buffered linear landscapes stops fire spreading during the emergency time which help minimize the losses for the infrastructure, industry and farmalnd.



Temporary sheltering nearby the high risk areas

The easily-built with recycled material shelters can work fast which sdirectly support human or animals to have a temporary living space.



Defensible space for isolated villages

Defensible space around the buildings creates a fire-resistant buffer in the context of flammable hills. They are planted by some non-combusted species to create recreational space at the normal time.



Fig. 9-14. Urbanization transect in Benidorm city, emergence state

Integrated Seasonality Events

An integrated approach that combines fire management strategies with tourism management is proposed in this timeline below. It explores the concept of integrating prescribed burning, collaboration with fire departments, communities, and family members, and the need for controlled agricultural burning to mitigate the risks and ensure sustainable tourism in the region.

By implementing prescribed burning strategies before the high peak of the tourist season, the risk of wildfires can be significantly reduced. Collaboration among various stakeholders, including fire departments, tourism authorities, and local communities, is essential for the effective execution of fire management programs. Additionally, regulating agricultural burning practices can further enhance fire prevention efforts.

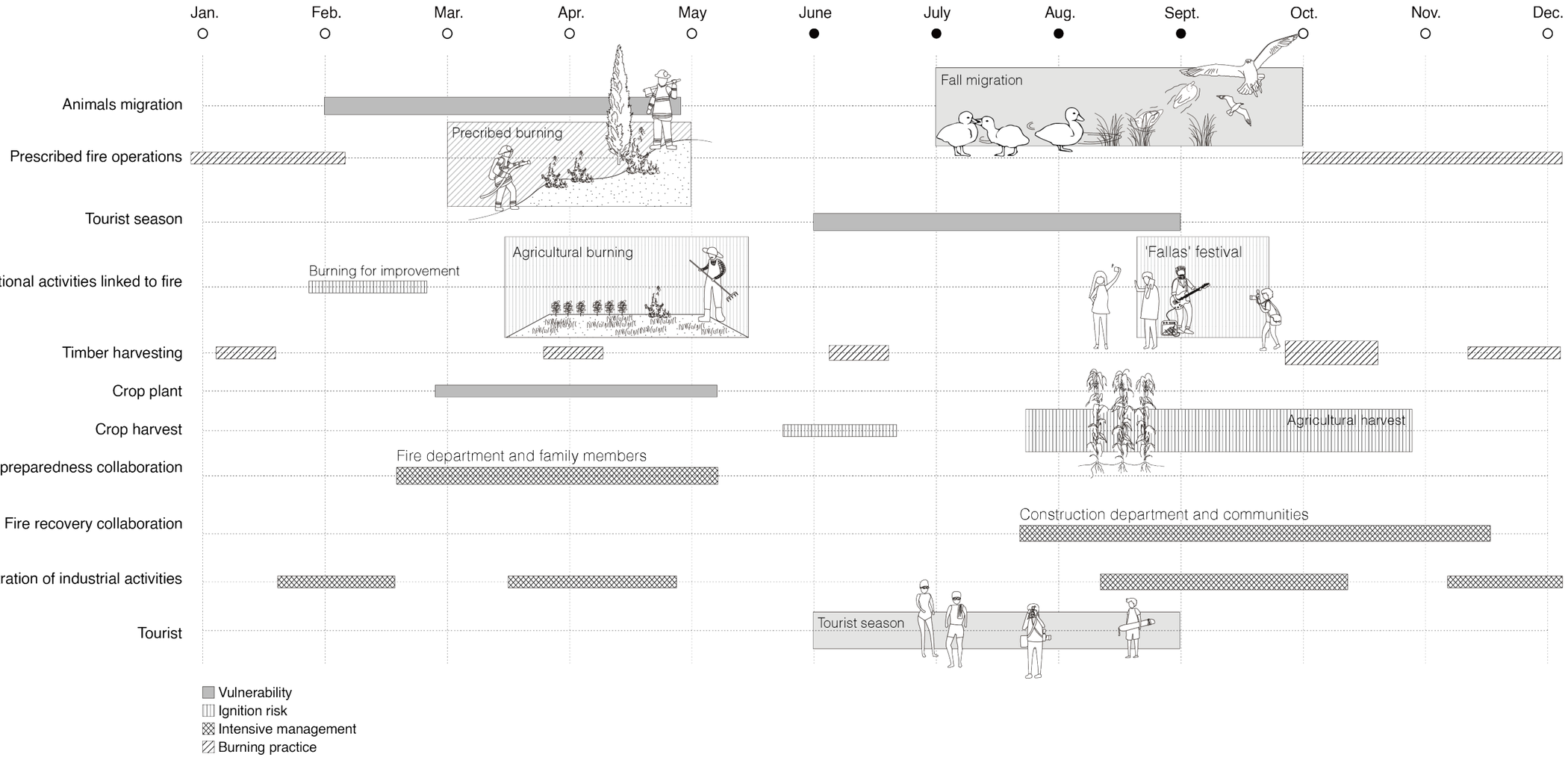


Fig. 9-15. Integrating seasonal events in to wildfire management

The Goal of Co-working Landscapes

Collaboration and Partnership: Addressing the risk of fires necessitates the active involvement and cooperation of various stakeholders, including government agencies, local communities, emergency services, research institutions, NGOs, and private entities. Through robust collaborations, we can leverage collective expertise, resources, and knowledge to develop comprehensive and sustainable solutions.

Knowledge Sharing and Innovation: By promoting research, data collection, and the exchange of best practices, we can deepen our understanding of fire risk factors, prevention measures, and response strategies. Creating an environment that fosters creativity and embraces new technologies and approaches allows for continuous improvement in fire safety.

Proactive Risk Management: By identifying and assessing potential hazards, vulnerabilities, and ignition sources, we can develop strong risk reduction strategies and implement appropriate preventive measures. This encompasses effective land management practices, the establishment of early warning systems, community education programs, and the creation of fire-safe infrastructure and zones.

Effective Communication and Engagement: Recognizing the pivotal role of communication in building trust, raising awareness, and mobilizing stakeholders, the framework ensures transparent and timely dissemination of information regarding fire risk, prevention measures, and emergency procedures. Actively engaging stakeholders through public consultations, workshops, forums, and education campaigns empowers them to actively participate in decision-making processes.

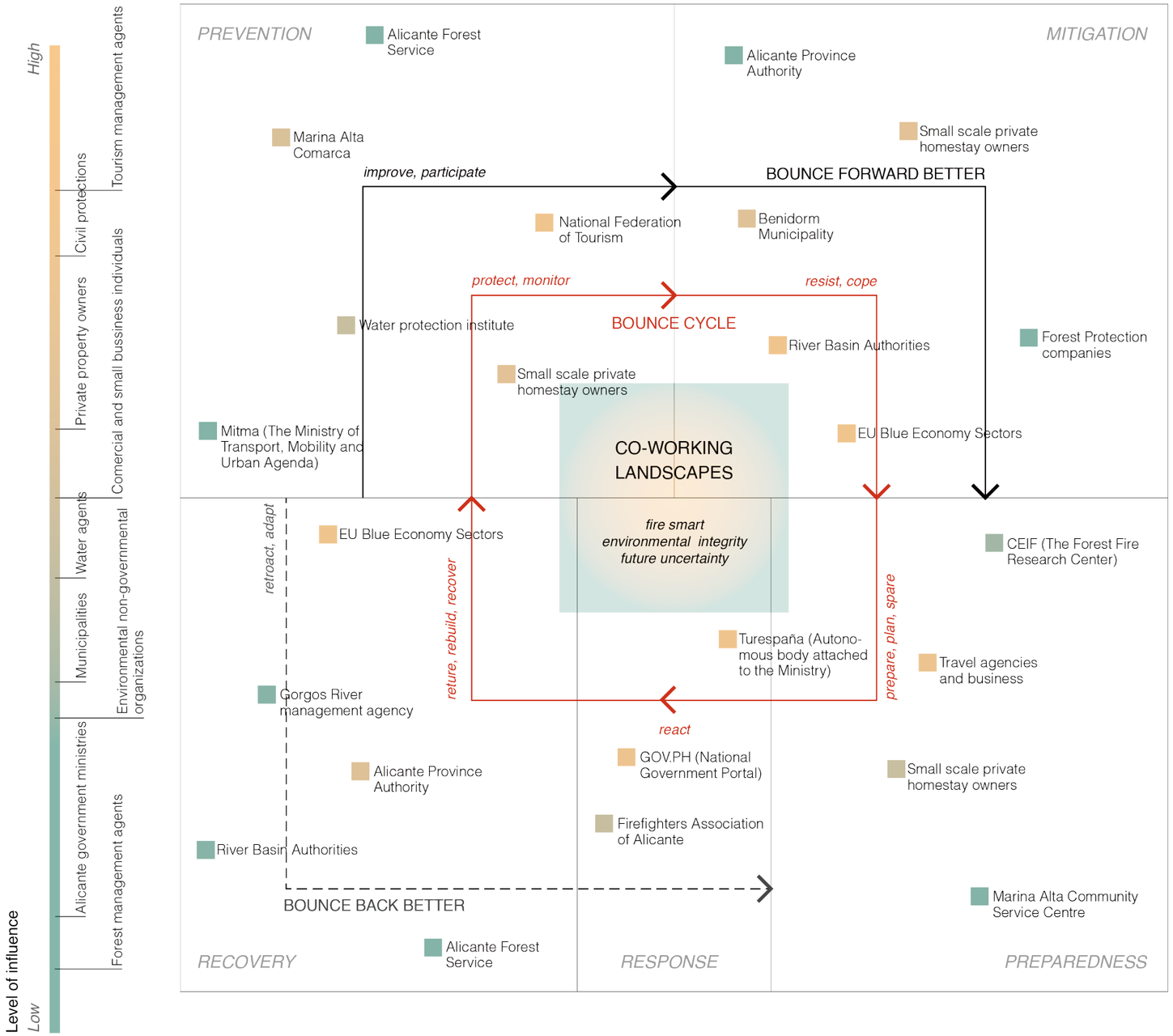




Fig. 9-16. The dry gorge passing through Gata de Gorges in the Province of Alicante, Spain. Image source: Keith Skingle, Alamy Stock Photo, 2019



Fig. 9-17. Long-term resilience for the local people

The long-term water replenishment process has resulted in a more humid and windy environment along the Gorgos River, benefiting the settlements located there by alleviating the extreme heatwave pressure. The transformation of the riverside into an accessible open space has provided ample recreational facilities for the local residents. These facilities are co-managed by the communities and the Marina Alta municipality, who work together to enhance wildfire resilience and prepare the region for future adaptation.



Fig. 9-18. Benidorm city in the tourist season. Image source: https://www.thesun.co.uk/travel/22359463/spain-holiday-tourist-tax-valencia-barcelona-benidorm-balearic-islands/

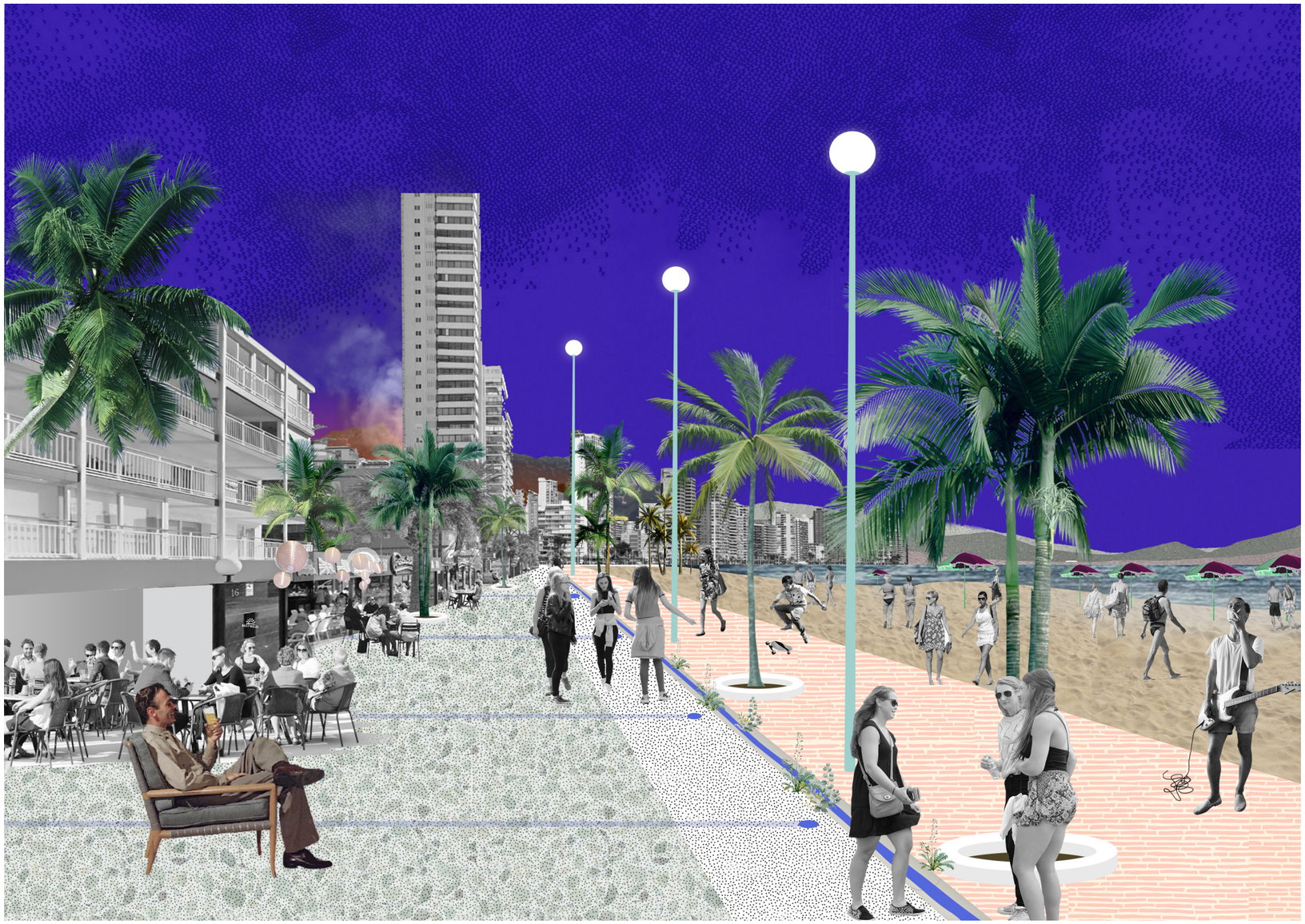


Fig. 9-19. Long-term resilience for the tourists

Urban modular "Plug-ins" are implemented in densely populated littoral areas to effectively mitigate wildfires during the tourist season. These plug-ins have the capability to seamlessly switch between emergency and normal states as required. As part of this initiative, innovative urban water systems are introduced along the coastal boulevard to combat the challenges posed by extreme dryness and heat. Simultaneously, the implementation of non-burning buffers at the urbanization interface acts as a barrier to prevent the remote spread of fires from the wildland.

10

CONCLUSION

Fire resilience synthesis

Conclusion

Reflection

Synthesis I: *Agro-pastoralism as a Landscape Asset*

The Iberian Peninsula has emerged as a suitable location for studying fire-landscapes, with various toolkits being utilized to enhance wildfire resilience. Through this analysis and design practice, agro-pastoralism has been identified as a unique system in the Mediterranean regions that can contribute as one possible but not the only answer to this resilience. Agro-pastoralism is a co-evolved system that has resulted from the interaction of natural ecosystems, land use practices, economic changes, and social movements. This system has shaped the regions over time, creating a dynamic mosaic of traditional landscapes that conserve ecological and cultural characteristics developed over centuries.

The management practices related to fire regimes, such as controlled burning, afforestation, and livestock husbandry, have produced intermediate disturbances in forest and silviculture management. These practices are crucial for ensuring the survival of the ecosystem, while reducing the threat of wildfires. The unique system of agro-silvo-pastoral is a hybrid human-animal community with extended sociality grounded in the territory and that pastoralists are peasants guided by the subsistence ethic. As a consequence, traditional agro-pastoral production systems still play a significant role in terms of employment, income, ecosystem functioning, and landscape management, despite their decreasing economic importance within the development process.

It is important to recognize the systematic and delaminated patches and corridors of agro-pastoralism, which can bring complexity and heterogeneity as a risk mitigation system in future scenarios. The interface overlapped with Mediterranean massifs buffer and the agro-silvo-pastoral land system can be identified as this corridor to shape a new form of agro-pastoralism. This recognition allows landscape entities to be envisaged in a more adaptable process by situating them under the hectare level of fire threats. The traditional landscape structure, which has resulted from centuries of agro-pastoralism, can be utilized to create a landscape mosaic that offers enhanced protection against wildfires.

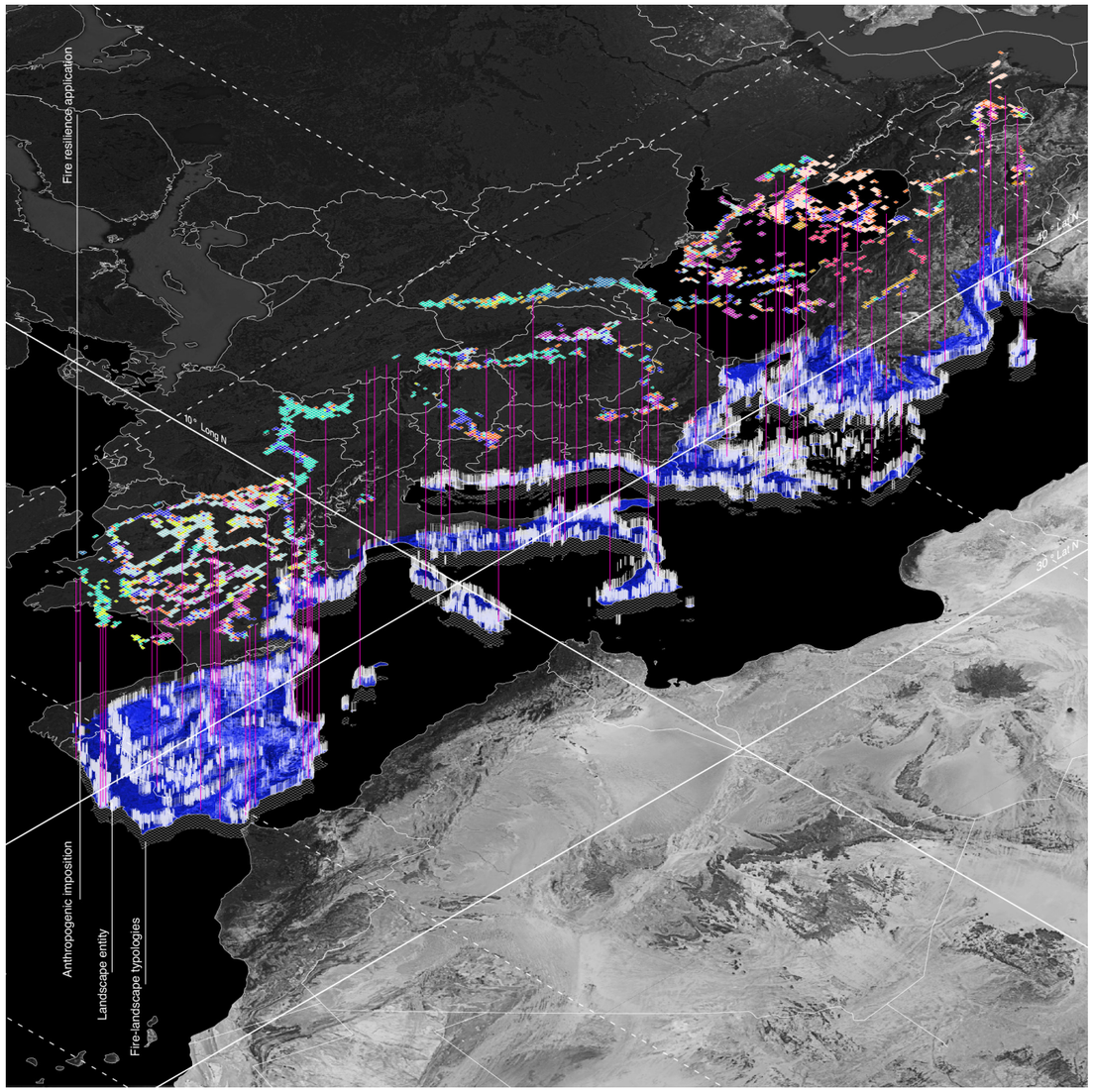


Fig. 10-1. Fire resilience synthesis_Agro-pastoralism as a landscape asset

The synthesis I of this image above shows the idea of one possible fire resilience scenario on the agricultural perspective.The interface overlaped with Mediteranean massifs foothill and agro-silvo-pastoral land is identified as the new landscape entity (white extrusion on the image). With this new form of agro-pastoralism corridor, the complexity of landscape can be brought back to avoid the homogeneity of the ground fuel, and the tiles of fire-landscape typologies and toolkits (grids on above) can be selected and applied as a potential solution to envisage risk resilience vision for the Mediterranean regions.

Synthesis II: *Making Littoralization as a Porous Process*

Considering the second design practice of the Iberian Peninsula, the Valencia Community in the territory forms an urban macro-region that encompasses multiple regional metropolises, as well as some highly developed tourist areas along the Mediterranean coast, including Costa Brava, Costa Daurada, and Costa del Sol. This region is regarded as one of the primary economic axes in Southern Europe. The concentration of economic activities, population, and settlements in coastal areas reflects a significant characteristic known as littoralization. This process is evident through seasonal variations in tourism and its development, sometimes in competition with other activities and sometimes parallel to them. Littoralization is also associated with the abandonment of settlements and agriculture in the hinterland, as previously mentioned in our last synthesis scenarios. In some cases, littoralization and land abandonment can be considered two aspects of the same problem.

However, in this context, the densely populated coastal corridor should no longer serve as a rigid boundary separating the coast and the wildlands. This dichotomy only exacerbates the spread of wildfires and increases the vulnerability of larger urban properties to natural risks. It is imperative to move beyond the analysis and demarcation of spaces that traditionally characterize cities—compactness, complexity, and continuous development—and instead argue for the study of urbanization as a gradient process from the coast to the hinterland. This approach shapes a porous littoral corridor that facilitates communication between the ocean and the inner wildlands. The emergence of these new forms of littoralization calls for a gradient integration of planetary space as interdependent networks, a sustainable and well-managed commercialization of tourism, and vertically linked eco-hydrographical scenarios. Additionally, it emphasizes the delineation of the urban edge and the wildland, with a focus on strengthening the mitigation processes against wildfires.

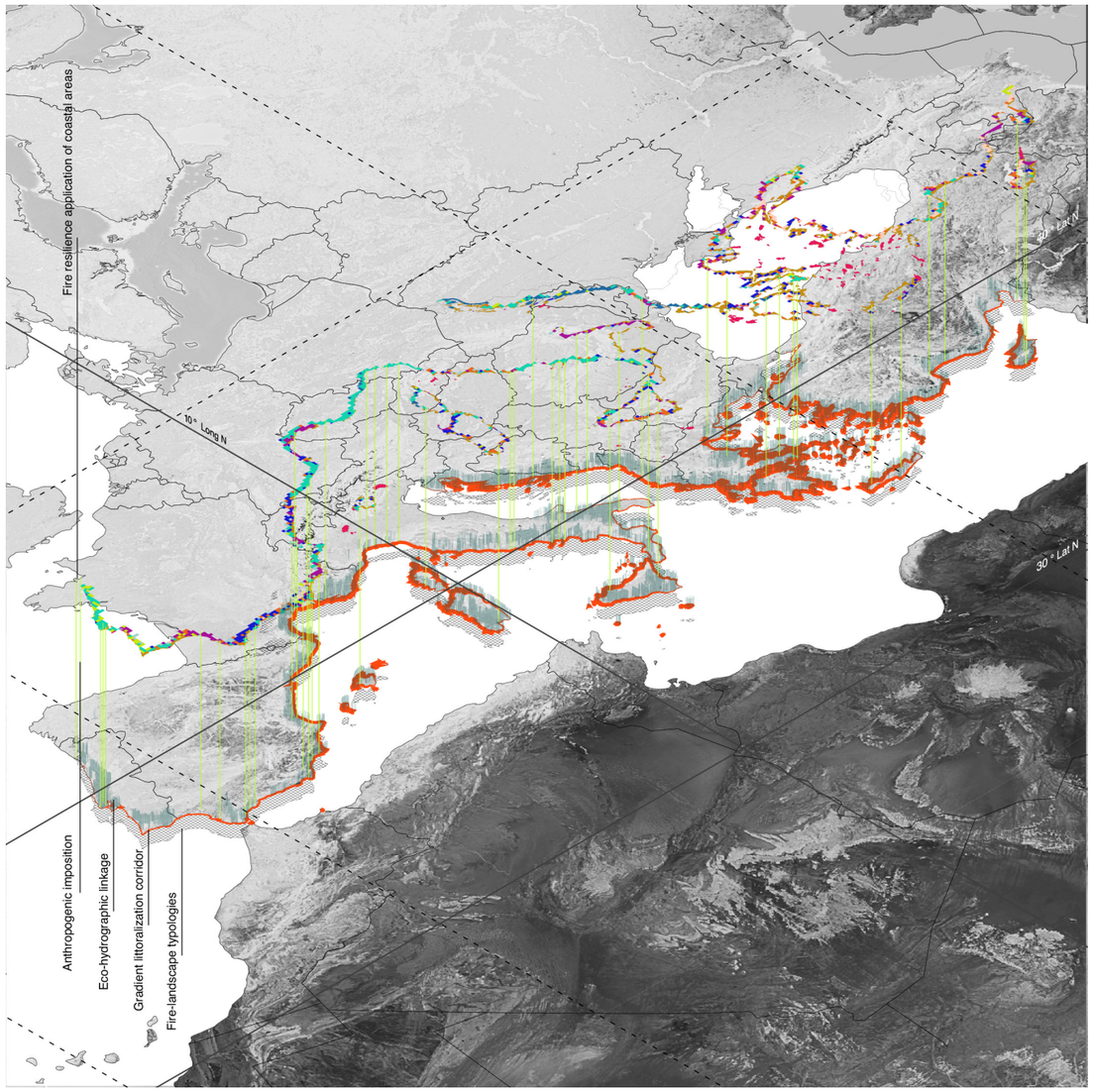


Fig. 10-2. Fire resilience synthesis_Making littoralization as a porous process

The synthesis II of new littoralization paradigm towards wildfire resilience are proposed by the image above. The red coastline is identified by 5-20km stripes from the sea depended on the local urbanization specificities, but connected as an entirety for the Euro-Med. It delimits a gradient zone from the ocean to inner wildland so that the toolkits strategies corresponding to the fire-landscape typologies can be applied as a systematic approach (upper layer in grids). Additionally, littoral hydrographic components (green extrusion) are identified as a landscape entity to build a porous interface, transforming the relationship between populated seaward and burning wild hinterland.

CONCLUSION

Representing Mediterranean Landscape System through the Lens of Wildfire

Contemporary landscapes are accumulated but contingent outcomes of past and present patterns, processes and decisions. In the Mediterranean regions, the wildfire overcomes the capacity of modern fire management, it is no longer reviewed as the positive ecosystem inputs historically under the aggregation of human activities. The result of catastrophic natural hazard leads huge landscape disturbance that the paradigm is simultaneously needed to shift toward territorial scale approaches. By recognizing the diversity and intensity of Mediterranean land system, the project reveals the intrinsic fire-landscape relation in the definition of territorial typologies which are implemented and categorized to find fire vulnerabilities of Mediterranean landscape elements. It starts from the aspects of meteorology, physiography, biology and anthropology and dialectally results in the susceptibility of settlement, land use, fuel management and climatic environment in both spatial and temporal dynamics that is exposed between fire regimes, landscape change and human activities.

Simultaneously, the reinterpretation of the Mediterranean landscape through a novel semantic system of wildfire risk introduces a fresh perspective on understanding territorial realities. This approach not only acknowledges the potential degradation of landscape value and the loss of cultural patterns in the Mediterranean region but also highlights the identification of the fire-landscape system as a dynamic process influenced by climate change, ecosystem evolution, and settlement emigration.

By visualizing and representing these studies and spatial patterns, a valuable decision and negotiation support tool is created. This tool serves a dual purpose: triggering and facilitating adaptive and mitigating interventions at the operational level. The strategies derived from the fire-landscape typologies function as toolkits, incorporating landscape elements such as monoculture, settlement, and geography as essential entities. These elements inspire possibilities for reconfiguring the territory through the resource of the land system, utilizing both natural and anthropogenic means.

Unlock the Potential

Although the landscape factors related to the fire risk have been identified as typological susceptibilities, we can not consider them as a stable process that the risk realities are permanently unaltered. Future scenarios differs in the situation of such complexity by geographic conditions, climatic dissimilarity, agriculture abandonment, deforestation or afforestation, urbanization interface, rural exodus and depopulation occurring in Mediterranean countries. Both humanized and un-humanized landscapes play a considerable role in regimes of wildfire and then, delimited the gathering zone in which, ecosystem and wildfire are co-evolving. As the consequence, the conversion potential of these landscape complexity and iteration needs to be unlocked simultaneously towards a long-term development of fire-resilient and adaptive ecosystems.

By taking two exemplary sites intervention in the Iberian peninsula, landscape entities have been deconstructed as the potential conversion based on the defined fire typologies, that are, interface, and settlement. Thus, the selection and combination of strategic tools can be applied into these entities. Firstly, the communal units and novel agro-silvo-pastoral forms has been applied to the interface in the district of Coimbra so that the rural heterogeneous spatiality has been brought back to mitigate the fire risk. The next site is chosen in Alicante, a populated costal area which is dominant by the typology 2. In this place, settlement configuration is reviewed as a flexible system that contributes more effectively to reduction in total area burnt and decreased the edge effect on remaining forest patches.

To rethink wildfire prevention and mitigation, understand fire as a management tool, adopt landscape-scale fuel-reduction and other strategies still remain challenges for the integrated territory in many other aspects such as socioeconomic movements, technical services and the global change. We should realize that the recognition of substantial associations between landscape potentials and risk regimes does not imply a simple nostalgic attitude toward conservation or restoration only, but a re-iteration or an alteration of a relationship between traditional activities, territorial realities, humanized processes and their modernity context. This recognition allows us to envisage and reconceptualize landscape forms that are more adaptable and resilient to processes of global change by situating them through the lens of natural hazards.

Indeterminate Alternatives in Regions

When we go back to the Mediterranean scale, the new agro-pastoralism form as one answer towards fire risk resilience has been explained from previous pages, but manipulable landscape entities still remain diverse and undetermined. As we said, the territory and risk are not stable results but still a dynamic process that are co-evolving over time and space. In that regard, contemporary design discourse is once again renewing its understanding of natural risk and landscape by intensively reexamining its devices for representing and intervening upon the territorial scale. Territory units and landscape entities in the Mediterranean regions that operate between landscape architecture and urban planning have the potential to become the responsive and effectual mediators to present-day ecological and climatic pressures.

Further studies should investigate the economic viability and social acceptance of these alternative fire-reduction strategies. In fact, landscape conversion of natural and semi-natural lands will likely have many detractors. Currently, most government budgets are spent on fire suppression (to control the impact of fires) rather than on fire prevention or alternative fire management policies. It is likely that socio-economic, political issues will arise when implementing such a landscape-scale management policy in a European Mediterranean region. Rethinking wildfire prevention and understanding fire as a management tool remain a challenge for the general public.

1. Relation between Research and Design

The project considers the wildfire as a risk object and criticize it as the crucial part of its ecosystem in the Mediterranean bioregion. Based on the theory of pyrogeography, the landscape system and the fire regimes have been evolving interactively which needs to be investigated in a comprehensive pro-cess. With GIS-based methods and techniques, the dataset is developed by the perspective of meteorology, physiography, biology and anthropogeny based on a fire-prone data interval in order to reinterpret the fire-landscape interaction as a system. The output of this reidentification map reveals 10 fire-landscape typologies and their spatial distribution in the Mediterranean, which improves the understanding of land system with natural crisis and is a basis for assessment of future changes under the regional climate, land use and land cover change and changes in management intensity.

The results of research provide a evaluation and decision support tool in some specific locations for fire management, biodiversity protection and conservation of landscape values. Thus, the downscale works following the research part are proceeded towards strategic toolkits for bridging the disconnection between Mediterranean research and landscape design practice. The prospective use cases additionally account for the geopolitical and socio-cultural context of the region in question, as a means of establishing an integrated framework for fire management.

As the consequence, the Iberian peninsula is selected as the site on design practice level to apply the toolkits strategies. Taking the results of research as account, three sites in the middle transect of the Iberian peninsula from west to east represent three different fire-landscape typologies respectively, that are, interface type, slope type and coastal type. By considering the local context specificities, policy and cultural backgrounds, the combination of the strategies from toolkits are applied consequently towards the future visions. This leads to new “fire-scapes” and new forms of resilience of the regions. can also modify the selected elements of landscape upscale to the part of Mediterranean regions in order to create an integral long time design.

To conclude, the fire-landscape typology definition as the core part of the research guides and supports the development of toolkits on strategic level and then accommodate on the design results part on practical level. On the contrary, the design practice helps to evaluate the result of the researches and provide solutions on both local and Mediterranean scale.

2. Relation between Project Topic, Studio Topic, Urbanism track and MSc AUBS Programme

With the exploration of wildfire regimes and territorial dynamics, the project builds on the interaction between risk and ground reality to envisage the possible actions of future resilience of wildfire management from local specificity to the Mediterranean solutions. This process follows the studio instruction of Transitional Territory that the heterology of landscape elements has been identified, deconstructed and recomposed across scales. Thus, seeing wildfire as one of the most vital resources we have, the project is framed by the studio theme to re-define a shared value system of fire-landscape in a post-humanist perspective. Both goals of the project and studio are consistent to lead to reconceptualization of modernity and, consequently, to a new way of relating to otherness, space and time.

Moreover, the topic of project reflects the manifesto of Urbanism track which focuses on the recreation of sustainable urban landscapes aimed toward climate adaptability, circularity, social equity, and ecologically inclusive urbanisation at all scales. The track adopts them simultaneously that helps the project to advance, share and apply knowledge on how to adapt the wildfire risk to societal and environmental changes. At the same time, the project includes the perspective of urban and landscape design, geomatics which also reflects the approaches of MSc AUBS programme, working in a multi-disciplinary way.

3. Evaluation of Methodological Relevance

The foundation of this project is cantered around establishing connections between landscape dynamics and the risk regime, with a focus on understanding and identifying their relationships. Through the utilization of the studio methodical Lines of Inquiry and the theory of pyrogeography, the project investigates the interaction between fire behaviour and territorial reality, primarily in four countries within their respective landscape contexts. This approach aims to advance the development of grouping landscape-related factors and characterizing fire-landscape typologies at the Mediterranean scale. By employing the **Lines of Inquiry** studio method and the theory of pyrogeography, this project delves into the intricate relationship between fire behaviour and the territorial context. Through in-depth investigations conducted in four countries, the project sheds light on how fire interacts with and shapes the landscapes in these regions. The insights gained from these investigations contribute to the advancement of understanding fire-landscape typologies and the factors that influence them on a Mediterranean scale.

To achieve this, fire typologies are considered as landscape units that are defined through the analysis and interpretation of diverse territorial factors. **Geographic Information System (GIS)-based** methods play a significant role in conducting spatial analysis, focusing on identifying areas with homogeneous attributes. By utilizing GIS, the project leverages the power of spatial data analysis to uncover patterns and relationships between various territorial factors and fire typologies.

Furthermore, the project adopts a **Multi-scale Approach** to its development. It begins with a global perspective, examining wildfire as a negative risk within Mediterranean climate regions (MCRs). Subsequently, through the reinterpretation and typification of the landscape system in the Mediterranean regions (specifically, the EU part), three local sites are selected to apply strategic landscape-based tools, considering their specific contextual factors. This localized perspective facilitates a deeper understanding of the dynamics between fire and the landscape, informing the design perspective of the project. Finally, the project scales back up to the Mediterranean regions to envision possible alternatives for enhancing wildfire resilience and adaptation. By synthesizing the findings from the local sites and considering the broader context of the Mediterranean, the project aims to provide comprehensive insights and strategic recommendations for managing fire risks and fostering landscape resilience.

4. Evaluation of Academic and Societal Value, Scope and Implication

The results of this research on the interplay between fire regimes and landscape dynamics in Mediterranean Climate Regions of the European part hold significant academic and societal value. From an academic perspective, the research contributes to the advancement of knowledge and understanding in the field of wildfire risk management and landscape dynamics. By exploring the complex relationship between fire and the landscape, the research fills gaps in existing literature and provides a novel methodology for characterizing fire hazard and landscape interaction.

Academically, the diagnostic map and typologies catalogue developed through this research serve as valuable resources for future studies, enabling researchers to build upon and expand the findings. The research outcomes can inspire further investigations into specific fire-landscape types, as well as the effectiveness of landscape-based approaches in mitigating fire risk. The methodologies employed in this research, such as the studio methodical Lines of Inquiry and the theory of pyrogeography, can also serve as a basis for future research endeavors in related fields.

From a societal perspective, the implications of this research are significant for wildfire risk management and public safety. The diagnostic map and typologies catalogue offer practical tools for identifying the most risk-prone areas, allowing for proactive planning and resource allocation to mitigate the potential impact of wildfires. This information can be utilized by land managers, policymakers, and emergency response agencies to develop effective strategies and allocate resources in a targeted manner. The research outcomes also contribute to enhancing societal resilience to wildfires. By characterizing fire-landscape typologies and promoting landscape-based approaches, the research offers practical solutions for managing and reducing fire risk. This has tangible benefits for communities living in fire-prone regions, as it enables them to make informed decisions about land use, infrastructure planning, and emergency preparedness measures.

The visualized typology study and spatial patterns have societal value by improving public awareness and understanding of wildfire risks. The clear representation of fire-landscape types and their distribution can help educate and engage the general public on the complexities of wildfire dynamics and the importance of landscape management. This increased awareness can foster a sense of shared responsibility among communities and encourage collective action towards wildfire prevention and mitigation.

5. Evaluation of Transferability of Project Results

This project provides a model to deepen our understanding of territorial susceptibility and its contribution to various occurrences and disturbances, such as flooding, erosion, and over-exploitation. It is not only aid in identifying and assessing areas that are most vulnerable to natural hazards but also enable the examination of different land-use trajectories and inform targeted management plans.

By integrating various data sources and analytical techniques, a comprehensive assessment of the susceptibility from this project can be transferred and reproduced in different territorial context. They incorporate factors such as topography, soil composition, hydrological patterns, and human activities to create a holistic understanding of the vulnerabilities. This information helps stakeholders, including land managers, policymakers, and environmental agencies, to identify regions that are at the greatest risk and require immediate attention in terms of planning and management.

Furthermore, the project allows for the simulation of different land-use trajectories and scenarios, providing valuable insights into how specific actions or interventions may impact the occurrence and severity of natural hazards. This enables decision-makers to explore different management strategies and assess their potential effectiveness in mitigating risks and reducing the impact of disturbances. This proactive attitude ensures that management efforts are focused on areas where they can have the greatest impact, effectively reducing the occurrence and severity.

6. Ethical Issues and Dilemmas

Firstly, data uncertainty could be a dilemma of the research. The presence of semantic inconsistencies arising from the combination of various remote sensing and modelling products can result in inaccuracies in datasets. Spatial resolution differences across the datasets have been mitigated to a certain extent via resampling and reassignment. But the primary source of uncertainty in the data is also attributed to temporal scale variations. It may limit its use in applications where shorter-term biodiversity or ecosystem changes prevail. The characteristics of each typology cannot be only observed and measured by single sensors since the complexity and heterology of territorial systems. In the future, the iterations of data are required in the attributes of upcoming fire-landscape typology research under the same proposed method in order to ensure the accuracy of the clustered result.

On the other hand, the assessment of social acceptance towards landscape conversion and alternative fire management strategies is crucial in the ethical aspect. Socio-political issues are likely to arise during the implementation of such policies in the European Mediterranean region. Public perception and stakeholders' attitudes can greatly influence the success of these initiatives. Engaging with local communities, landowners, environmental organizations, and other relevant stakeholders is crucial to ensure their concerns, values, and perspectives are considered. Public consultations, participatory processes, and stakeholder engagement initiatives can help foster dialogue, build trust, and address potential conflicts or opposition to landscape-scale management policies.

A

APPENDIX

Additional drawings

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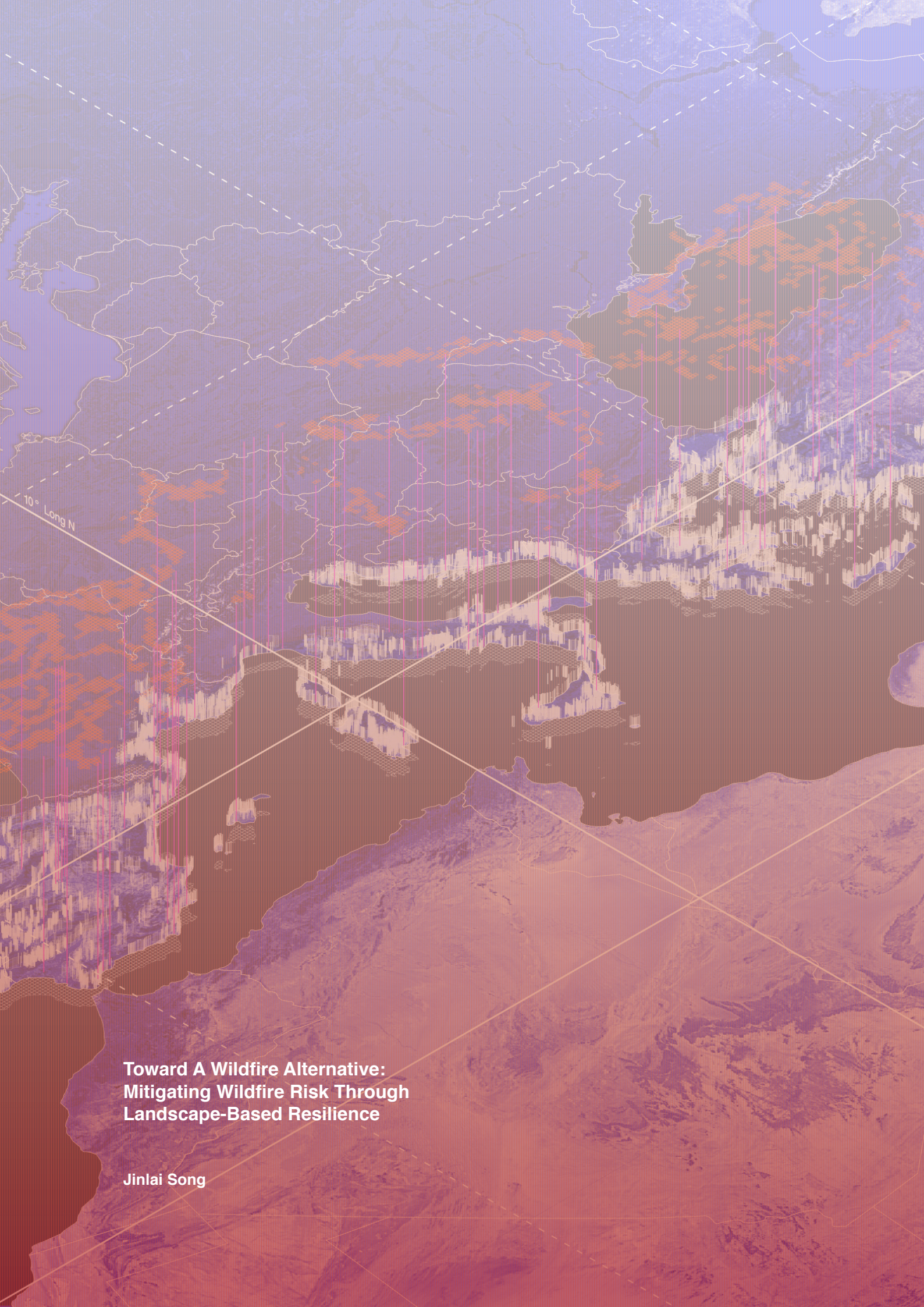
Catagories	FactorsU	nits	Format	Scale / Resolution	Source of data	Details	Website
Meteorological	Wind speed	m·s-1	Raster	3 km	New European Wind Atlas	Wind speed at 10m (max)	https://map.neweuropeanwindatlas.eu/
	Wetness index	/	Raster	0.5° x 0.5°	Copernicus Climate Change Service	Near surface meteorological variables from 1979 to 2019, specific humidity	https://cds.climate.copernicus.eu/#!/home
	Annual temperature	K	Raster	0.5° x 0.5°	Copernicus Climate Change Service	Near surface meteorological variables from 1979 to 2020, air temperature	https://cds.climate.copernicus.eu/#!/home
Physiographic	Slope	degree	Raster	30 km	Copernicus	Reclssify to find the steep part (0-5,5-10,10-15,15-25,25-33,33-81)	https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1-0-and-derived-products
	Aspect	N-NE-E-SE-S SW-W-NW	Raster	30 km	Copernicus	Reclassify to find the south part (SE, S, SW)	
	Elevation	m	Raster	30 km	Copernicus	/	
Biological	Fuel density	% proportion of total forest from land area	Raster	1 km	European Forest Institute	EU forest map, version 2011	http://dataservices.efi.int/euromap/phase2/register.php
	Soil moisture	Soil Moisture Index (SMI) 0-1	Raster	5 km	EEA geospatial data catalogue	/	https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/a21e58ad-ff91-436c-866a-fcbcf2615841
	River density	/	Vector	/	HydroSHEDS	Hydro BASINS, Drainage density	https://www.reachhydro.org/home/params/global-drainage-density
Anthropohenic	WUI proportion	Percentage of cell area (%)	Raster	1 km	EFFIS	EU wildland urban interface proportion	https://effis.jrc.ec.europa.eu/apps/fire.risk.viewer/
	Population vulnerability	Percentile (%)	Raster	1 km	EFFIS	Proportion of people who live in wildland urban interface	https://effis.jrc.ec.europa.eu/apps/fire.risk.viewer/
	Road density	/	Vector	/	European Environment Agency	/	https://www.eea.europa.eu/data-and-maps/data/external/openstreetmap
	Land-use change	/	Vector	/	CORINE Land Cover	/	https://land.copernicus.eu/pan-european/corine-land-cover
	Forest management intensity	/	Raster	/	BBN session	/	https://www.quickscan.pro/case/informing-eu-investment-agenda-mapping-forest-management-intensity



Toward A Wildfire Alternative: Mitigating Wildfire Risk Through Landscape-Based Resilience

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