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Natural hazards and disaster risk management in mountainous regions of southwest Europe: **MONTCLIMA Project**

Technical sheet

Title

Natural hazards and disaster risk management in mountainous regions of southwest Europe: MONTCLIMA Project

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Funding

This document was prepared within the framework of the MONTCLIMA project - Climate and natural hazards in the SUDOE mountains", co-financed by the European Regional Development Fund (ERDF) by means of the Interreg SUDOE programme (SOE3/P4/E0874)

DOI

https://doi.org/10.34620/montclima_project

Handle

http://hdl.handle.net/10198/26628

Year of Publication

2023

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EXECUTIVE SUMMARY

People have inhabited mountainous regions for generations, living with the dangers posed by drought, erosion, wildfires and landslides [1]. Currently, perceptions of natural hazards have improved, but increasing numbers of people visiting, traveling or inhabiting mountainous regions have experienced higher levels of risk as well as an increase in vulnerability in these territories [1].

The understanding of hazards and consequent disasters is based on mutual knowledge of the human and biogeophysical dimensions [2], and how these impact the ecosystem. The mountainous regions are relatively active geophysically and hydrologically, structure a great landscape diversity, encompassing diverse ecosystems and many species of fauna and flora. Due to the heterogeneity of mountainous regions, there are several natural hazards, which are highlighted by the fragility of their ecosystems, the low population density, the growing abandonment of the territory, and the composition of their social systems. Added to all these characteristics, several studies have configured that climate change has interfered with the frequency and intensity of disasters [3]. In this way, managing natural risks and adapting to climate change are essential for ecosystems and the protection of populations.

In south-western Europe there are mountainous areas that encompass part of the territorial space of Portugal, Spain, Andorra and France [4]. The main mountain ranges are the Iberian, the Pyrenees, the French massifs and the Alps.

Therefore, the main objective of this report is to provide a state-of-the-art overview of natural hazards in the SUDOE mountain region and current strategies used to deal with disasters, as well as some effects of climate change. We carry out this report through two main parts: i) review of the EM-DAT database to identify the main disasters in the countries that comprise the SUDOE region; ii) analysis of projects in databases of European funding programs. In addition, we also use academic databases as support tools to search for terms and definitions directly related to our study focus.

We identified that disasters in the region have increased by approximately 26% in the last four decades, with meteorological disasters being the most representative, with 16, 33 and 87 events recorded in Portugal, Spain and France, respectively. Heatwave was the deadliest event in the period studied, being responsible for 95%, 76% and 68% of deaths in Spain, Portugal and France, respectively. However, in Andorra, snow avalanches are the hazard that has caused the most deaths in the country, with 18 deaths since 1975.

Based on these projects, we highlight that 72% of selected projects work with partner countries. In particular, wildfires receive great attention, since most of the good practices addressed this type of hazard through prescribed burning, guided herbivory and early detection of forest fires.

Mountains vulnerability to climate change

"Mountains are among the most sensitive ecosystems to climate change and are being affected at a faster rate than other terrestrial habitats. Climate change impacts are a major threat to their integrity and the services they provide, and to the large often vulnerable populations that depend on them."

UNESCO. "Climate change impacts on mountain regions of the world" (Impacts du changement climatique sur les régions montagneuses à travers le monde), 2013, p.4-5.

Moutains natural hazards

1 Erosion
2 Wildfire
3 Flood
4 Avalanche/Landslide
5 Drougth

1. OBJECTIVE

To analyze state-of-the-art of management practices for the four main risks (drought, floods, wildfires and erosion) in the mountainous areas of the southwest region (SUDOE).

Action 1.1 Study on the current state of practices with a transnational approach in the SUDOE space

2. INTRODUCTION

2.1 THE MOUNTAINS IN THE SUDOE REGION

The mountainous regions of SUDOE (**Figure 1**), cover about 53% of the territorial space and directly support more than 23% of the population in these countries – Portugal, Spain, Andorra and France [4]. In the SUDOE region, the main mountain ranges are the Alps, the Iberian, the Pyrenees and the French massifs.

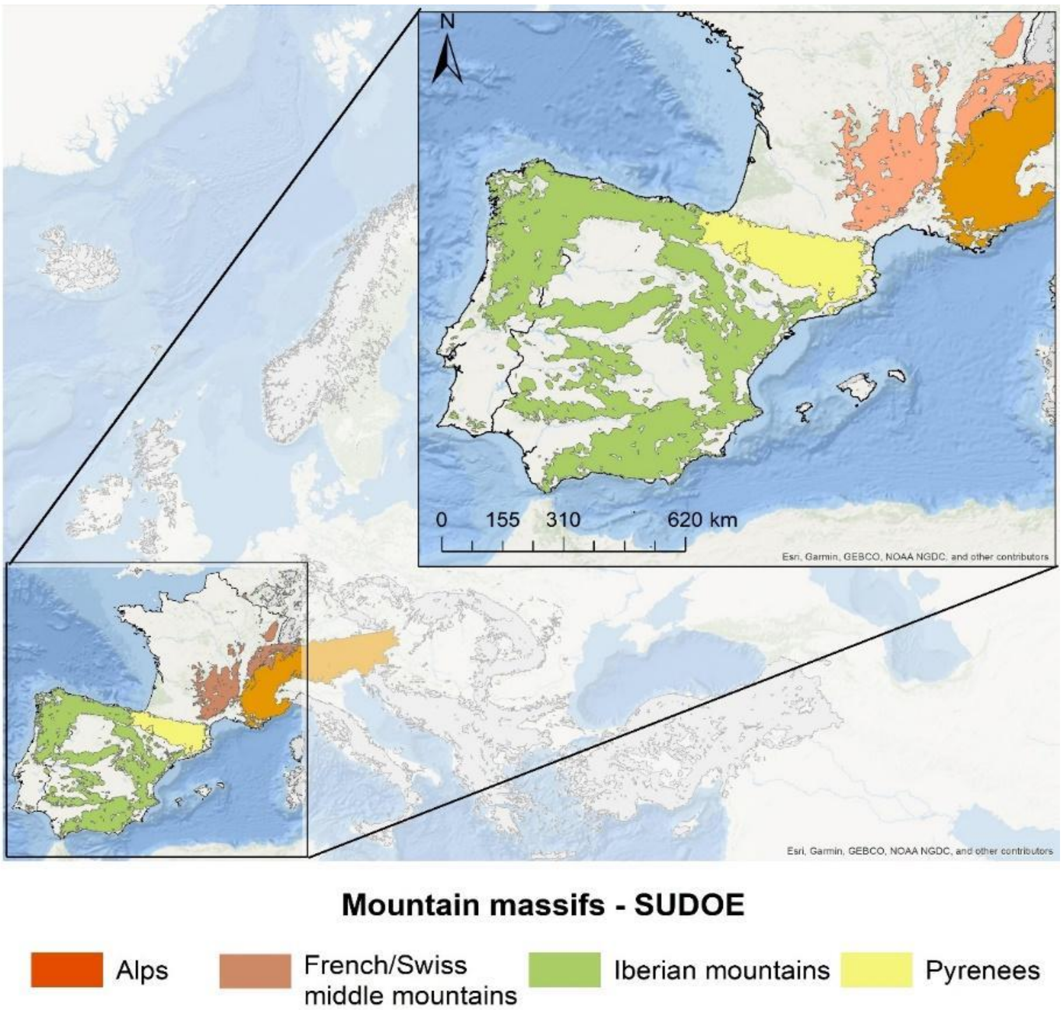


Figure 1. Mountainous massifs from south-western Europe, representing Portugal, Spain, Andorra, and France.

Southwest Europe has complex relief features, the altitude difference across the entire region is over 3400m and land use/cover types include forests, agricultural lands, pastures, scrubland and urban lands, with cropland being the dominant type. Forests also occupy a large percentage of the area, and are located mainly in the northern and mountain regions. The climate is seasonal temperate with hot and dry summers inland, wetter and cooler summers along the coasts, and cool and wet winters. Most precipitation occurs during the winter. Overall, the south is dry and hot and the north is relatively wet and cool [5].

In Portugal, geographical mountain areas cover approximately 18% of the national territory, in particular the large mountainous masses dominate, above all, the northern and central regions of the country. Of the twelve National and Natural Parks that constitute the country's protected areas, around 75% correspond to mountain areas [6]. In Spain, areas above 800m occupy around 35% of the country’s territory, 37% of its territory is wooded forest area (forests), and 19% is treeless forest area (bushes, sandbanks [7]).

In France, mountain areas include the massifs of the Alps, the Pyrenees, the Central, the Vosges, the Jura, Corsica and the overseas regions. Approximately 58% of the mountain surface is covered by forest and semi-natural environments while 38% is occupied by agricultural land. In addition, tourism represents a significant part of the activity of most mountain territories, with spin-offs estimated at 20 billion euros (2018-2019), with the French offer in terms of ski areas one of the largest in the world [8].

In French territory there are officially three administrative borders for the mountains, namely mountain areas covered by the urban planning law, less favoured mountain agricultural areas and massif borders [9].

Andorra has a mountainous territory divided by a network of narrow valleys and high peaks. The average height is around 2,000 meters, with peaks over 2,850 meters. The vegetation is composed of a rich mosaic of species and the higher slopes of the mountains are mainly grasslands and conifers.

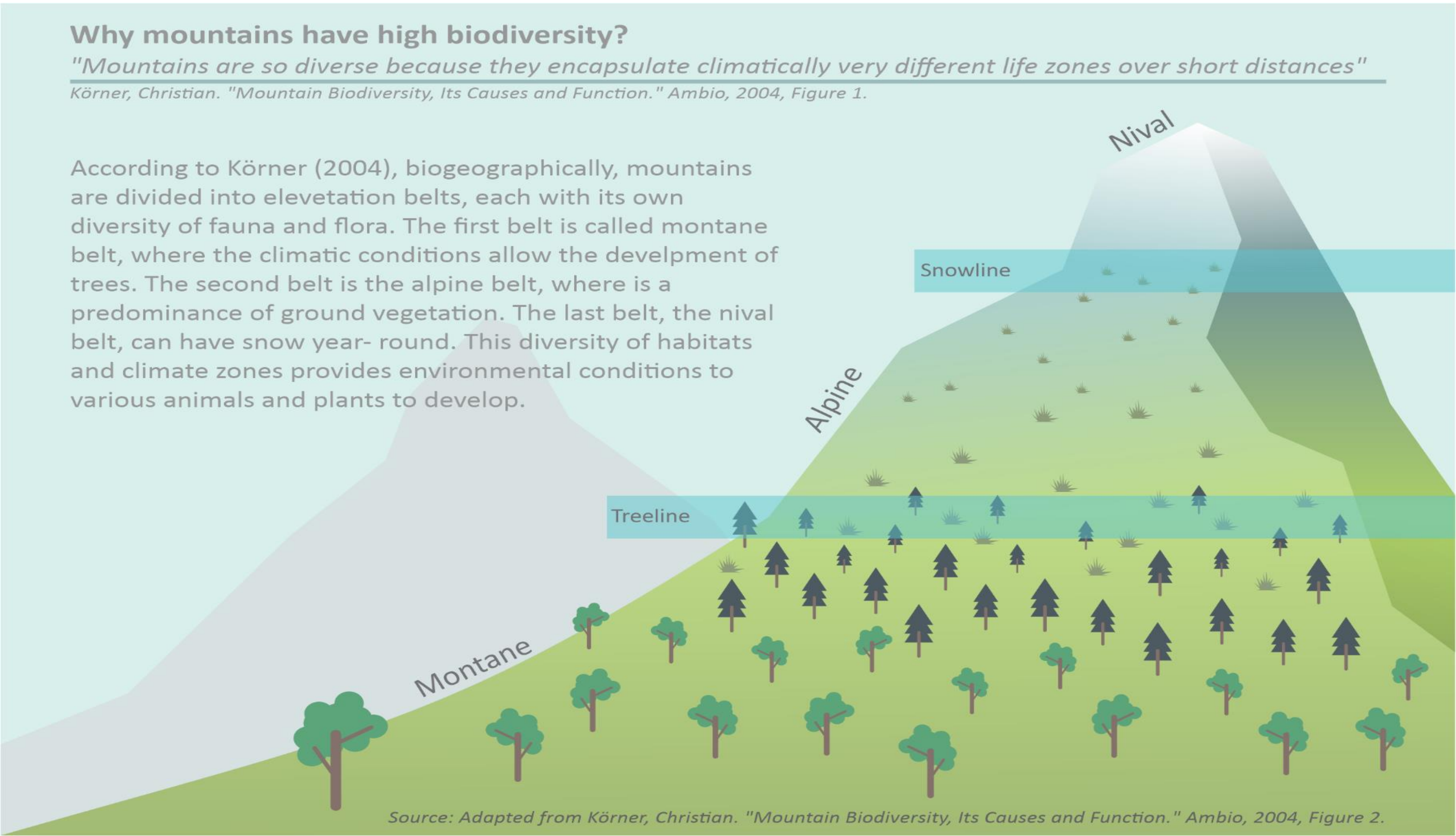
The mountainous areas have a great diversity of species and habitats, mainly due to the local environmental conditions related to the altitude and slope favouring biodiversity. They are crucial for the existence and sustainability of human societies, playing an essential role in global and regional climates [10] and they have significant influence beyond their geographic areas because they are the source of most rivers and act as cradles, barriers, and corridors for a high number of species. About 50% of the global biodiversity hotspots are found in mountainous regions [11].

In addition to supplying much of the continent's water and sources of electricity, the mountains provide opportunities for leisure and tourism based on natural attributes and local heritage, being centres of diversity, both biological and cultural. However, in the European territorial expansion, mountainous regions are considered disadvantageous locations due to topographic restrictions, specific economic activities, climatic conditions, and peripheral conditions [12]. Moreover, their ecosystems are particularly vulnerable to climate change [10–13].

Climate change is known to deeply affect the biosphere and the cryosphere, with direct and indirect impacts on global resources. Mountain ecosystems are sensitive to these changes, and the fast increase in temperature over the last decades may have high impacts on the mountain habitats [14, 15].

Mountains act as key elements in regulating the hydrological cycle. However, with changes in precipitation regimes, the frequency and intensity of extreme events and disasters may be increased, having a massive impact on water availability and distribution, resulting in more mega fires, severe droughts, flash floods, and intense debris flow. Part of the effects of climate change in the hydrological cycle in the mountains may be explained due to the replacement of areas with a high albedo that reflects sunlight (areas covered with ice and snow) by areas with low albedo (dark rocks, vegetation). Also, as they are highly sensitive, mountainous geosystems and ecosystems experience more frequently the extreme events that result from climate change, with significant consequences both in mountainous areas and downstream [15].

Additionally, mountains present a series of natural hazards that affect life and development of communities in these regions. For this reason, there is a need for a social, economic, and environmental understanding of how policies concerning natural hazards can serve as a basis for future planning and policies aimed at increasing the resilience of these areas [14].



2.2 DEFINITION AND CLASSIFICATION OF NATURAL HAZARDS

Natural hazards are natural characteristics, inherent to all biomes, which are dependent on several geophysical and environmental variables and have the potential to cause harm to society as casualties, damage on buildings and structures, interruption of services and activities [16]. Mountain regions have various ecosystems, and this characteristic also allows mountain regions to present multiple natural hazards that may be worsened by climate change (**Figure 2**).

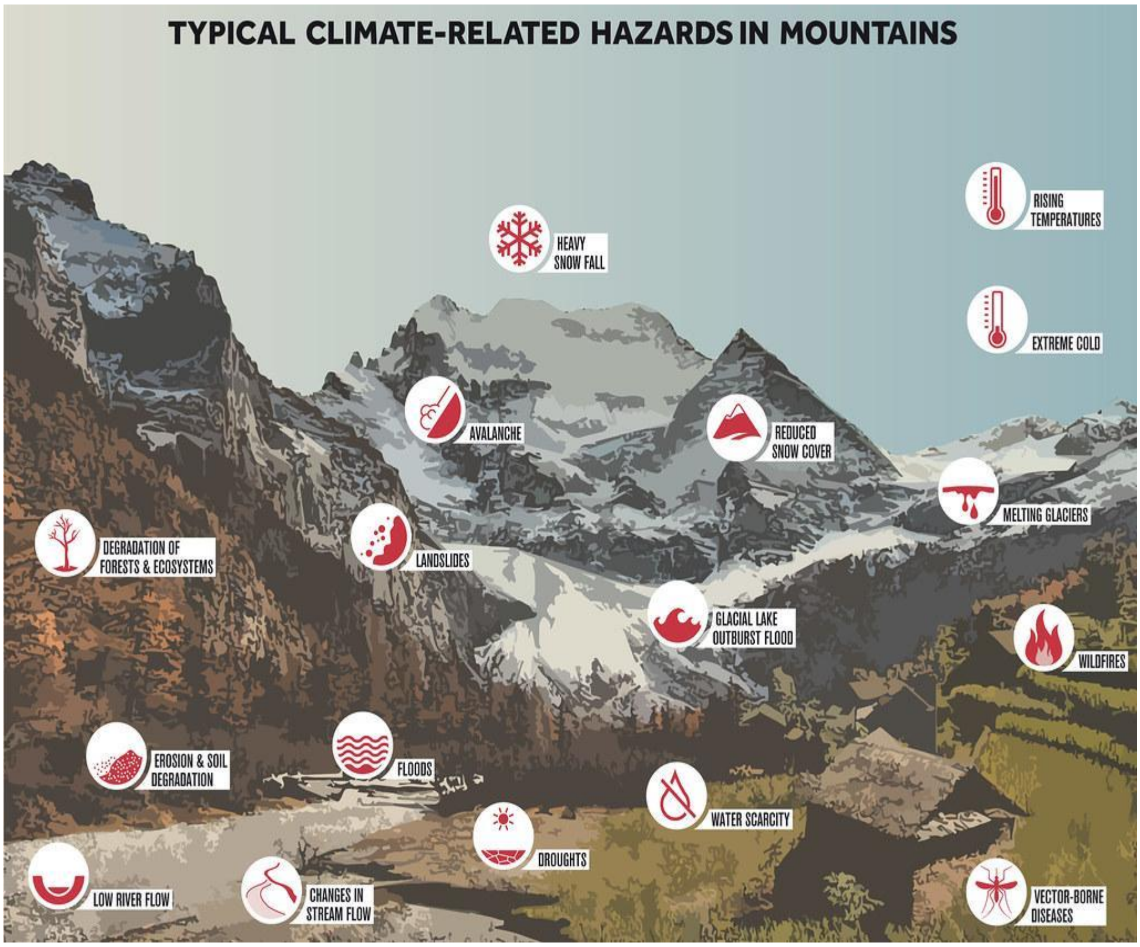


Figure 2. Typical natural hazards in mountain regions [17].

Taking this into account, the importance of an all-hazard analysis approach relating to climate change impacts emerges in international organizations [18] highlighting the relevance of this analysis to provide more effective adaptation and mitigation measures, both for the present and for the future.

Generally, a particular hazard approach is taken to assess the consequences of natural hazards and their relationship to climatic conditions (e.g. drought, floods and, erosion). This unique risk analysis allows you to determine the individual risk and the processes involved for a given geographic area over a given period of time, not providing an integrated assessment of the multiple risks that can be triggered by different forces, both natural and anthropogenic [19–20].

For example, mountainous areas are exposed to different impacts and consequences resulting from climate change, such as drought, wildfires and erosion [21, 22]. This highlights and emphasizes the importance of all these hazards being considered simultaneously during analysis and management, bringing their dependencies and factors together to provide an overview for that particular location.

A comprehensive approach must be applied to the assessment of disaster risks and relate them to the climate, in order to consider all aspects that contribute to the increase or aggravation of hazards, vulnerability and exposure in a multi-hazard perspective [23].

2.2.1 WILDFIRES

Europe has been frequently affected by large wildfires, especially Mediterranean countries [24]. Spain, Portugal, France, Italy and Greece account for 85% of all European burned area. Particularly, in 2017, large wildfires occurred in the south of France, Italy, Portugal and Spain associated with unusual droughts and heatwaves. These events caused damage in the region, with Portugal being the most affected country [25].

In this context, based on data obtained from PORDATA regarding the burned area (**Figure 3**), 2017 was the most severe and tragic year for the three countries in the region in the last five years (2015-2020), in all, 744533 hectares burned, of which 73% were burned in Portugal, with more than 21000 fires recorded that same year. Also, Spain suffered the devastation of about 178234 hectares, of the 39202 fires in the region, 35% were registered in Spanish territory. Compared with Portugal and Spain, France recorded the lowest number of wildfires (4403), which caused 26378 hectares of burned area.

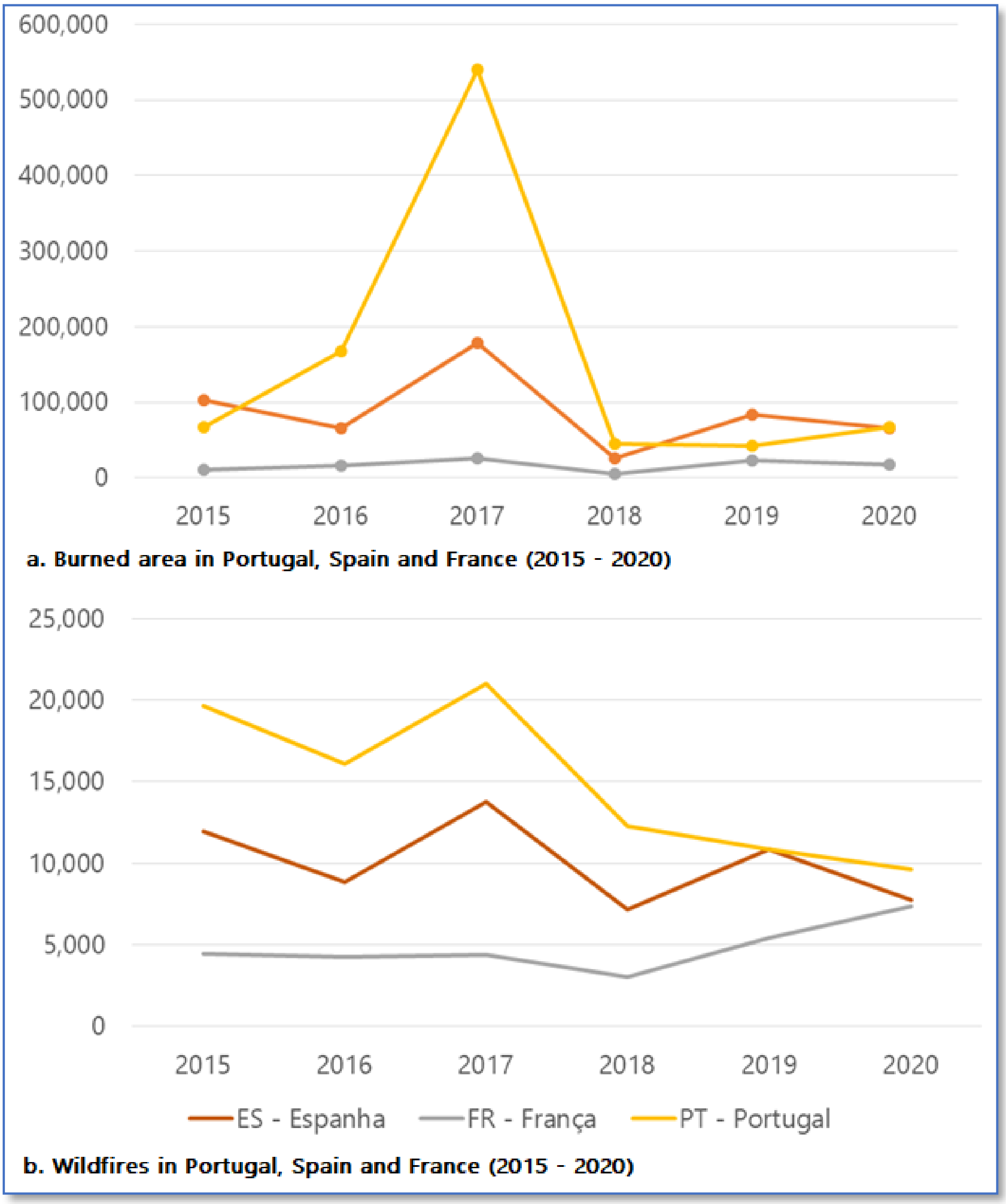


Figure 3. Burned area and wildfires in Portugal, Spain and France (2015-2020).

There has been a decreasing trend in the number of fires and burned areas annually since 1980, indicating that fire prevention and control practices have been effective. Despite that, the number of larger and destructive fires increased, indicating that climate change has favoured the number of extreme wildfires [26].

As shown in the report *Wildfires: Sparking firesmart policies in the EU* "This new wildfire context is defined by extreme fire behaviour characterised by rapid fire spread, intense burning, long-range fire spotting and unpredictable shifts" [3, p. 11]. In light of the new reality of forest and rural fires, more than ever there is a need for adaptation and to make territories resilient and capable to overcome extreme events.

The frequency and intensity of wildfires are usually dependent on climate, topography, land cover and fuel availability. It is also known that human activities have influenced the climate, promoting an increase in the severity of wildfires. Additionally, land use and management are directly linked to the amount of fuel available on the field, being the only variable possible to control for wildfire risk management [27]. Before the 1970s, most fires were limited to the amount of fuel present on the field, however, after the 1970s, the rural exodus increased the number of abandoned lands, and an increment was also observed in the number of forest plantations, which, together with prolonged dry seasons, led to more intense fires [28].

In addition to environmental factors, studies addressing relationships between socioeconomic variables and wildfires, reveal that human behaviour may affect wildfires ignition [29, 30]. Such evidence shows a need for more robust models for fire risk, which must take into account socioeconomic variables, in order to facilitate management and allow actions focused on more sensitive areas [30].

2.2.2 EROSION

Basically, soil erosion is the movement and transport of soil by the action of several natural agents, mainly water and wind and comprises the processes of displacement, entrainment, transport and deposition of soil particles [31, 32]. Although soil erosion is caused by natural agents, anthropic actions tend to facilitate and accelerate this process, especially in regions with steeper slopes, such as mountain regions [31].

In recent decades some erosion processes seem to be increasing in the SUDOE region, mainly those of shallow erosion on pasture slopes in mountain elevation zones, representative of denudation mechanics due to flooding, added to poor soil management resulting from subsequent treatments. This dynamic generally does not pose a direct threat towards natural hazards, however, considerable soil losses undermine agricultural land use, landscape aesthetics and other ecosystem services [33].

The literature review shows that few projects directly address erosion control and prevention, however, many projects address factors and other hazards that influence erosion, such as fires, droughts, nature conservation, floods and landslides. Thus, despite not being a topic addressed directly, many projects consider it secondarily. This observation also strengthens the multi-risk approach, considering the existing influence between different natural hazards.

2.2.3 GRAVITATIONAL NATURAL HAZARDS

Landslides are a significant geomorphological hazard that occurs mainly in mountainous regions, impacting lives, resources, and infrastructure. In the last decades, with the expansion of urban settlements and the development of several economic sectors, there has been an increase in construction pressure in inadequate and unfavourable areas, increasing exposure to this danger. The landslides occurred in several mountainous places in the SUDOE region, differing in geomorphological and environmental characteristics. Among them, avalanches and rockfalls are the main and most frequent types of landslides that occur in this territory [34]. Major historical disasters such as the multi-landslide event in the Plateau d'Assy region (1970) in France and events that occurred in Azagra (1874) and Felanitx (1844) in Spain, showed the vulnerabilities of the territory and how these are negatively impacted, requiring strategies to prevent and minimize impacts in the face of this threat.

Avalanches are prominent natural hazards in mountainous regions, differentiating into two types: snow avalanches and debris avalanches. Both are characterized by a large mass of loose terrestrial material, which flows down the mountain under the force of gravity [35], contributing to the landscape configuration, affecting the forest, influencing geomorphic processes and exposing the population to this danger. In addition to natural factors, such as weakness in the formation of accumulated snow and blizzards, anthropic factors such as the increase and intensity of winter sports activities and tourism influence the occurrence of these events [36]. In this section, we will cover only snow avalanches, recurrent in the SUDOE region.
Avalanches are a traditional concern in European mountainous regions, mainly in French territory, where the occurrence and frequency of events is more significant in relation to Spain or Portugal. In Portugal, the phenomenon of snow avalanches is not favourable, due to the little formation that occurs in the territory. In Spain, snow avalanches also do not pose a significant risk to the population, but with the popularization of winter sports an increasing number of people have been exposed to these dangers, causing victims due to the direct action of this event [37]. Snow avalanche events in Spain occur mainly in the mountain ranges located to the north, such as the Pyrenees [38–39], and in Cantabria bands [40]. All mountain ranges in France are subject to avalanche risks, however the occurrence is generally observed in high mountain areas [41], such as in the alpine space. The International Alpine Rescue Commission (ICAR) reports an increase in fatal accidents due to avalanches, with

around 140 deaths annually, based on data from more than 20 years in Alpine countries.

Accumulated snow, terrain and meteorology are the three main variables for triggering avalanches [42], and it is necessary to understand the interaction of these factors for the development of prevention strategies. In addition, climate change has been a widely discussed contributor in the scientific community, with climate warming being identified as one of the main triggers, influencing behavior, uncertainty, and the frequency of avalanches. Thus, forecasting changes in snow cover and avalanche events is crucial for managing and minimizing negative impacts on society, providing relevant information for the design of resilience and mitigation strategies.

The impact of **Rockfall** in the SUDOE region is significant, since much of the territory is mountainous and housing and transport routes are generally found near or on rocky slopes. The risk of rockfalls is clearly higher in areas with intense seismic activity, where earthquakes are triggering factors [43], however instabilities in rock masses in the SUDOE region are mainly affected by other mechanisms and driving forces, such as strong winds, floods, wildfires and human actions. The frequency of occurrence of these events depends on the environmental conditions and the lithostructural predisposition [44].

Rockfalls are a type of small landslide, which although they do not represent the same level of economic risk as other types of landslides, the number of people killed by rockfalls tends to be of the same order as all the other types of rock slope instability sliding [45]. The process of rockfalls differs from other types of slope instability due to its high fall speed, being of a sudden and unpredictable nature, exposing human lives and urban areas to risk, even if they are small rocks [46].

Monitoring rock walls is fraught with challenges, difficult accessibility to the site, inadequate or insufficient data collection, and incomplete understanding of areas of potential sources of falls are the most prominent factors that restrict the applicability of techniques and instruments. In this sense, improvements in the analysis of the scenarios and their variables become necessary, such as the support of a slope monitoring network in almost real time [47].

2.2.4 DROUGHT

As drought affects economic and social sectors, various definitions have been developed by different disciplines. A universal definition of drought can be understood as a prolonged period of time with reduced precipitation, for one season or more, being a natural phenomenon in all climates. Since the importance of drought lies in its impacts, we can group it by types, namely meteorological, agricultural, hydrological and, socioeconomic (**Figure 4**). The three characteristics that differentiate one drought from another are intensity, duration, and spatial extent. Deficiencies in precipitation, soil moisture and stream flow/reservoir storage lead to meteorological, agricultural and hydrological drought respectively [48].

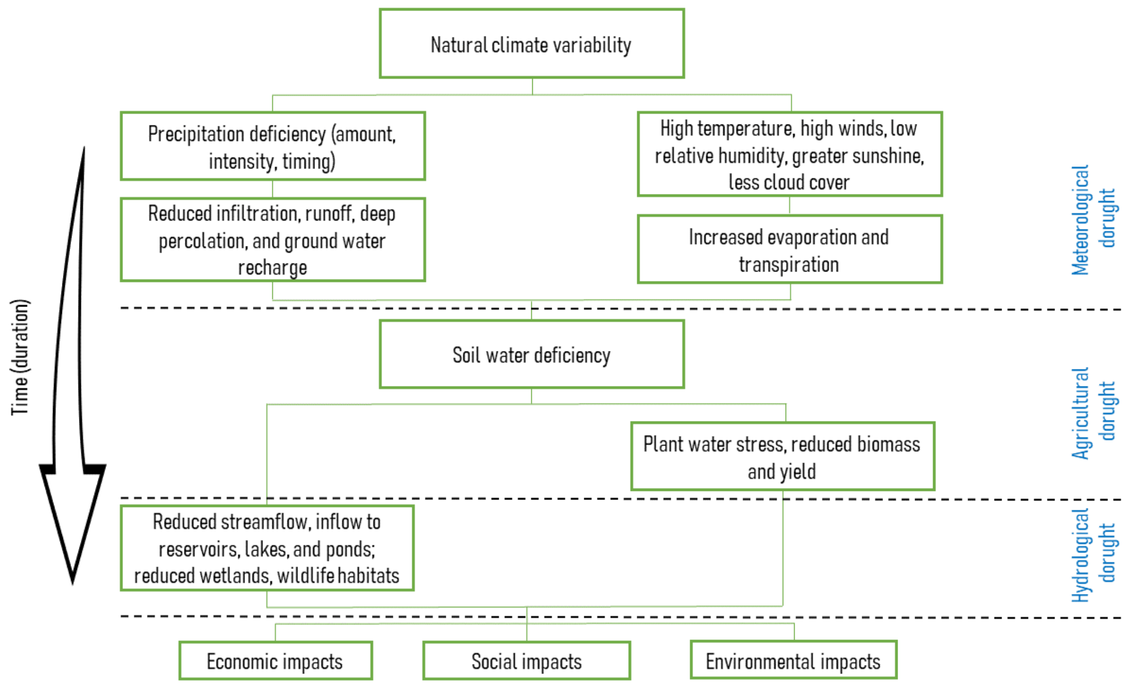


Figure 4. Relationship between types of drought and duration of drought events from [48].

Drought has been a recurrent climate problem in Europe, not limited to specific regions. The severity and intensity observed in droughts in the 21st century and climate forecasts until 2100 indicate that a greater number of people will be exposed to periods of drought with impacts on water availability [15]. Droughts will be more frequent and longer in the European Mediterranean region and the Iberian Peninsula [49, 50] and the assessment of changes depends directly on their type and origin (meteorological, hydrological, agricultural, ecological and socioeconomic).

Droughts can cause widespread and long-term impacts on both the environment and societies, being one of the most damaging events related to the climate in terms of people affected and economic costs [51, 52]. As a result, droughts cause and trigger a series of impacts, such as wildfires [53], hydrological droughts [54] and losses in the agricultural sector [55]. In the SUDOE region it is no different, future changes in rainfall regimes coupled with an increase in temperature could have an impact on water availability, affecting ecosystems and economic sectors such as agriculture, which are extremely important for the region's economy, representing about 2.1% of GDP in Portugal, 1.6% in France and 2.7% in Spain [56]. Previous droughts that occurred in the alpine space [57] allowed to emphasize the composition of the systematic analysis of the effects and impacts of droughts in mountainous regions, which may compromise the availability and supply of water and contribute to the spread of multiple impacts [58].

The severity and frequency of droughts have increased in recent years in Europe. Particularly in the southern part of Europe there was a decrease in soil moisture content during the summer period. Lower flows of watercourses were recorded throughout the second half of the 20th century. Furthermore, Europe's freshwater resources are under increasing stress, with a mismatch between the continuously increasing demand and the limited availability of water resources across the EU [59].

2.2.5 FLOODING

A flood is an overflow of water onto land that is normally dry, can occur in minutes or over a long period, and can last for days, weeks or longer [60]. The main types of floods include flash floods, coastal floods, river floods, urban floods and pluvial floods. A **flash flood** is usually due to heavy or excessive rain in a short period of time, (less than six hours). Flash floods can also occur even after a levee or dam has failed, or after a sudden release of water by a debris or ice jam. **Coastal floods** are caused by strong winds or storms that move towards a coast during higher above-average high tide. A **river flood** occurs when water levels overflow the top river banks due to excessive rainfall over an extended period of time [60]. **Urban floods** can occur when the drainage system in a city fails to absorb the water from rain. The lack of natural drainage can contribute to flooding. A **pluvial flood** is caused by extreme rainfall events during which flat area terrain cannot absorb rainwater, causing puddles to appear.

Climate change is expected to affect the frequency of this natural risk, intensifying and accelerating the hydrological cycle [61]. In much of French territory, floods are expected to be more frequent, while in Spain and Portugal these events have been showing a decrease in their occurrences.

Increasing losses due to flood risks have been reported for the whole of Europe [62], in particular related to large rivers. However, there is a scarcity of studies on the effects of flooding on Mountain Rivers. Based on data from EM-data, over the past decade, there have been at least 23 flood events that have caused death in the SUDOE region between 2011 and 2020.

The management of hydrological risks is complex, and floods are events that cannot be avoided; however, these extreme phenomena can be controlled and have negative impacts minimized through a series of measures and actions. By affecting mountainous areas, floods have highlighted the vulnerability of these communities, which tends to increase with the lack of infrastructure and the authorities' capacity to mitigate the socio-economic effects of the threat, requiring a set of good practices aligned with good risk management to control its effects.

2.3 CLIMATE CHANGE AND NATURAL HAZARDS

Climate change is influenced by natural and anthropogenic factors and has attracted global attention and concern in recent decades because of the intensification and frequency of extreme events. The impacts caused on natural and anthropogenic systems can be observed worldwide, especially in communities located in areas of high vulnerability, such as the mountainous regions [63].

The scientific community is confident that the Earth's climate is changing due to the trends observed in the climate records. Human activities are identified as the main contributors to the intensification of global warming - the increasing of greenhouse gas emissions lead to the retention of infrared radiation, increasing the mean global surface temperature [64].

The increase in the mean global surface temperature is higher in mountainous regions since the rise in temperatures leads to a decrease in the areas covered by snow and ice that reflects solar radiation. Then, the original landscape is replaced by rocks and vegetation, which, unlike the original landscape, absorb solar radiation and increase the temperature of the soil. In the European Alps, during the 20th century, an increase of 2°C was observed, which is higher than the 1.4°C observed in France, and almost twice as much as in the northern hemisphere [65].

Increasing empirical evidence between climate change and extreme events such as floods, droughts and fires can be useful and necessary to improve understanding and perception of climate change risk. The climate models have several uncertainties, resulting from natural climate deviations, emissions of greenhouse gases and intrinsic errors in the models [66]. Furthermore, particularly in mountainous regions, applying climate change models is a great challenge, mainly due to the effects of topography on climate, where considerable variations in weather can be observed over short distances [67]. However, several studies present the effects of climate change on natural hazards, mostly showing an increase in the frequency and intensity of disasters [66, 68].

Mountain ecosystems are among the most affected by climate change. The main factors are because mountains have a high thermal gradient making them more sensitive to temperature variations. In this way, mountain regions may lose their snow cover and glaciers, favouring other natural hazards such as landslides and rockfall [67]. Another critical point is the effects of mountain regions on the climate. Mountains have a strong influence on wind and rainfall patterns, on the water cycle through melting snow cover, so that climate change in mountain regions can have both local and regional effects [67].

According to the IPCC AR5, the increase in economic losses for communities is mainly related to the growing exposure of people and economic assets to climate disasters. The scientific community suggests that economic losses are mainly associated with an increase in population, development of vulnerable areas and prone to hazards and negligence in land use, however the observed increase in heavy rainfall, longer drought periods, and more intense wildfires may also have played an important role, especially when related to climate change. A recent review study [69] showed that globally, most of the analysed events of heat waves, droughts and floods were considered more likely and/or serious due to global climate change. There are signals that climate change will increase the probability of systemic failures in European countries due to extreme weather events affecting numerous sectors, leading to increasing losses. It is up to the countries to structure themselves in the face of the new measures proposed to increase their resilience and vulnerability as a society, aiming to reduce the harmful impacts of disasters that may occur.

2.4 DISASTER RISK

Disaster risk is based on vulnerability, exposure and hazard (**Figure 5**). Thus, in a region where no specific natural hazard exists, there is no risk of that hazard becoming a disaster. In the same way an event that does not affect any population is not considered a disaster, such as a tropical hurricane in the middle of the ocean. It is also highlighted that the vulnerability conditions of the local community affect how an extreme event is considered a disaster or not, such as the ability to build houses that can withstand high winds and the resilience after an extreme event [70].

Vulnerability is the state of community, system or asset characteristics and circumstances that make them susceptible to the damaging effects of a hazard [71].

Exposure can be defined as "The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social, or cultural assets in places and settings that could be adversely affected" [72].

Disaster can be defined as "severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" [73].

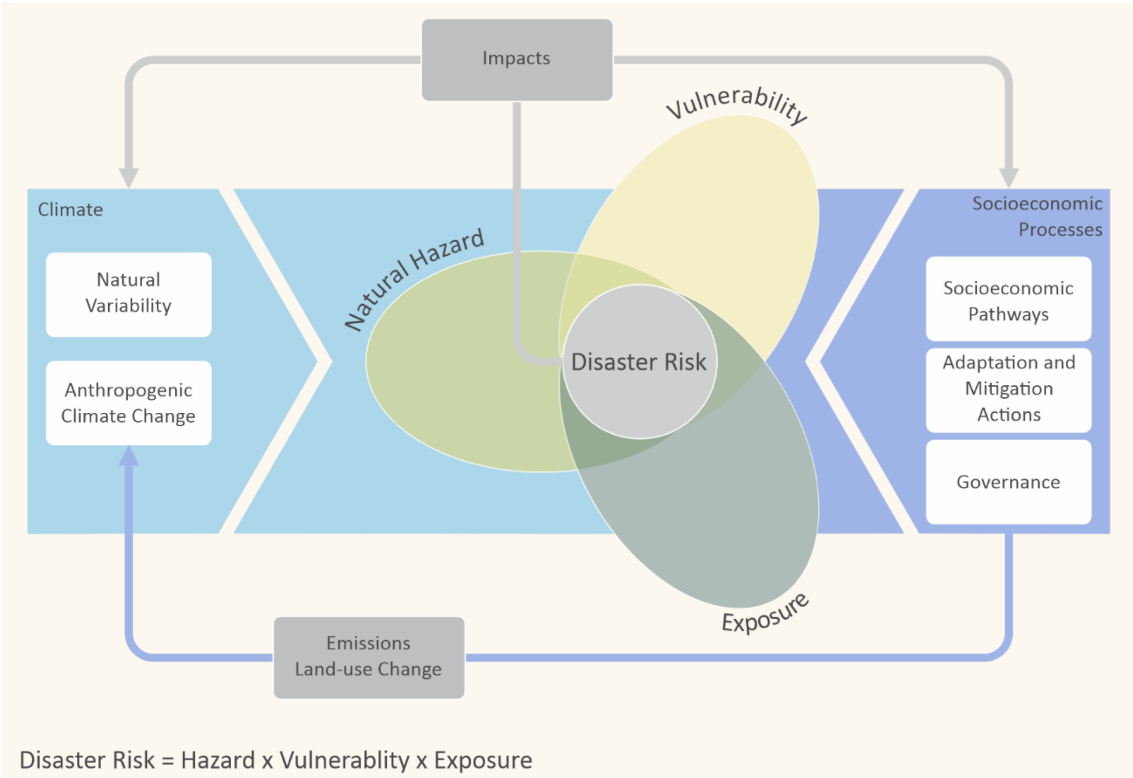


Figure 5. Natural hazard, vulnerability and exposure combined create the risk of a disaster. Disaster risk can be reduced by working on these variables. The exposure and vulnerability are influenced by socioeconomic processes while natural hazards are influenced by climate. Adapted from [73, 72].

There are several disasters, which are generally divided according to their process of origin. The most widely used classification was presented by the Centre for Research on the Epidemiology of Disasters (CRED) where disasters are divided into six subgroups: geophysical, meteorological, hydrological, climatological, biological and extraterrestrial (**Table 1**).

Table 1. General classification of disasters according to the EM-DAT database [35].

Natural hazard subgroup	**Definition**
Geophysical	A hazard originating from solid earth. This term is used interchangeably with the term geological hazard
Meteorological	A hazard caused by short-lived, micro- to mesoscale extreme weather and atmospheric conditions that last from minutes to days
Hydrological	A hazard caused by the occurrence, movement, distribution of surface and subsurface freshwater and saltwater
Climatological	A hazard caused by long-lived, meso to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability
Biological	A hazard caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g. malaria)
Extraterrestrial	A hazard caused by asteroids, meteoroids and comets as they pass near-earth, enter the Earth's atmosphere and/or strike the Earth; changes in interplanetary conditions that affect the Earth's magnetosphere, ionosphere and thermosphere

For each of these subgroups, different types of disasters are assigned. The main types of disasters are presented in **Figure 6**. The Montclima project is focused on the natural hazards of drought, flood, wildfire and erosion. As this last one is not included in the aforementioned classification, it has been added as a hydrological hazard. It should also be noted that the scope of this review was expanded to include landslides: avalanche and rockfall.

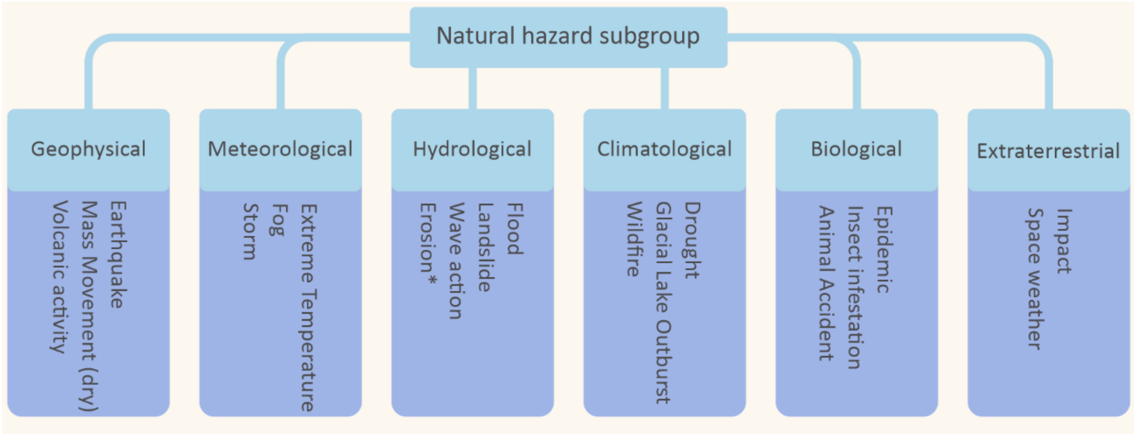


Figure 6. Natural hazards subgroups and their main types. These types are presented by CRED at the Emergency Events Database (EM-DAT) in https://www.emdat.be/classification. *Erosion as added to the Hydrological hazard due to its definition and being one of the hazards studied by The Montclima project.

2.4.1 DISASTER RISK MANAGEMENT

Disaster Risk Management (DRM) is a systematic approach to designing, implementing and evaluating strategies, policies and measures to improve our understanding of disaster risk and promote disaster risk reduction (**Figure 7**). DRM consists of two components: Disaster Risk Reduction (DRR) and Disaster Management (DM). DRR focuses on strategies and practices to reduce the impact of vulnerabilities and disasters throughout society and the environment and involves prevention/mitigation activities while DM includes process of designing and implementing strategies and policies that improve preparation, response and recovery activities [74]. Four activities comprise the DRM lifecycle [75]:

a) Mitigation: Activities to prevent damage
b) Preparation: Early activities for the development of emergency procedures and institutional capacity of stakeholders to ensure an effective response to the impact of disasters
c) Response: Activities to minimize deaths or losses and damage during and following a disaster
d) Recovery: Rehabilitation (short-term) and reconstruction (long-term) activities in order to restore life support systems.

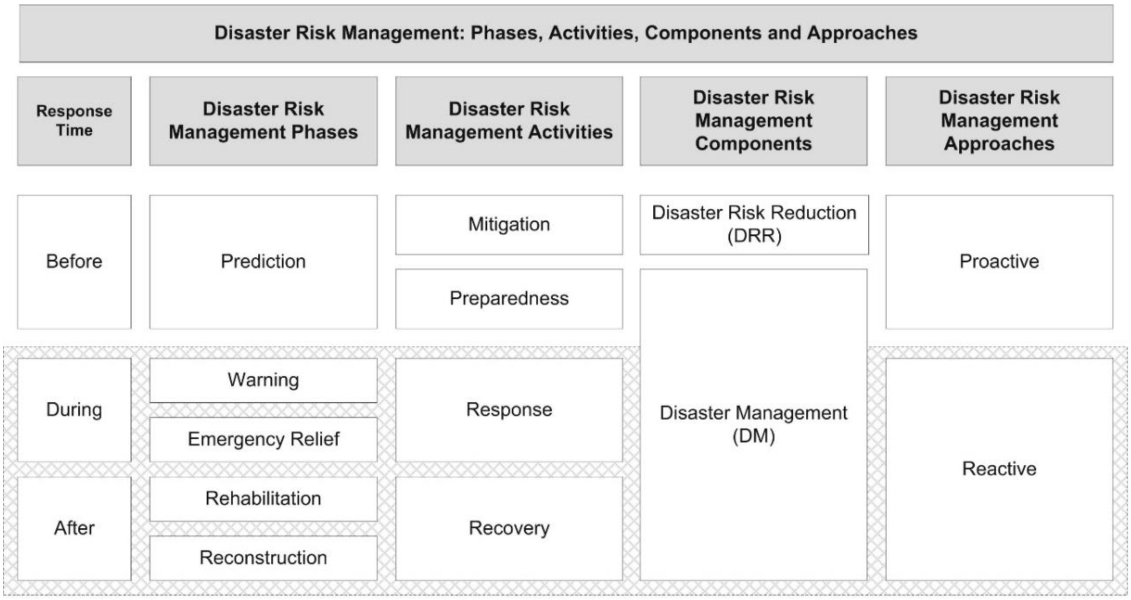


Figure 7. Disaster Risk Management: Phases, Activities, Components and Approaches [75].

The SENDAI Strategic Framework for Disaster Risk Reduction 2015-2030 has been adopted by 187 Member States, in which a global plan is established that brings together closer collaborative efforts in disaster risk reduction. The SENDAI framework proposes four priorities to prevent new disaster risks and reduce existing ones: i) understanding disaster risk; ii) strengthening disaster risk governance to manage disaster risk; iii) investment in disaster risk reduction for resilience; iv) improving disaster preparedness to provide an effective response and better rebuild in recovery, rehabilitation and reconstruction [76].

2.4.2 MULTI-HAZARD APPROACH

Kappes et al. (2010) [77] explains that multi-hazard analysis is one of the central aspects of risk reduction. Although methodologies involving the study of risks and hazards are well developed, the multi-hazard approach presents several challenging aspects due to the different characteristics of each natural hazard. It should be noted that interactions between different natural hazards can generate another hazard or amplify their impacts. Usually, the literature presents some types of interactions between natural hazards (**Figure 8**): **Triggering** (cascading) is a hazardous event inducing one or more hazardous events in a domino effect; **amplification** (aggregation) refers to the occurrence of events simultaneously without a cause-effect relationship, which impact is amplified, being more significant than the sum of the events separately; **disposition** refers to the influence of one hazard to the general settings of another hazard altering its response to a possible trigger event [77, 78].

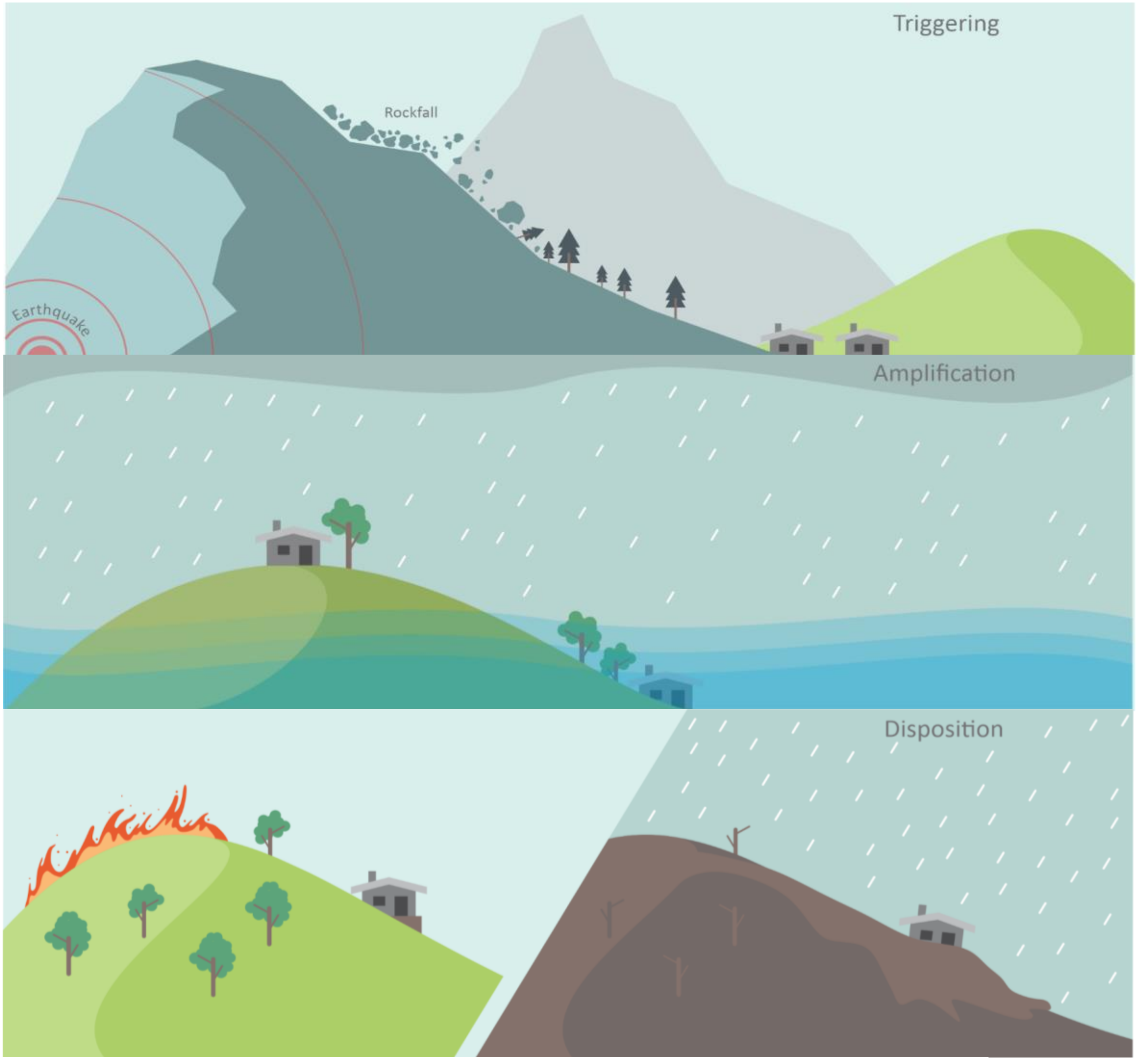


Figure 8. Multi-hazard approach from Kappes et al (2010) [77].

2.4.3 TRANSNATIONAL OVERVIEW

Better integrated of natural hazards management involves the collaboration of several institutions and actors at different levels so that the actions of each one complements each other. The joint management of a natural hazard is necessary because natural hazards do not respect maps; a fire will spread to wherever there is fuel. National borders are not fire barriers at all. **Figure 9** shows the levels of cooperation for natural hazards management [79].

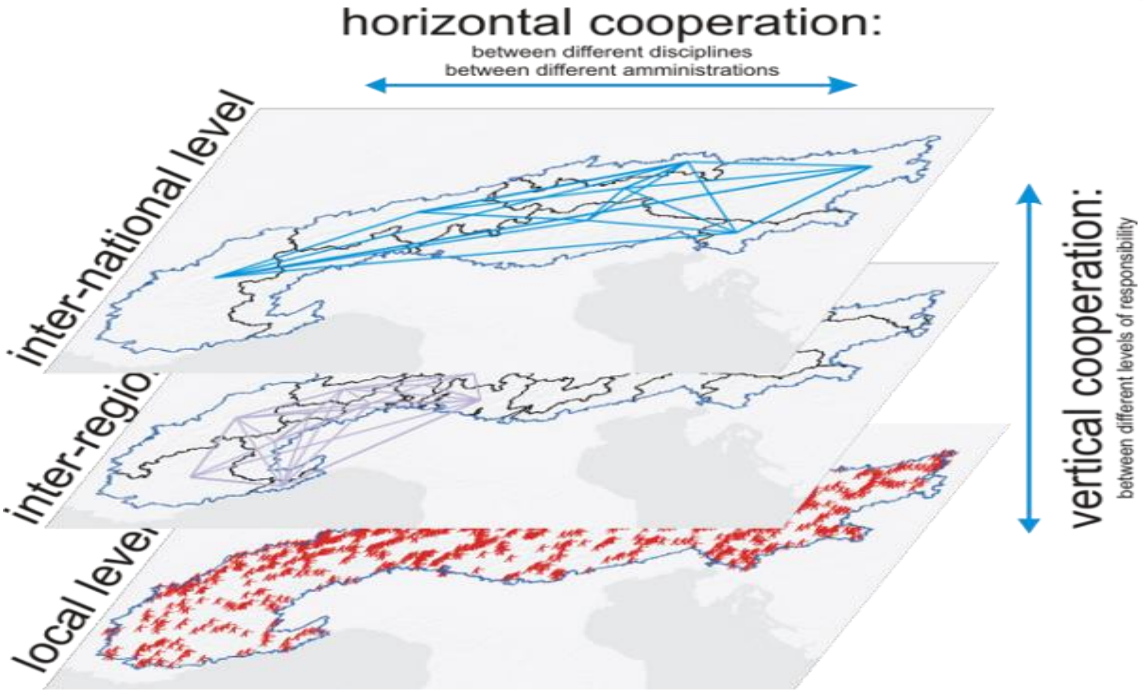


Figure 9. Horizontal and vertical levels of cooperation in natural hazards and risk management [79].

As observed in **Figure 9**, levels of cooperation can be divided into vertical and horizontal. Horizontal collaboration refers to the interaction between different administrative areas, while vertical collaboration refers to the interaction between different levels of responsibility.

The cooperation for natural hazards management can start at a local level, involving collaboration between local actors (e.g. landowners, local authorities). However, even at this basic level, collaboration is challenging because of different land uses [80].

2.5 GOOD PRACTICES IN DISASTER RISK MANAGEMENT

A good practice is a viable action or initiative that has the objective of improving the risk management of some natural hazard. Good practices allow the sharing and transfer of knowledge and learning to the general population.

In short, this document brings together knowledge and experience in risk management with the ultimate goal of achieving more effective disaster prevention and mitigation practices, but with a dynamic conception. Therefore, the good practices presented here are the result of: i) searches in the scientific literature; ii) projects executed in at least one of the countries of the SUDOE region. Giving main attention and importance to mountain territories.

2.5.1 WILDFIRES

Wildfires have affected huge areas in southwest Europe, therefore the development of wildfire management practices is important because it not only helps to minimize the occurrence of fires, but also because it plays an essential role in the conservation of forests and policy formulation. Some of the most common practices in wildfire management are modelling, prescribed burning, goat grazing and silvicultural treatments.

Livestock Grazing: In mountain regions the climate and the terrain are limiting factors for various farming activities, however, the abundance of natural pastures has made cattle farming a widely used activity [80]. Like prescribed burning, grazing is a form of biomass control, an activity that uses animals - cattle, goats - to control shrub vegetation. Several studies point out the effects of cattle ranching on plant growth, especially shrub species [81–82].

Prescribed Burning: Prescribed fire or controlled burning is described as a "careful application of fire under specified fuel and weather conditions to meet specific resource management objectives and long-term management goals, and this adds a planning aspect to traditional ways of fire use" [15, p. 5]. More precisely, prescribed burning is used to prevent and control wildfires by limiting the biomass present in the field [83]. **Table 2** shows the main prescribed burning practices according to the different vegetation types observed in the Mediterranean territory.

Picture by Adege from Pixabay

Table 2. Prescribed burning practices in the Mediterranean area.

Brood vegetation type	Species	Countries	Hazard reduction
Mediterranean pine forest	Pinus canariensis, Pinus halepensis, Pinus nigra, Pinus pinaster, Pinus pinea	Portugal, Spain, France	Range or biodiversity management as secondary objectives
Mediterranean shrubland	Variable, but usually dominated by Cistus spp or Quercus coccifera	France, Portugal	Range and biodiversity management
Heathland	Ulex spp, Erica spp, Calluna vulgaris, Pterosparum tridentatum, Cytisus spp, Genista spp	Portugal, Spain	Rage management
Mountain shrubland and grassland	Cytisus oromediterraneus, Cytisus scoparius, Spartium junceum	France, Spain	Biodiversity management and hazard reduction as secondary objectives
Eucalypt plantation	Eucalyptus globulus	Portugal	Post-harvesting slash disposal

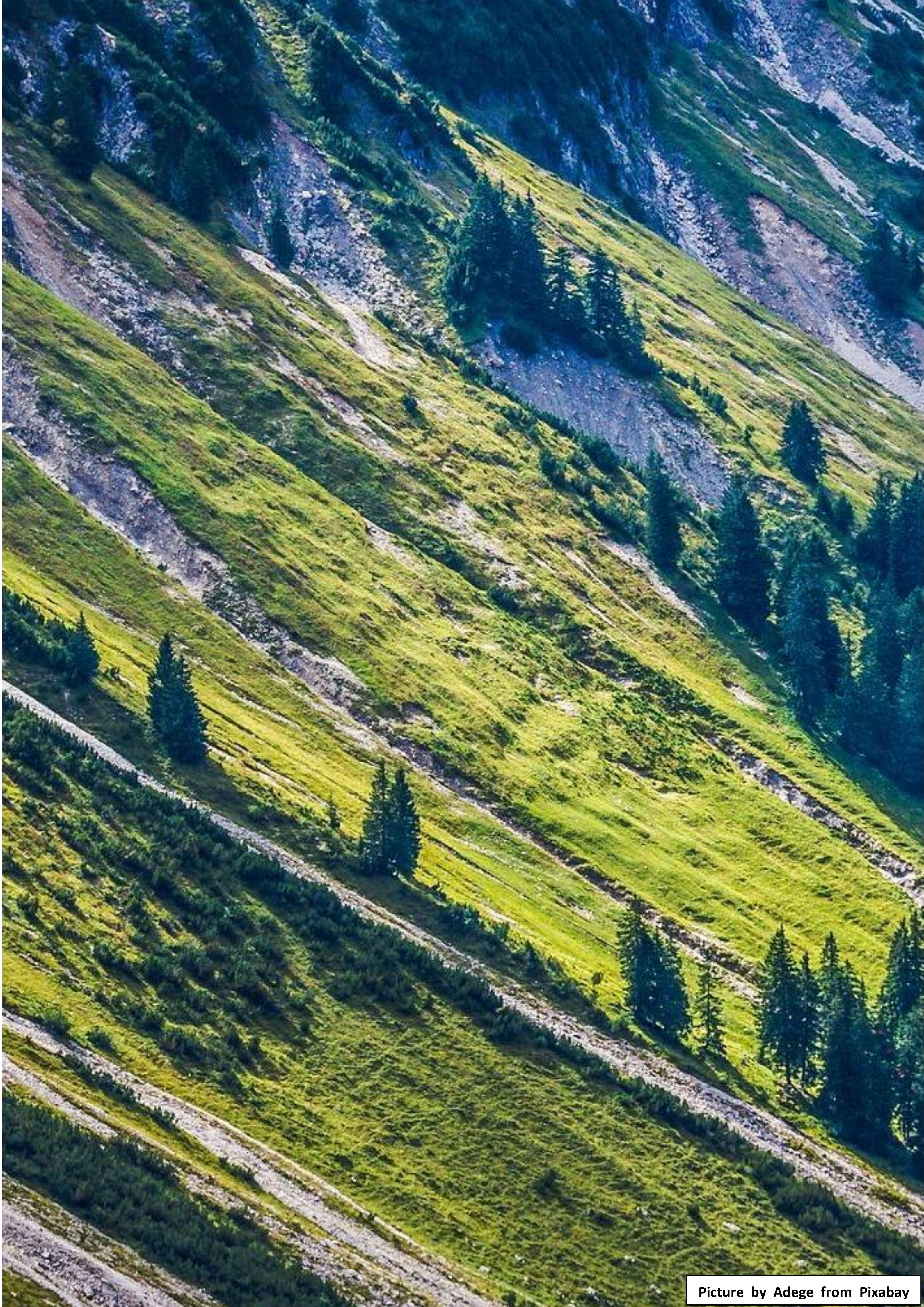
Source: [12, p. 3]

Firebreak and Fuel Break: Firebreak and fuel break are two widely applied techniques, which consist in the control of vegetation to stop and slow down the advance of a fire, respectively. Firebreak, is the complete removal of vegetation and organic matter to the mineral soil and can be performed using various methods including thinning, mechanical clearing, prescribed burning, slashing, mastication, mowing, plowing [84, 85]. Generally, firebreaks have a linear shape and should have a width of two to three times the height of the nearest vegetation to avoid the fire spreading across the section. They also require regular maintenance to keep their function [84].
Fuel break consists of the reduction and control of vegetation cover, favouring plant species with less biomass. In these regions, the fires have a slow advance compared to natural vegetation allowing the fire suppression teams to focus on these areas to control or extinguish the wildfire [84, 85]. This type of control can be applied in line or blocks and is less aggressive than firebreak [84].

Wildfire Mapping: Currently, fire risk models are widely used and are an excellent management tool. In addition to environmental factors, socio-economic variables may influence the appearance of wildfires, in this way, the vulnerability models can be improved by the insertion of socio-economic indicators, especially in more populated regions [30].

There are several methodologies for mapping wildfire hazard, mostly using geographic information systems associated with the multicriteria analysis to obtain better results [86, 87]. Most works use slope, slope aspect, altitude, land cover, normalized difference vegetation index, annual rainfall and annual temperature as base variables for model building [86, 87].

Modelling: In forest fire management, modelling can be carried out for different purposes: i) to determine risk assessment and ignition prediction of wildfires, ii) to calculate fire weather indexes, iii) to predict human-caused fire occurrence, iv) to identify the main factors that explain the likelihood of fire occurrence, v) to identify areas where vegetation reaches the highest level of combustibility, vi) to predict fire containment probability, vii) to investigative the effects of climate change on fire risk.



Picture by Adege from Pixabay

2.5.2 EROSION

Bioengineering techniques: Soil erosion control and slope stability problems demand solutions designed for local conditions. The adoption of heavily engineered structures may be beyond the reach of maintenance budgets for rural areas, so the application of environmentally friendly bioengineering techniques can offer much to mountainous environments [88]. Bioengineering is the use of vegetation (both live and dead plants as well as use of raw materials derived from plants) in concert with engineering structure to improve slope stability and protection. These include use of vegetation and horticultural practices, use of coir/jute netting, use of geo-textiles, retards, etc. in combination with slope modification and improved agronomic practices [89]. Yet, according to Singh et al. (2010), erosion can be checked by:

- Slope stabilization through contour wattling, mulching and planting: This technique consists of breaking the length of slope into shorter stable portions by providing contour wattles, mulching the inter wattle area and effective plantation
- Slope stabilization and erosion control by coir netting
- Slope stabilization and control of erosion through jute-geo-textiles (jute geo-grid)
- Slope treatment by asphalt mulch technique of vegetative turfing: Asphalt Mulch method effectively prevents surface movements when used in combination with other techniques of landslide mitigation
- Riprap: A riprap is effective on many types of eroded slopes and landslides. The strong rip rapping embedded in the slope acts as a permeable base buttress, allowing increased resistance to failure.

Terraces: Terraces are anthropic interventions on steep slopes, forming a sequence of flat surfaces, facilitating agriculture on extremely slopes, reducing the risk of erosion and allowing better water retention in the soil [90, 91]. The most common terraces found in the Mediterranean region consist of two parts, a flat upper part intended for cultivation and a side part designed for soil containment, usually formed by a stone wall. Moreover, terrace farming is an ancient technique and considered cultural heritage in the Mediterranean [91].

Studies show that the use of terraces contributes to the reduction of erosion, improving water and soil conservation in relation to the original land [90, 91]. However, despite being a widely used technique, allowing cultivation in mountainous regions, rural exodus and changes in land use have caused many of the terraced areas to be abandoned. After abandonment, especially in the first years, an increase in erosion rates and the risk of landslides is observed due to lack of maintenance [92, 93]. In this way, it is understood that although it is a technique that allows the reduction of the risk of erosion, its continuous maintenance is necessary to achieve the expected effects.

Universal Soil Loss Equation Models Family (rusle/usle): The most widely used model for determining erosion risk belong to the family of (R) USLE equations: Universal Soil Loss Equation (USLE) and its family of models: the Revised Universal Soil Loss Equation (RUSLE), the Revised Universal Soil Loss Equation version 2 (RUSLE2), and the Modified Universal Soil Loss Equation (MUSLE) [94]. This group of equations are empirical models for calculating erosion risk and are the most widely used due to their flexibility, easy adaptation, accessibility to data in a way that can be applied to almost all regions of the planet [95].

Picture by Adege from Pixabay

2.5.3 DROUGHT

Healthy ecosystems, including freshwater ecosystems, can play in managing drought hazard. This includes using natural infrastructure to: reduce the chance of drought, reduce the consequences of drought on society and, sustain basic human needs such as food and water [96]. Some measures for Strategic Drought Risk Management (SDRM) are presented in the **Table 3**.

Table 3. Measures for SDRM according to the relevant ecosystem. Adapted from [96].

Freshwater ecosystem element	During drought	After drought
Catchment processes	Implement SDRM measures for critical areas set out in the plan. Maintain protection to key areas for water resource generation. Maintain landscape permeability measures.	Review and adapt protection of critical areas and measures in an SDRM plan
Flow regime	Maintain environmental flows for priority areas (e.g. through infrastructure operation and/or modified water abstraction).	Maintain temporary abstraction restrictions and storage operation rules until river flows return to optimal levels. Pro-actively restore ecosystems that are close to or have passed tipping points.
Water quality	Temporary restrictions on some types of discharge where river flow is low. Allow some types of effluent discharge, which might support maintenance of environmental flow without disproportionate damage to ecosystem. Maintain environmental flows to priority areas which are sensitive to pollution, e.g. for drinking water abstraction, species refugia.	Revert to normal effluent discharge regime once river flows return to optimal levels. Maintain temporary abstraction restrictions and storage operation rules until river flows return to optimal levels
Habitat	Safeguard environmental flows to and between refugia and limit pollution. Maintain riparian vegetation and prevent removal of fallen trees in priority refugia/protected areas to keep water temperature within a suitable range and create micro-habitats. Prevent conversion of dry streambeds or dehydrated wetlands into farm land. Restrict fishing and livestock access to water in priority refugia/protected areas	Maintain temporary abstraction restrictions and storage operation rules until river flows return to optimal levels. Pro-actively restore ecosystems that are close to or have passed tipping points. Revert to normal effluent discharge regime when river flows return to optimal levels.
Biodiversity	Implement careful ex-situ conservation, e.g. through translocation, captive breeding, seed banks	All measures outlined above. Reintroduce captive bred or translocated species providing habitat has returned to normal conditions

Most good practices are aimed at predicting and monitoring any type of drought as well as irrigation and water use management. According to Sayers et al. (2016) [96], the monitoring activities should support the SDRM decision making through:

- ✓ providing data on the severity and spatial variation in drought, with data-quality statements
- ✓ synthesizing local observations into meaningful indicators
- ✓ ground trothing and assessing the credibility of the risk assessment processes.

Drought Monitoring, Early Warning, and Awareness: Models and indexes are the main methods used for drought monitoring. The creation of an index helps managers understand the main areas affected by droughts and have a forecast of the duration of the drought period. Drought indices are crucial for good management of drought periods and generally utilize a series of meteorological variables for their estimation (precipitation, temperature, radiation, relative humidity). Among the main drought indexes are the Standardized Precipitation Index (SPI), the Palmer Drought Severity Index (PDSI), the Crop Moisture Index (CPI), the Surface Water Supply Index (SWSI), and the Vegetation Condition Index (VCI). Although drought indices provide an overview of locations susceptible to droughts, their use must be accompanied by socio-economic factors to define areas of greater vulnerability [97].

Considering that droughts are slow-onset disasters, by combining models and drought indexes, it is possible to create early warning systems that allow actions to be taken before the onset or worsening of the drought. Another critical point is the education of the parties affected by drought. Teaching the local population, government, industrialists and farmers about drought risk reduction, presenting different means and actions that these authors can implement, and even increasing knowledge on the topic are great ways to improve the sensitivity to drought hazards [98].

Water Conservation Practices: Water loss reduction system involves several actions, ranging from water reuse and awareness to the construction of reservoirs. **Table 4** shows some of these actions presented by Vickers (2017) [99].

Table 4. Overview of Water Conservation Measures. Modified [99].

Category	Conservation measure
Water system	System water losses reduction Leak detection Infrastructure rehabilitation and replacement
Residential	Financial incentives for conservation High efficiency home appliances (washing machine, dishwasher) Faucets and urinals with limited flow rates Maintenance
Landscape	Limited irrigation and irrigation times stipulated Use of native and/or drought-tolerant plants Efficient irrigation systems and devices Rainwater harvesting
Industrial and commercial	Conservation-oriented inclining water rates Efficient cooling and heating systems Process and wastewater reuse
Agricultural	Efficient irrigation systems and practices Native and drought-adaptive crops Dry farming Land conservation methods

Picture by Adege from Pixabay

2.5.4 FLOODING

The pillars of protection against floods are composed of risk analysis, assessment and management [100]. The first consists of comprehensive analyses (hydraulic conditions; hydro meteorological situation; aquatic and territorial issues; damage potential), flood risk estimation, determination processes, and a definition of impacts. Risk assessment involves quantifying the risk depending on the disaster, the vulnerability, and its value, describing the risk acceptance, and comparing the benefits with the costs of implementation. Finally, risk management is based on defining protection objectives, developing solution concepts, plans and implementing response measures, emergency planning and increasing local resilience to deal with residual risks.

Good practices related to flood management are advocated by the common diagnosis of flood policies, institutions involved, early warning systems, data monitoring stations and emergency protocols. The creation of maps of disasters, risks and vulnerability are indispensable steps to defining the priority areas (action plans) and more likely to occur in these events. In addition, assessments of the impact of climate change, discharge observations, flood formation processes, and differentiated safety concepts must be addressed to better understand the risk [101]. Alternative measures to protect against floods include:

- ✓ Maintenance of water courses - suppression of vegetation, sediment retention structures, repair of damage to existing structures, maintenance of river banks and banks;
- ✓ Hazard maps related to land use - identify danger zones, establish appropriate constructions, assess vulnerable zones;
- ✓ Structural protection measures - retention dams, construction of dams, opening of river beds, breakwaters, block ramps, and the measures must be kept as close to nature as possible without interfering in its landscape;
- ✓ Emergency planning - flood forecasting, operation of early warning systems, evacuation planning and viable routes, creation and training of units prepared to combat rescue.

Among the strategies applied in the SUDOE region are the diversion of water and sediment to less vulnerable locations, watersheds monitoring, early warning systems, plans for prevention and emergency management, construction of houses with strong foundations above ground.

Picture by Adege from Pixabay

2.5.5 AVALANCHES

Avalanche risk can be eliminated from decision making, but it is usually possible to just reduce it in frequency and / or intensity, the uncertainty of these events being an inherent part of avalanche risk management. The recognition of uncertainty is necessary to accommodate and manage decisions, it is through its existence that techniques and measures are taken to minimize impacts [102]. The technical aspects of avalanche risk management presented here are widely used as a solid framework for the assessment and mitigation of these events.

The main recommendations for avalanche management have been evolving and being adapted based on common knowledge, where the main measures and actions presented here are considered useful for any country or region prone to avalanches in Europe.

The initial stage consists of the prediction and understanding of the phenomenon through a set of interconnected good practices. Obtaining information and quantifying variables is one of the crucial steps for understanding the resulting phenomena. Immediate forecasting is necessary to transmit and alert the population to the imminent danger and to make preventive decisions. In general, this system consists of several instruments and sensors for observation and data collection, including radars, satellites, monitoring stations, among others [103]. Immediate forecasting depends on high-resolution data and updates quickly, which requires training of the operator in front of the integrated system.

The main parameters and variables analysed are related to meteorology, snow depth, blizzard events, and snow drift [102]. Based on the variables analysed, a series of exploratory materials can be produced to contribute significantly to the understanding of the processes. The definition of risk areas and evacuation zones is possible through the knowledge of the drainage distances in the avalanches, in addition to the terrain analysis and map production. The use of GIS techniques is extremely necessary to classify risky and highly vulnerable zones, relating terrain data to predictor variables. The variables are also used as input data for the simulation of scenarios through numerical models, as well as to evaluate the conditions and efficiency of structural measures. The forecast relies heavily on information from the history of events, present and future, related to climatic and local variables, which may affect the accumulation and transport of snow, being considered an integral part of prevention [104].

The prevention stage is aligned with the mitigation process, generally divided into structural and non-structural measures. Non-structural measures include issuing bulletins with information on avalanche risks, land use restrictions, warning messages and temporary evacuation, mapping the risks and degrees of exposure, safety regulations and procedures and artificial avalanche activation. Structural defences, on the other hand, consist of technical measures for the direct protection of buildings in the surroundings (reinforced walls, containment barriers), in the diversion or channelling of avalanches (dividing structures), to retain and store the accumulation of snow (retention dams, warehouses) snow, trees and nature elements), avoid or reduce the size of the block released in the starting area (support structures such as terraces, snow nets, steel bridges and combined types), and alter snow deposition areas (fences and wind deflectors). The application of these measures is based on calculations performed in advance using the information from the variables previously collected.

The final step is characterized by the dissemination of information to the public, being interconnected with all the previous steps, being fundamental for the dissemination of information and knowledge related to the danger of avalanche, as well as emergency planning and response decisions in the event of occurrences, the role of digital media for the flow of information being extremely important.

Picture by Adege from Pixabay

2.5.6 ROCKFALLS

Rockfall Hazard Rating System (RHRS): It is a classification system for rocky slopes facing highways developed by Pierson [105]. The RHRS method assesses the degree of exposure of the highway in relation to rockfalls using parameters that control and govern the problem in the rock masses: height of the slope, average risk to the vehicle, width of the pavement, geostructural characteristics, dimension of the blocks, and history of falls among others. It is used as a tool for rapid determination of rocky embankments that offer hazards to users through a semi-quantitative analysis. The categories are framed in different scores and the scoring criterion increases exponentially between 3 and 81, allowing the distinction between the most problematic or dangerous slopes, with the slopes with the highest scores pointing to a priority need for remediation.

Rockfall Risk Management (ROMA): The rockfall risk management method combines the analysis of the trajectory of falling blocks and cracks, with the aid of the construction of an abacus, better known as event tree analysis. It is a very useful tool in the mountains, due to the particular geometries and peculiar geological contexts, requiring a representative model of the problems faced [106]. An event tree is composed of several branches and nodes, which, depending on the occurrence of events, leads to an analysis directed by collision probability calculations, for example between rocks and vehicles. The information is extremely relevant to the knowledge of the likelihood that a rock release will cause any accident or damage.

3. METHODOLOGY

The methodology adopted comprised two main parts: First, we reviewed the EM-DAT database to identify the main disasters in the countries that comprise the SUDOE region; second, we analyzed projects in databases of European funding programs, we use The Community Research and Development Information Service (CORDIS) and The EU's funding instrument for the environment and climate action (LIFE Program). In addition, we also use academic databases as support tools to search for terms and definitions directly related to our study focus, such as: mountain areas, natural hazards, and disaster risk management.

3.1 DISASTER DATABASE ANALYSIS

The Emergency Event Database (EM-DAT) was created with initial support from the World Health Organization (WHO) and launched by the Centre for Research in the Epidemiology of Disasters (CRED). The BD contains important information about the occurrence and effects of disasters in the world from 1900 to the present day. The BD EM-DAT is composed of data from various sources, including EU entities, research institutes and non-governmental associations. The BD EM-DAT considers 4 alternative criteria for the inclusion of a given disaster: i) report of 10 or more deaths; ii) notification of 100 or more affected persons; iii) request for international assistance; and iv) declaration of a state of emergency. Thus, events that do not meet at least one of the parameters are not logged.

The objective of this step was to provide an overview of the most relevant disasters or those with the greatest impact on the region. For this, we use data from 1980 to 2020, considering only nationally reported disasters for countries in the SUDOE region (with the exception of Andorra, which has no data available).

3.2 PROJECT ANALYSIS – EUROPEAN DATABASES

One of the activities of the Montclima project was the capitalization of projects and good practices related to the prevention and management of natural hazards in the mountainous areas of the SUDOE region. Therefore, the objective of this stage was to seek and compile the most recent projects that exclusively addressed these subjects. For this, we carried out an initial phase of surveying projects based on previously defined criteria (**Table 5**), followed by an eligibility phase through the application of evaluation criteria (**Annex I**) with purpose of extracting relevant information for the composition of a database with the projects most aligned within the scope of

Montclima. Finally, we defined a list of fixed characteristics to be researched within each project. These elements were selected in order to derive relevant information about strategies to address disasters and to prepare information sheets that were later made available on the Montclima website, 5 of which were carried out with more detailed information obtained from scheduled meetings with a member of each selected project.

Table 5. Project Selection Criteria.

Criteria	Description
Language	English
Timeline	2015 to 2021
SUDOE countries	Portugal or Spain or France or Andorra
Natural hazards* type	natural hazards OR natural disasters OR multi-hazards OR geophysical OR meteorological OR hydrological OR climatological OR wildfires OR forest fires OR droughts OR flooding OR floods OR erosion OR landslide OR rockfall OR rock-falls
Document type	Projects

*or disasters

4. DATA ANALYSIS

4.1 OVERVIEW OF DISASTERS IN THE SUDOE REGION

According to data extracted from EM-DAT, a total of 296 disasters were recorded between 1980 and 2020 for the SUDOE region. In general, for all types of disasters, meteorological and climatological were the most frequent, mainly through storms and forest fires, respectively (**Figure 10**).

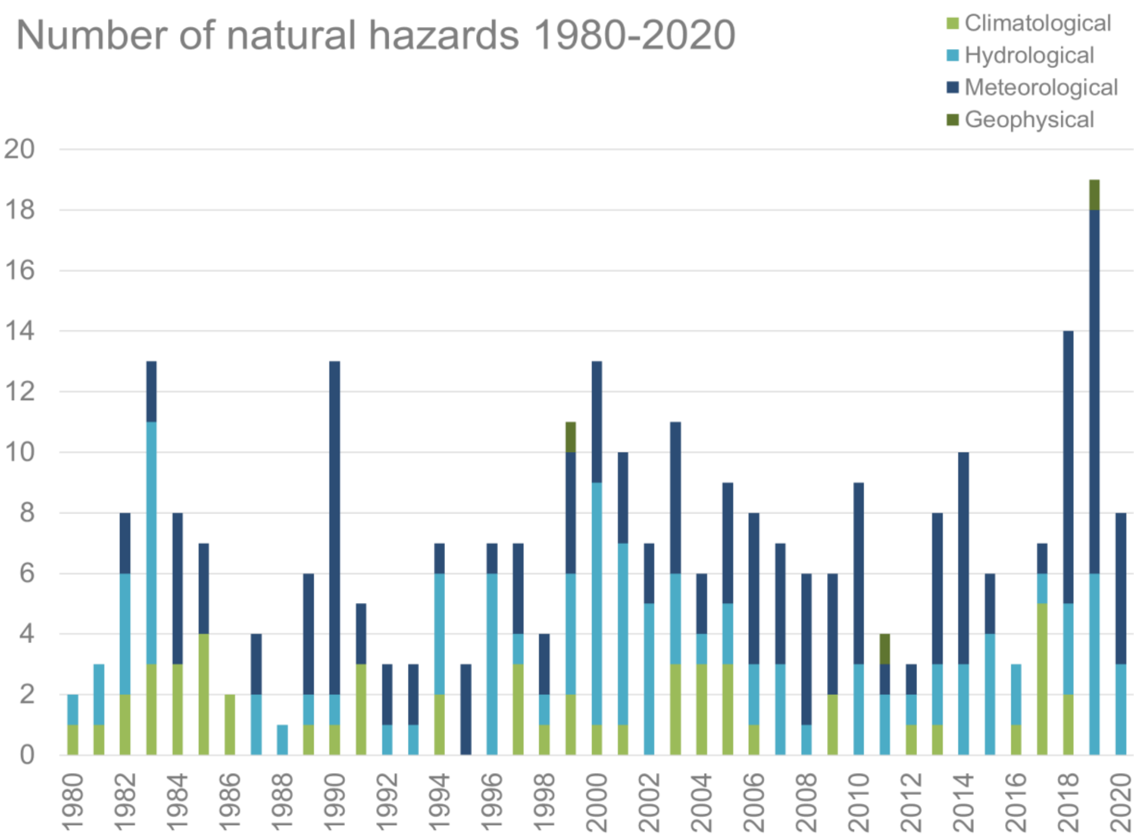


Figure 10. Summary of type of disasters for the SUDOE region between 1980 and 2020.

Considering the relationship between deaths and occurrences for this time period, Spain had the highest ratio (177.6). The total number of deaths was mainly due to the heatwave that occurred in 2003, were mainly responsible for 69%, 95% and 76% of the total fatalities in France, Spain and Portugal, respectively, being the most lethal disaster in the region (**Table 6**).

Table 6. Relationship between the number of disasters and the number of victims.

Country	Number of disasters	Total deaths	Ratio	Heatwave deaths
France	164	28380	173.2	19490
Spain	89	15803	177.6	15090
Portugal	43	3535	82.2	2696

In terms of economic losses, France was the country in the region with greatest losses, with meteorological events contributing more than half of the total damage to this country (**Figure 11**), mainly storms (84%). This same behaviour was not observed in Portugal and Spain, since in these countries climatological disasters were main responsible for the total damage. In the case of Portugal, wildfires contributed to 75% of the economic losses associated with climatological disasters and, in Spain, droughts contributed 79% of total climatological damage.

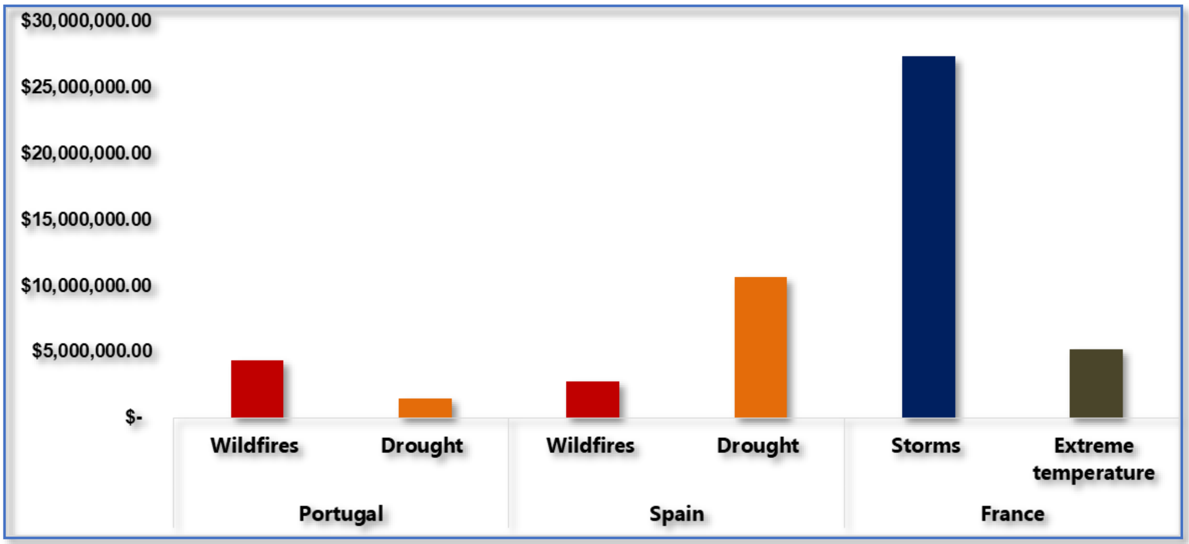


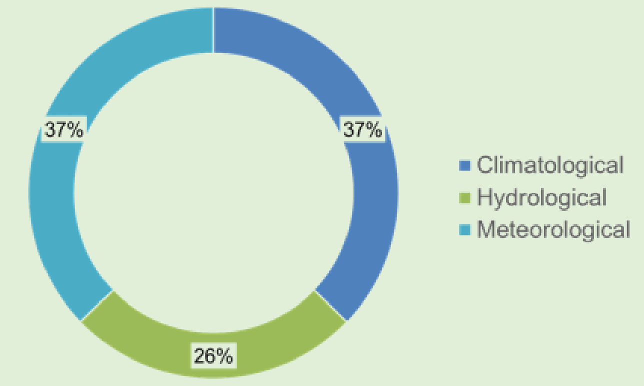
Figure 11. Most representative disasters in terms of damage.

4.1.1 PORTUGAL

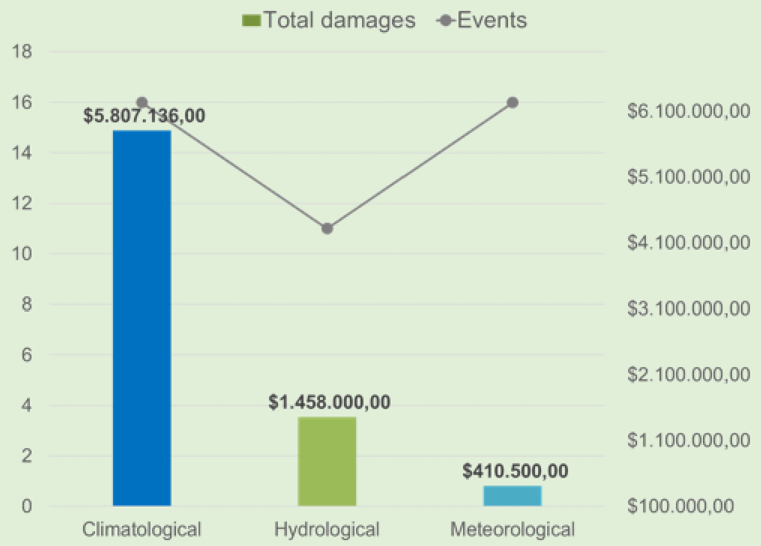
Overall, 43 disasters were recorded between 1980-2020, including floods, windstorms, earthquakes, wildfires, landslides, droughts and extreme temperatures. Climatological disasters contributed to the greatest economic losses in the country, while meteorological risks were the ones that provided the smallest losses (**Figure 12**). There were no recorded data on geophysical events (e.g. earthquakes), but that does not mean that the country is free from these hazards. The last recorded earthquake was in 1969, which occurred in the region of the Bank of Gorringe (magnitude 7.5), near the contact between the African and Eurasian plates.

Wildfires affected the population more economically than any other disaster in the country, accounting for an estimated $4.3 million in total losses. Large areas were burned in 2017, this year 21,006 fire occurrences were recorded and fire consumed 539,920 hectares [107], making it the most catastrophic year of the las decade in relation to this danger. In addition to the burned areas, 2017 was marked by the loss of human life as a result of forest fires, as in the Pedrógão Grande region, where there were 64 deaths and hundreds injured. The incidence of disasters shows that the country is more vulnerable to meteorological and climatological hazards, more specifically to events related to extreme temperatures and forest fires.

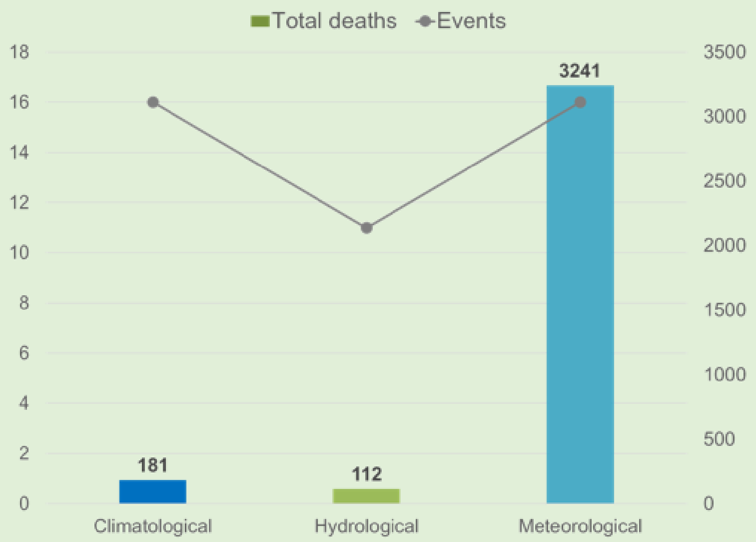
Meantime, the number of deaths recorded for 2015-2020 (117 deaths) more than doubled compared to 2009-2014 (56 deaths), indicating an increase in the vulnerability of the territory. Even when we increase the analysis of the timeline, for example, 2006-2014, the number of deaths (99 deaths) remains lower than in the last 6 years.



a. Distribution of different hazards in Portugal (1980-2020)



b. Number of events and their respective economic losses by category.in Portugal (1980-2020)



c. Number of events and respective deaths by category in Portugal (1980-2020)

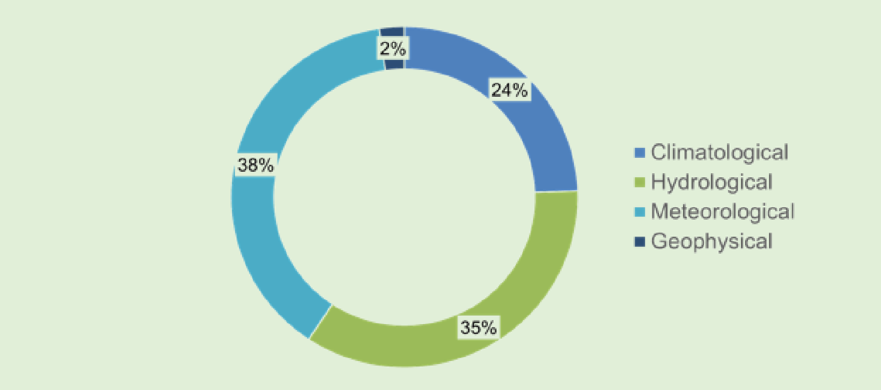
Figure 12. Overview of disaster events reported in Portugal.

4.1.2 SPAIN

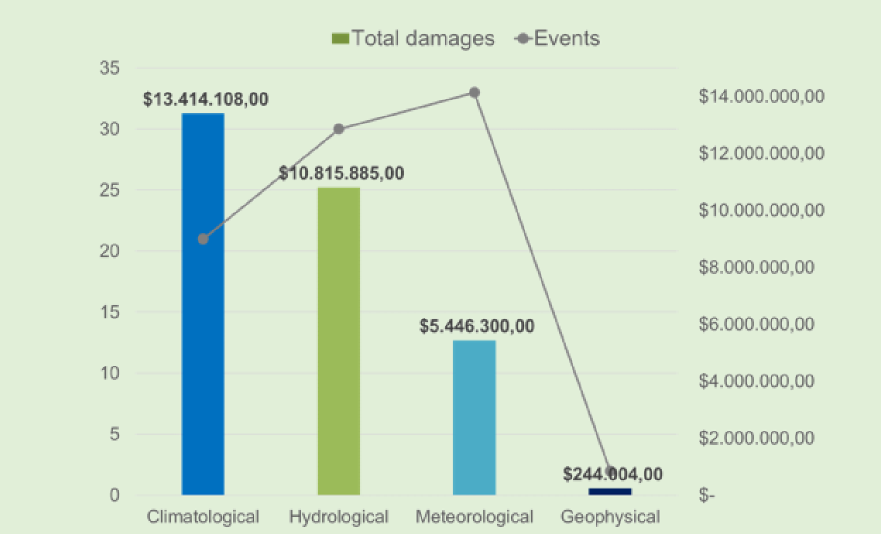
Spain is vulnerable to many natural hazards, including wildfires, droughts, floods and extreme temperatures. According to EM-DAT data, meteorological disasters accounted for 38% of the total disasters that occurred between 1980 and 2020 (**Figure 13**), with 73% related to storms and 27% related to extreme temperatures. However, climatic disasters such as droughts have drastically affected the Spanish territory, causing economic losses and exorbitant damage to the country. The worst drought in recorded history was in 1990, affecting more than 6 million people. In addition, forest fires were responsible for more than 74 deaths during the entire period, and the intensity and magnitude of this danger has increased in recent years.

At the same time, the floods caused more than 10 million dollars in damage to the country, with more than 7 events occurring in the last 6 years (2015-2020). The most catastrophic floods occurred in 1982 and 1983, which together caused around 125 deaths, totalling over 5 million in financial losses. Only one landslide event was reported, which occurred in 1996 near the Biesca region (Pyrenees), where approximately 84 people died after a heavy rain event that triggered a landslide. Only two earthquakes were reported, the only one that caused fatalities (10 deaths) occurred in 2011 in the Murcia region of southern Spain.

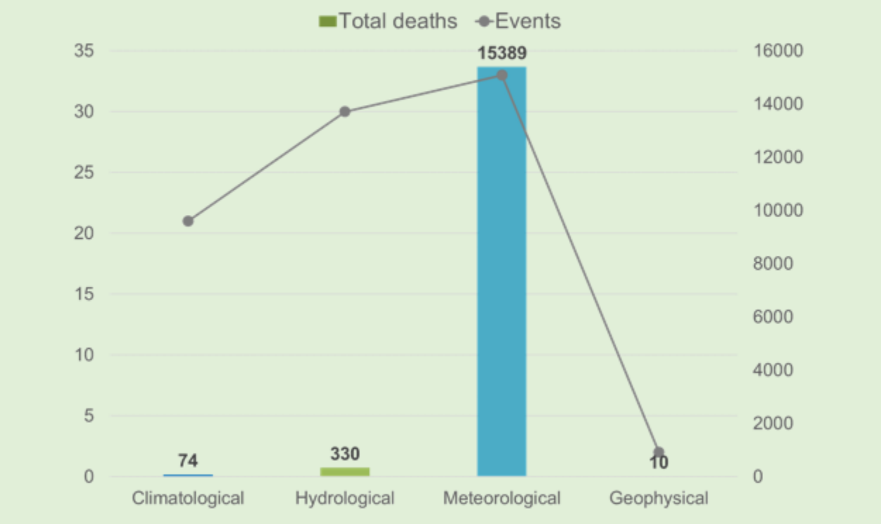
Regarding the victims, for the period 2015-2020, 71 deaths were recorded, while for the years 2009-2014, 53 deaths were recorded, indicating an increase in the vulnerability of the territory to disasters, such as floods, which caused 43 deaths and over 2.6 million dollars in economic losses in the last 6 years.



a. Distribution of different hazards in Spain (1980-2020)



b. Number of events and their respective economic losses by category.in Spain (1980-2020)



c. Number of events and respective deaths by category in Spain (1980-2020)

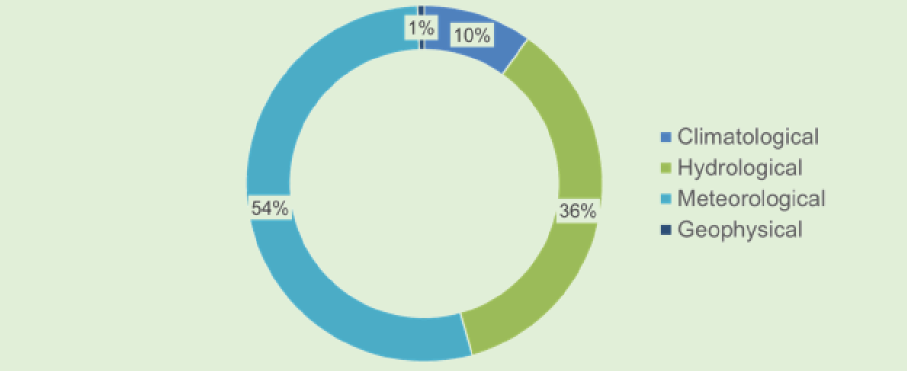
Figure 13. Disaster events reported in Spain.

4.1.3 FRANCE

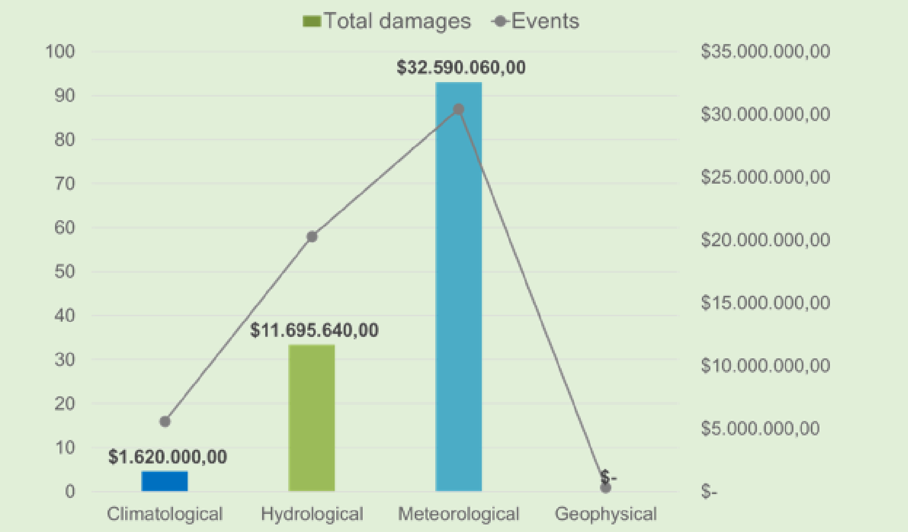
France is one of the most affected countries in the SUDOE region in terms of number of events, economic losses and fatalities. The region is mainly affected by meteorological disasters 54% (specifically storms and extreme temperatures) and hydrological 36% (specifically floods). More than $11 million was recorded in terms of economic losses from hydrological disasters, with 322 deaths over the entire period. In the last 6 years alone (2015-2020) there have been 10 flood events, 50 deaths and over 5 million dollars in damages (**Figure 14**). As for meteorological disasters, there were around 28,000 deaths, these being especially linked to the numerous events of extreme temperatures that occurred in the country, where damage has already reached 32 million dollars.

The extreme temperatures show the vulnerability of the territory to this danger, since several events in recent decades have caused thousands of deaths: 2003 (19490 deaths), 2006 (1388 deaths), 2015 (3275 deaths), 2018-2019 (1435 deaths) and 2020 (1924 deaths). The resilience of territories and buildings is closely linked to the natural hazard and its consequences, for the year 2003 it is estimated that most victims belonged to the elderly group [108] and the places associated with the deaths were unprepared, with lack of thermal insulation in old buildings and lack of green spaces around the buildings [109].

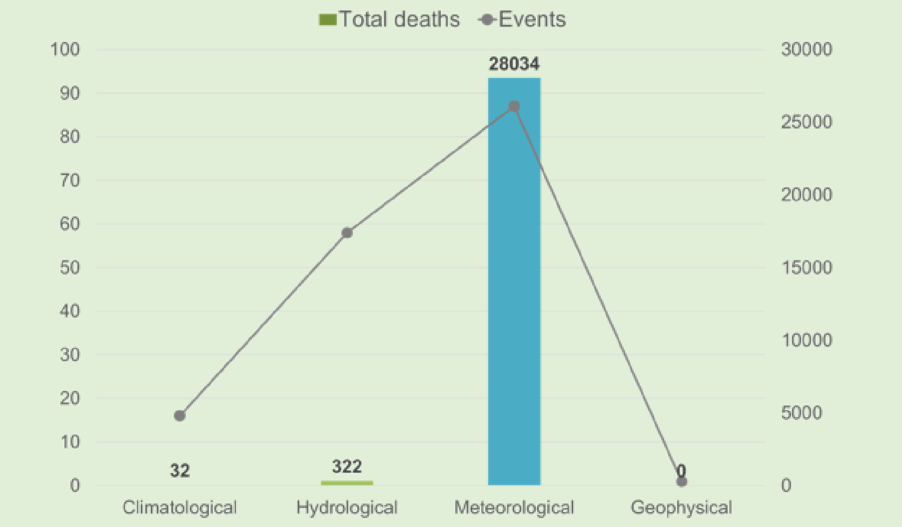
In terms of meteorological hazards, another risk plaguing the region are storms, which is the hazard that most affect France economically, reaching more than 28 million dollars in economic losses for the period 1980 - 2020. In the last 6 years of analysis of the EM-DAT 2015-2020 data, there were 3434 fatalities, more than 24 times for the period 2009-2014 (141 deaths), highlighting the weaknesses in the face of the dangers that have been intensifying increasingly, both by the vulnerability of the places and by the impacts of climate change.



a. Distribution of different hazards (1980-2020)



b. Number of events and their respective economic losses by category (1980-2020)



c. Number of events and respective deaths by category (1980-2020)

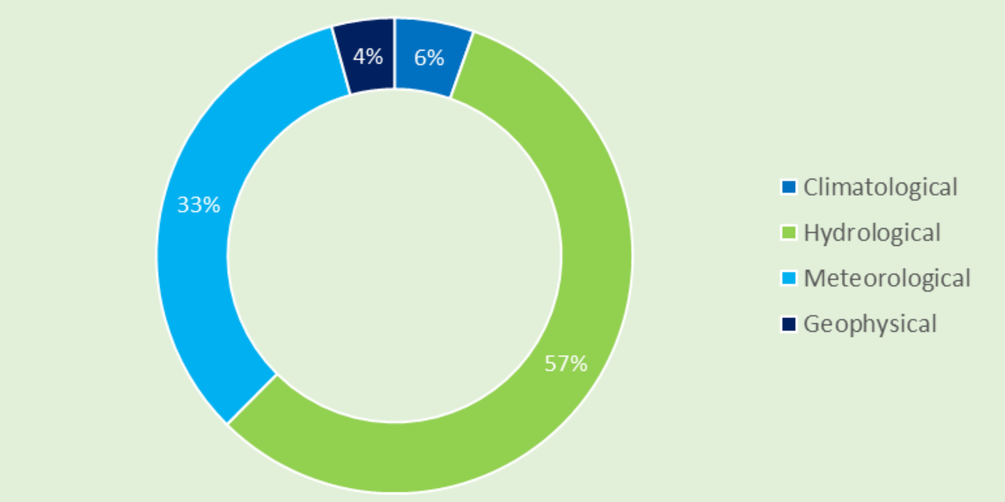
Figure 14. Disaster events reported in France.

4.1.4 ANDORRA

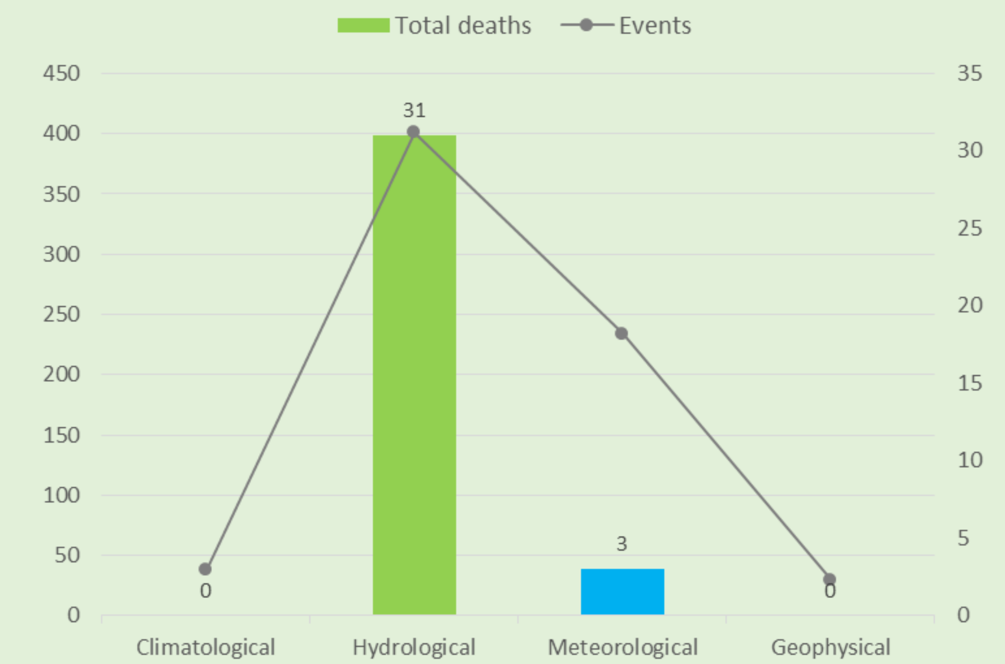
Andorra is a small mountainous country located in the Pyrenees but is not included in the EM-DAT database. This text is based on a local database under construction by Andorra Research + Innovation. It is being developed mainly from data collected from newspapers and firefighting interventions. However, information on economic losses is not included. So, the meaning of disaster included in the EM-DAT is different from the Andorran context, since all the events are included in the database (e.g., report without deaths). According to the local database (not completed), hydrological hazards represented 57% (**Figure 15**) of the total natural hazards that occurred from 1980. It must be noted that all mass movements (landslides, rockfalls, debris, etc.) are included in the hydrogeological group since they are generally related to rainfall. Rockfalls and landslides represent 68% of hydrogeological hazards, floods 22% and snow avalanches 9%.

Snow avalanches are not very frequent but are the hazard that caused more fatalities in the country, with 18 deaths since 1975. Six heavy snowfall episodes in 1996 led to a huge avalanche in Arinsal which caused no fatalities thanks to an orderly evacuation of more than 300 people. Floods are the phenomena that caused more fatalities in one single event: the 1982 flood. It caused 13 fatalities in the country and was also catastrophic in Spain. Meteorological risks also affect Andorra with 33% (mainly snowfalls). Due to the mountainous nature of the country, landslides and rockfalls are quite common in Andorra, although they have not caused any casualties. In 2019 the road that connects Spain with Andorra (the main entrance to the country) was closed for hours due to a large landslide. Economic losses are at least 5 million euros.

The orography of Andorra and the urban development the last few decades lead to building increasingly in areas more exposed to natural hazards.



a. Distribution of natural hazards



b. Number of events and respective deaths by category

Figure 15. Disaster events reported in Andorra (1980-2020).

4.2 GOOD PRACTICES IN THE SUDOE REGION

By sharing Disaster Risk Management good practices from various locations, a "culture of prevention" may be established based on communication and mutual learning. The initiatives compiled in this document are mainly focused on floods, wildfires, erosion and droughts. To look for more examples of good practices, see the appendices to this document or go to https://www.montclima.eu/.

The search of the projects on the databases produced 77 results for our evaluated period. The most highly cited natural hazard were climatological and multi-hazards (**Figure 16**).

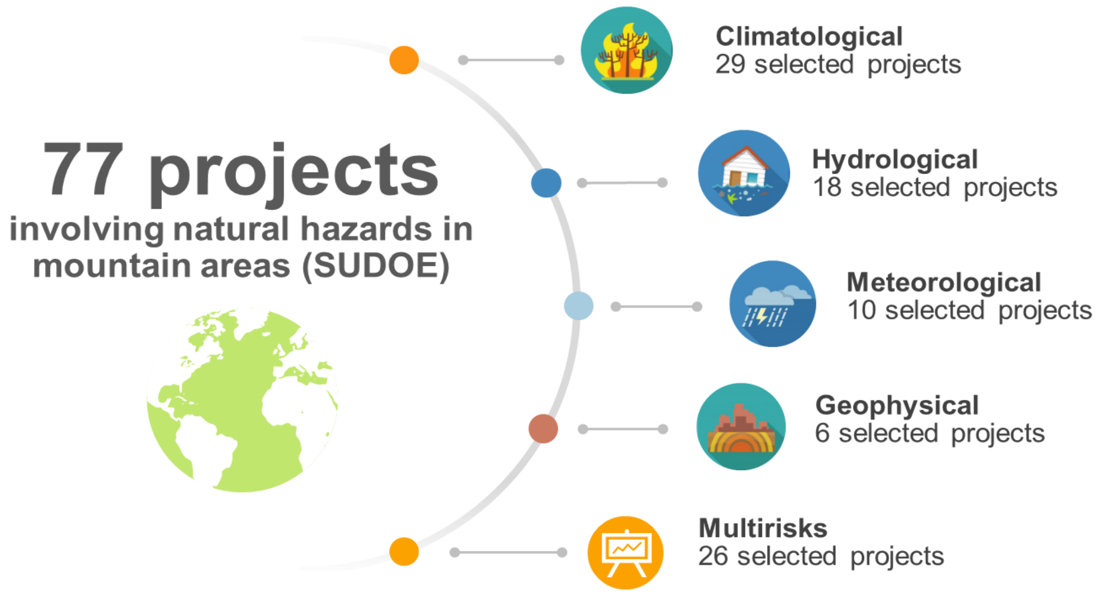


Figure 16. Total number of projects and its classification.

A quantitative analysis by region and by hazard classification showed that most of the study cases were carried out in Spain and, when we compared the natural hazard and the location of the study area, it is clear that in France and Spain the main natural hazard studied was for multi-risk, while in Portugal it was for climatological risk (**Figure 17**).

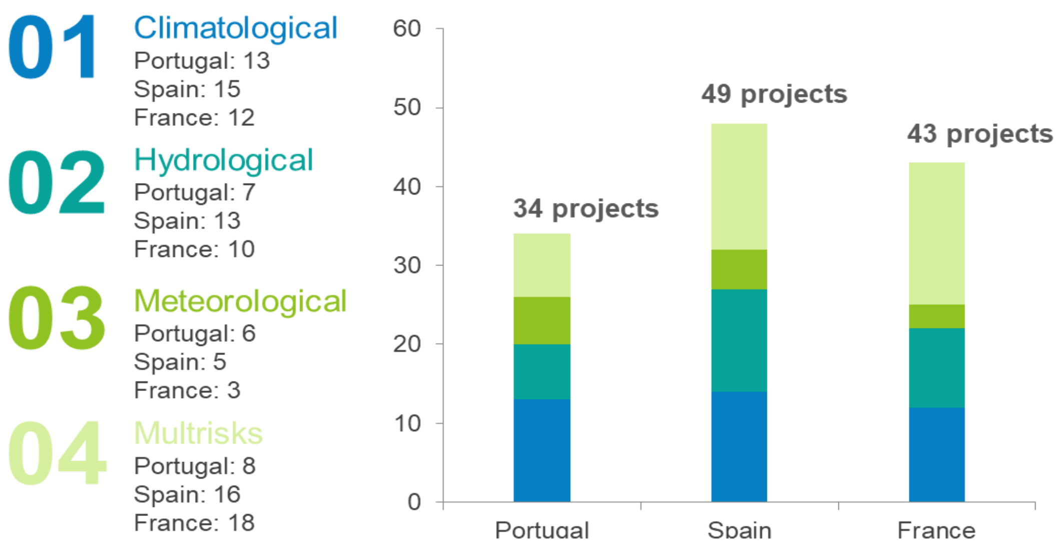


Figure 17. Classification of projects by country.

Following a review based in criteria adopted, 32 projects were selected, most of the projects selected for review addressed strategies focused on climate change, wildfires and multi-risk analysis (**Figure 18**).

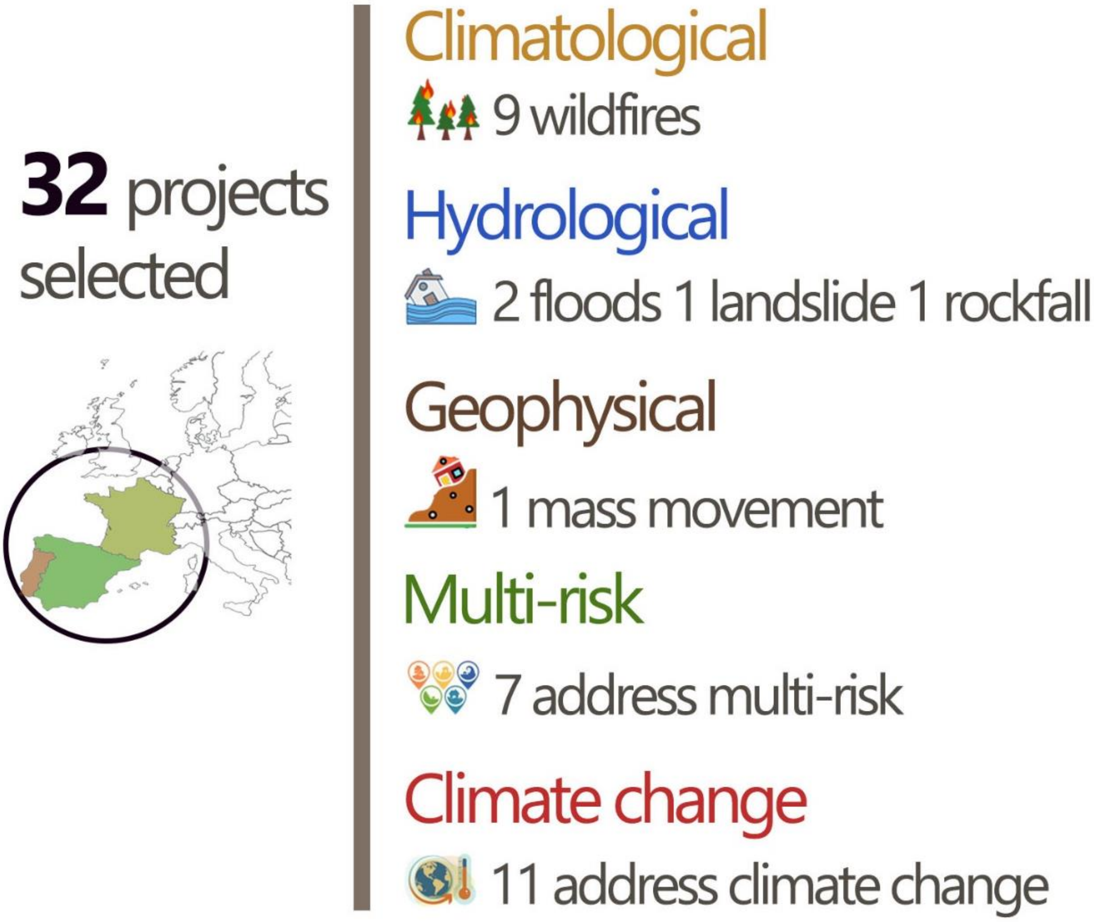


Figure 18. Natural risk management strategies in the SUDOE region.

Many disasters are related to each other, so managing a specific natural risk can decrease the risk of another one, in the same way, one natural hazard can promote or enhance another hazard. Prolonged droughts favour the ignition of wildfires [68] and mountain-burned regions favour soil erosion [109]. This perception strengthens the use of multi-risk approaches and some strategies identified in the projects include this approach. For example, the same project can present different strategies for the same natural hazard and in some cases the same strategy can be used to combat more than two hazards, as is the case with intensive controlled grazing, used both a strategy to fight climate change, and as a wildfire mitigation strategy.

The complete list of selected projects is available in **Annex II**. However, the 5 fact sheets made from information obtained through online meetings with a member of the projects are available as external attachments to this document. We identified that most of the selected projects work with a mutual approach involving partner countries, strengthening transnationality and international cooperation. It is not surprising to local governments that resilience to disasters is a top priority, and to that end they are continually developing national strategies for disaster risk reduction. Alongside the efforts of each country, international cooperation is being strengthened, both because disasters do not recognize borders and because of the exchange of knowledge and information to mitigate and manage natural risks.

In this review, we found projects addressing all of the natural hazards included in the Montclima objective. However, there are some strategies that also focus on territories that are not necessary mountain areas but are within the study countries. While all these practices seem excellent and easy to implement, their effectiveness depends on several factors, involving policy actions, training and field study (**Annex III**).

4.2.1 WILDFIRES

The Mediterranean territories are the most affected by wildfires in Europe, with several registered events that have been catastrophic, leading to the death of many people. For this reason, there is a great interest in the wildfires prevention and control, existing an extensive set of good practices aiming at this natural hazard. As previously mentioned, the management of wildfire hazard depends basically on actions directed to the management and use of the soil, which despite appearing simple requires a joint effort of several actors for its efficient implementation.

Among the good practices used to manage the risk of forest fires observed in the SUDOE projects, we highlight the prescribed burning, use of animals to control biomass, firebreaks and mapping the risk of wildfires.

4.2.2 EROSION

Landscape and fire management are key to minimizing soil loss and its impacts on ecosystems [111]. For example, soil erosion rates are high when conventional practices are applied to upland rainfed olive (Olea europaea L.) plantations in a semi-arid Mediterranean environment. In this case, integrating a mixture of organic and conventional doctrines is vital for slopes and low fertility soils because they maintain or improve the functioning of the soil ecosystem [112].

On the other hand, the abandonment and revegetation of agricultural lands also have impacts of the dynamic of soil properties in the mountainous areas in the Mediterranean, however, the results of a study carried out in the Central Pyrenees of

Spain raise the question of what are the best practices for soil recovery and erosion control in abandoned land, since no difference was found between soil improvement by natural succession and by afforestation [113].

4.2.3 GRAVITATIONAL NATURAL HAZARDS

The SUDOE region, like other mountainous regions in the world, suffers from a lack of geomechanical, historical and statistical data regarding the activity of rockfalls. In this sense, numerical evaluations, such as scenario modelling, are often challenged by the absence of information added to the variability and uncertainties of nature [117, 118]. Some of the strategies identified for managing rockfall, landslide and mass movement risks include risk maps and runoff material collections and characterization (**Annex III**).

4.2.4 DROUGHT

Climate change and the environmental demand for water further increase competition for scarce water resources in several arid and semi-arid regions of the world (e.g. Spain). In this context, it is necessary to incorporate the strategic behavior of water stakeholders in the design of acceptable and stable drought mitigation policies, as there is evidence that cooperation in water management policies reduces the cost of damage caused by drought [114].

In addition, forest management is also key in strategies to combat drought, considering that the forest in the Mediterranean basin are dominated by pine species and have a number of characteristics that make them more vulnerable to droughts. Therefore, promoting the conservation of high-altitude pine plantations and improving the regeneration of natural pine and oak trees can improve the resilience of these forest ecosystems [115].

4.2.5 FLOODING

Using morphological approaches to map landforms is a valuable tool to assist policymakers and planners in managing flood risk and land use, as it requires less data and is less time consuming than hydrological and can be used in situations where hydrological data are not available [116].

4.2.6 CLIMATE CHANGE

Climate change is not considered a disaster in itself but a changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of weather and climate extremes and adds uncertainty to the assessment of hazards and vulnerability

[73]. Therefore, climate change increases people's vulnerability and should be seen as a complex danger, which is weakening the resilience of communities [119]. Even if there were no changes in climate due to anthropogenic factors, meteorological and climatic extremes would still occur [73].

The most common scenarios used for long term are the Representative Concentration Pathways (RCP), which were adopted by the IPCC in the fifth Assessment Report (AR5) in 2014. These pathways represent the total radiative forcing (W/m^2) by the year 2100, expressing the cumulative measure of human emissions of GHGs from all sources [120]. In this way, it is possible to have a perception of which natural hazards will be most influenced by climate change, allowing specific adaptation actions to reduce future impacts when a disaster occurs.

In the case of the SUDOE region, the strategies identified to fight climate change range from adaptation practices to resilience measures (**Annex IV**), that agricultural developed in a sustainable way, such as through agroforestry systems, agroecology or organic agriculture, is a common strategy in several projects to make territories more resilient to climate change. The change in the agricultural model contributes to combating a series of environmental challenges such as the loss of biodiversity, water pollution and soil degradation due to intensive use of pesticides. The change in the agricultural model in the region can also be verified through the increase inland destined for organic crops. According to IFOAM Organic Europe [121], over the last decade organic farming has been growing in Europe and 7%, 21% and 26% of hectares of organic land in 2019 were destined as permanent crops in France, Portugal and Spain, respectively **(Figure 19)**.

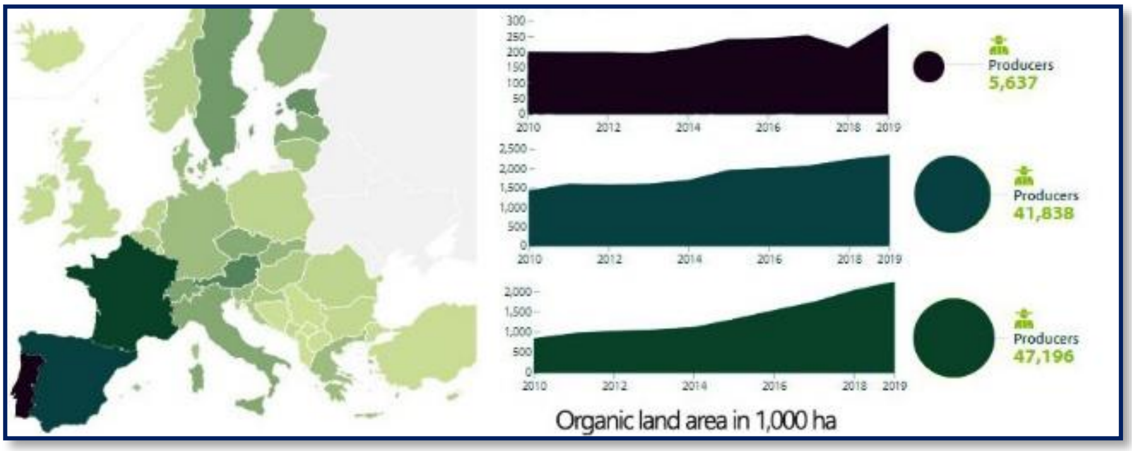


Figure 19. Organic land area in Portugal, Spain and France.

5. CONCLUSION

This overview of natural hazards and disaster risk management in the SUDOE region allowed us to observe current advances and trends in natural hazards such as heatwaves, droughts, floods, landslides and wildfires, using datasets recorded in different European sources and results of environmental projects developed in the region.

One of the main conclusions is that disasters in the region have increased by approximately 26% in the past four decades, rising from more than 60 events between 1981-1990 to more than 85 in 2011-2020. The number of disasters related to meteorological and hydrological events increased sharply in that period. In terms of numbers of occurrences, meteorological disasters were the most representative, with 16, 33 and 87 events recorded in Portugal, Spain and France, respectively. Otherwise, in Andorra, hydrological risks accounted for 57% of the total natural risks that occurred from 1980 onwards. Particularly the heatwave was the deadliest event in the period studied, accounting for 95%, 76%, and 68% of deaths in Spain, Portugal and France, respectively. Although in Spain and Portugal the greatest economic losses were associated with climatological disasters, in France it was the meteorological disasters that caused the greatest economic losses.

On the other hand, based on information collected in the projects, we highlight that 72% of selected projects work with partner countries, strengthening international cooperation to engage stakeholders through the exchange of knowledge, information and experience. Moreover, projects in the region developed techniques to deal with disasters associated with wildfires, floods, landslides, mass movement and rockfall, when classified by DRM activity and hazard type, the strategies selected focused on mainly mitigation and preparedness activities. However, there are some strategies that also focus on territories that are not necessarily mountainous areas but are within the study countries.

In particular, wildfires receive great attention, since most of the good practices addressed this type of hazard through prescribed burning, guided herbivory and early detection of forest fires. However, in the SUDOE region, in addition to practices to face natural hazards, there are also many strategies based on sustainable agricultural techniques to combat the risks associated with climate change.

In Europe, Portugal, Spain and France lead the list of countries with the largest area burned and the largest number of occurrences, therefore, it is necessary that future projects include new techniques and strategies to combat forest fires, mainly through mitigation activities that involve the community, public authorities and stakeholders.

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ANNEX I – EVALUATION CRITERIA FOR PROJECT SELECTION

Criteria	Description	Rating scale
<u>Adherence</u>	The project was not aligned with the research objective	Yes = 1 or no = 0
<u>Natural hazard*</u>	Natural hazards included in the Montclima project	At least one natural hazard considered = 1 No natural hazard considered = 0
<u>Pilot plans or strategies</u>	Activities dedicated to testing or implementing strategies related to disaster risk management	No pilot plan developed in SUDOE countries = 0 At least one pilot plan developed in SUDOE countries = 1
<u>Documents and files</u>	Documents that contribute to the knowledge of the main techniques and tools used in risk management	Yes = 1 or no = 0
Campaigns of awareness	Set of actions in promoting project support (webinar, workshops, social media, communications, outreach material)	Yes = 1 or no = 0
Cooperation with other organizations	Projects developed with more than one international organization active in the countries that comprise the SUDOE region	Yes = 1 or no = 0
		Yes = 1 or no = 0

*disaster

Note: A project was selected when the four underlined criteria were met

ANNEX II – PROJECTS IDENTIFIED IN THE SUDOE REGION

Project	Objectives	Description	Activities	Results	Websites
LIFE Montserrat Financing: Life Program 2014-2020 Target: Wildfires Location: Metropolitan Region of Barcelona, Spain	The creation of strategic fire prevention areas and their maintenance through silvopastoral practices The conservation and improvement of biodiversity in the area through the maintenance and restoration of priority habitats and the habitats of threatened and protected species Increased ecological connectivity of the territory and spaces of the Natura 2000 network Montserrat-Roques Blanques-Riu Lobregat and Sant Llorenç del Munt i l'Obac	This project has created a green infrastructure to present large forest fires and promote the conservation of natural heritage in an area of 14 municipalities around the Montserrat mountain	Once the priority areas of action (PAA) has been defined, possible alliances complicity with actors in the territory are analysed. The forest farms and the area necessary for the viability of each livestock farm overlap with the PAA, allowing each pastoral management unit to be defined from there. To set of all of them form the area of project management (APM). Thinning has been carried out to reduce the density of the trees to 1000 ft/ha. This accelerates the maturation of the pines, notably improving the habitat for various plant species from the shrubby and herbaceous strata and increasing the diversity of fauna Combination of prescribed burning and mechanical works on a land area of 181h The grazing management plans are approximately 30 pages long, with very detailed information on the planning of the livestock management model for each project management area The grazing agreements are the commitment of the beneficiary parties of the conservation actions, with the objectives of the project, and the guarantee of the durability of the investments made	Reconnect the territory and its people with the practice of ranching, which had disappeared in the area; 65ha of open spaces have been recovered through prescribed burning and 45 ha with mechanical means; forest restoration work on more than 1300ha; 10 livestock management units structured around strategic areas for fire prevention; work carried out with the local educational community to generate a sensitivity in the territory	https://lifemontserrat.eu https://www.facebook.com/LifeMontserrat https://twitter.com/LifeMo

Project	Objectives	Description	Activities	Results	Websites
DEMORGEST Financing: Life Program 2013-2017 Target: Wildfires Location: Catalonia	This project aims to reduce the vulnerability of the forests of Catalonia to large forest fires (GIFs), facilitating the adoption of new models of multifunctional forest management (ORGEST models) that include the production of various goods and services to promote the prevention of GIFs; and which raise awareness in the public of the role of forest management in firefighting and the conservation of agricultural landscapes	LIFE+Integration cost-effectiveness of the prevention fires in the planning and forest management	Preparation: The coordination of the collaborating institutions of the project, technical workshops, improving networks of forest management groups (XPDs) and the creation of a volunteering human resource hub within the voluntary XPDs, the design, location, and diagnosis of land on a massive scale (ZPM), and the formation of agreements with landowners, forestry companies and other companies operating in the region; Implementation: The carrying out of forestry work in the ZPM. The selection and installation of classrooms; Monitoring activities: Tasks to measure and document the effectiveness of project activities against the set objectives. Four different components were studied: fire risk, carbon flow, water use efficiency, and potential biodiversity; Communication and dissemination: Seminars, workshops, and field visits; Continuous review: Networks on a Mediterranean or transnational level will also be created	The ORGEST guidelines propose a total of 127 management models for 32 different tree species. In reference to their objective, 64 of the models are productive, 53 have a dual aim (production-prevention) and 10 are preventive; Protection of 3 massifs, which represent 3,176 hectares, based on the management of 5% of their total area identified as strategic for the prevention and fighting of large forest fires; 58% of the Forest Management Plans approved between 2014 and 2017 use the ORGEST silviculture models; 2 collaboration structures created to continue the research, dissemination, knowledge transfer and training on multi-functional forest management; 11 management support documents published; 740 people participating in training activities (attending workshops) in the field; 34 workers from forestry companies trained in the practical application of the ORGEST models and the criteria for the reduction of a stand's vulnerability to fire; Networking with 2 research institutions, 2 training centres, 2 administrations and 2 owners' association	http://cpf.gencat.cat/en/cpf_03_linies_actuacio/cpf_transferencia_coneixement/cpf_projectes_europeus/cpf_life_demorgest/ https://www.facebook.com/cpforestal/ https://twitter.com/cpforestal

Project	Objectives	Description	Activities	Results	Websites
OPEN2PRESERVE Financing: 75% by the European Regional Development Fund 2018-2021 Target: Wildfires Location: South slope of the Western Pyrenees. Sector NW of the LIC Roncesvalles-Selva de Irati. Roncesvalles (Navarra)	The main objective of this project is to connect current interdisciplinary scientific knowledge with technology and practical operation. The project proposes regional pilot experiences based on: combination of guided herbivory and controlled fire: PYRIC HERBIVORY Use of indigenous breeds of equine and ovine livestock for pyric herbivory Identification and foresting of innovative assessment solutions	One of the pilot experience is in Navarra, the area includes a total of 325 hectares that extend to the west and to the east of the Ibañeta hill to the Ortzanzurieta peak. The PE aims to guarantee the preservation of ecosystem services and the ecological quality of open mountain spaces and ensuring the viability of the long-term management model by identifying innovative solutions for economic recovery	Two surface areas have been selected for the combined and monitored practices of controlled burn and guided grazing. A management model for pastures of high environmental value through the combination of guided herbivory or biological clearing, by means of native horse breeds Jaca Navarra and Burguete, accompanied by initial techniques to reduce the accumulation of biomass through controlled or prescribed burning. In 2018, one of the areas has been grazed per 12-15 studs, and the other one, which was grazed by 10-11 studs. This latter zone has also been grazed by sheep. For the pilot experience, the presence of 2 to 6 studs/ha has been scheduled. The animals will change plot when the grazing on offer has finished and will return after successive re-growth	Pasture areas of high biodiversity and good nutritional quality have been maintained and created, which had been invaded by dense monospecific covers of gorse scrub; These recovered pastures have contributed to the breeding of foals that, through grazing, generate meat with a very high intrinsic quality; Through the Focus Group methodology, information has been extracted on the main goods and services, and on the added value provided by pasture production in areas of high environmental value	https://open2preserve.eu/en/ https://www.facebook.com/open2preserve/ https://twitter.com/open2preserve

Project	Objectives	Description	Activities	Results	Websites
PRINCALB Financing: Interreg / Poctefa 2007-2013 Target: Wildfires Location: Massif of the Alberas, Cap de Creus and surroundings	The project aims to work in the defence of forest resources and natural heritage, prevention of natural risks, and to achieve a concerted planning and management of the border massifs in the broadest sense (Salines massif, Albera massif and Cap de Creus) in the field of prevention of fire. In addition, prevent forest fires in the cross-border area of the Eastern Pyrenees, acting in a coordinated manner between the two regions	The Mediterranean Pyrenees form a geographical unit differentiated from the rest of the Pyrenean massif. The easternmost massifs are located in a high-risk area for forest fires. This risk has been increasing with the progressive abandonment of crops and pastures that has produced an increase in the masses, being more combustible and more continuous. The cross-border area of the eastern Pyrenees is very susceptible to a large forest fire, especially due to situations of wind coming from the north, the so-called north wind	Fire prevention planning for the L'Albera massif, Cap de Creus and surroundings: the transfer of information (cartographic and documentary) between the two regions and the adaptation and extension of existing fire prevention plans. A pilot experience in the maintenance of arboreal firebreaks is also planned, wine and pastoral, focusing mainly on the wine sector of Banyuls (France); Materialization or improvement of priority forest fire prevention infrastructures: Execution of the infrastructures considered the highest priority. The works may be the opening or improvement of low fuel load areas, the construction or improvement of roads and the adaptation of accessible water points for land and air means. In addition, a pilot experience to promote the maintenance of vineyards as firebreak areas with means that respect the environment; Dissemination on the prevention of forest fires	The repair of a border water point for firefighting in Portbou has been carried out, which did not have an autonomous supply, now it has a pipeline from the French water company, which feeds it continuously; Installation of new standardized hydrants in each territory so that it can be used by the Catalan and French extinguishing systems indistinctly; Drafting of an executive project in the Coll de Banyuls (Rabós d'Empordà); First planning process of the 73 ha divided into various plots of action to adapt them. A first group of units (28.3 ha) has been divided into sectors that were initially planned with prescribed burning, but with the approval of the project they will be carried out through manual and mechanized clearing	http://agricultura.gencat.cat/es/ambits/medi-natural/gestio-forestal/dar_obres_forestals/dar_prevencio_incendis/dar_princalb/

Project	Objectives	Description	Activities	Results	Websites
Project: FORRISK Financing: Interreg 2012-2014 Target: Multi-hazard Location: Portugal, Northwest of Spain, and southwest of France.	This project aims to identify, in each of the participating regions, the measures adopted to manage the identified and foreseeable risks, and to propose innovations to improve the management of these threats	The risks that weigh on the forest know no borders. This highlights the need to take stock of all the measures that can be taken in a concerted way between neighbouring countries and regions to prevent the spread of certain types of forest damage.	The project is structured into three groups of technical tasks (GT 2, 3 and 4), two groups of management tasks (GT 1 and 5) and a group of communication and dissemination tasks (GT 6). First stage: In each region, an inventory and analysis of the existing tools for risk management, risk anticipation and risk monitoring were carried out. In addition, the efficiency of the tools and the existence of a multi-risk approach were evaluated; Second stage: Comparison of existing tools in the regions studied in the project; Third stage: With the information acquired in the previous stages, improvements in risk management tools in South-West Europe were suggested and a methodology for effective inter-regional cooperation was proposed	Institutional tools for forest risk management: Twelve key recommendations for improving forest protection; Tools adapted to stand-level risk management: Installation, evaluation and analysis of devices to define methods of combating risks (ecological, genetic and forestry); Decision-making tools embedded in models simulating forest growth: Toxicity risk analysis of adaptive soil management strategies; Evaluation of the risks of soil erosion and compaction in Pinus radiata plantations in the Basque Country; Evaluation of the risks of erosion and depletion of soil nutrients in eucalyptus plantations in Portugal; Vulnerability maps to wind and fire in the Basque Country, based on the 2012 Lidar flight; Evaluate the impact of different silvicultural practices on the wind resistance of maritime pine, among others	http://forrisk.efiatlantic.efi.int/?lang=fr

Project	Objectives	Description	Activities	Results	Websites
Landscape Fire Financing: European Union LIFE Program 2019-2022 Target: Wildfires Location: Viseu Dão Lafões (Portugal) and Extremadura (Spain)	To develop large-scale measures to prevent forest fires, conserve biodiversity, increase forest resilience, train decision-makers on the benefits of prevention, as well as identify one of the options for local adaptation that will make it possible to identify and propose actions to reduce the current and future territorial vulnerability of the region	The LIFE Landscape Fire Project aims to contribute to reducing the impact of forest fires, both in terms of carbon emissions into the atmosphere and the loss of biodiversity, while reducing their economic and social impact	Expansion of the study on the classification and typification of Major Forest Fires, with a view to enriching a database of the history of this disturbance in the landscape; Development of actions with the use of fire associated with pastoral activity, to identify the best techniques and prescription parameters for the improvement of pastures; Reconstruction and analysis of large forest fires and application of propagation simulators; Develop a Forestry Management Plan, through experimentation with pilot areas; Expansion of the study on the classification and typification of Major Forest Fires; Training of operators and technicians on the use of fire in prevention and suppression	Training: Practical sessions for training and accreditation in Controlled Fire; Introduction to Integral Management and Advanced Grazing Planning; delivery of equipment to Controlled Fire Technicians; Pastoral Action Planning Techniques, Invasive species	https://life.cimvdl.pt/objetivos/

Project	Objectives	Description	Activities	Results	Websites
ROCKTHEALPS Financing: European Union via INTERREG Alpine Space 2016-2019 Target: Rockfall Location: Alpine Space (Italy, France, Switzerland, Germany, Austria, Slovenia)	The overall objective of the project RockTheAlps has been to reinforce and strengthen the implementation of rockfall risk prevention policy and mitigation strategy support in line with a sustainable forest management approach	In natural hazard management and disaster risk reduction worldwide, but especially in the Alpine Space, forests are increasingly considered equal to technical or civil engineering measures. This project is capitalizing the current knowledge and developing innovative concepts, tools and methodologies for providing the first Alpine Space regional rockfall risk zoning tool	Worpackage T1 - ROCK-EU: Development of an innovative AS rockfall assessment methodology using harmonized criteria and objective data; Worpackage T2 - TORRID: Construction of the first AS Toolbox for assessing the protective effect of forests against rOckfall and expressing the protective role in a Risk Reduction InDex; Worpackage T3 - Production of the first harmonised map of protective services of forest ecosystems against rockfall for the entire AS; Worpackage T4 - From the implementation of an economic model to the economic assessment of rockfall protection forest ecosystems services; Worpackage T5 - Implementation of guidelines, a Territorial Information System and recommendations for sustainably valorise rockfall protection forest ecosystems services	Three outcomes based on the timing of results have been achieved by the end of the project duration: Operational: production and dissemination of 1) the first entire Alpine Space harmonized mapping of rockfall risk and protection forest, 2) protection forest management integrative approach; Strategic: generating scenarios and their economic valuation for decision makers to improve territorial resilience facing with rockfall risk; Policy: production of the first Alpine Space harmonized statistics on protection forest ecosystems service, recommendations for developing forest based rockfall prevention policy. The main results are available via the download section of this website	https://www.alpine-space.org/projects/rockthealps/en/home

Project	Objectives	Description	Activities	Results	Websites
AA-FLOODS Financing: INTERREG VB Atlantic Area 2014-2020 Target: Floods Location: Portugal, Spain, France, United Kingdom, Ireland	The overall objective is to reduce human and material damages due to flooding by improving the tools of Prevention, Alert and Crisis Management the Local Scale	Floods are Climate Change phenomena that most people affect in the Atlantic Area. In the EU costs overpass 1,500 lives and 52,000 M€ over the past 20 years	Prevention: It begins with a analysis of the Atlantic Area policies against Floods, then development of procedures and regulations for the coordination between urban planning and risk prevention, improve local communities resilience, Pilot 1 – Torrential Rains RunOff at Local Scale and Local Action Plans for Flood Prevention & Emergency Management; Early warning: Development Protocols to access Early-Alerts EFAS / COPERNICUS data and Pilot 2 – Rivers overflow early warning System Crisis Management: Pilot 3- Reservoirs' Water Discharges Management, Improving the Coordination among Emergency Management bodies and Promote the use of real time information in Response Planning; Assistance and recovery: Two Activities, first The Improvement of the evacuation protocols and second Attention procedures. Health and Shelter	Guidelines to achieve a better Coordination between Territorial, Urban and Risks Management Planning; Pilot regulations and tools for enhanced design of sanitation networks based on modelling torrential rains runoff and networks evacuation; Models for Local Emergency Plans against Floods to Reduce human and material losses through Local Scale Flood Risks Management; Guide to implement rivers overflow monitoring system for Early-Warning. Target groups are National, Regional and Local Authorities; Protocol for Reservoirs' management to Plan, Manage & Coordinate water discharges; Enhanced Coordination Protocols for an Improvement in the rapid response of the Intervention and Emergency Corps for Harm Reduction	http://aafloods.eu/

Project	Objectives	Description	Activities	Results	Websites
INUNDATIO Financing: INTERREG VB South West Europe 2019-2022 Target: Floods Location: Portugal, Spain, France	This project aims to create a system, based on new technologies and big data, monitoring the headwaters of the river basins, through sensors, which will gather hydrometeorological information, to control in real time the river flow or the rain forecast. The information will be transferred to a platform that will additionally offer simulations of possible risk scenarios	INUNDATIO monitors, in real time, the headwaters of rivers and torrents, where the behaviour of meteorological phenomena is less predictable. Three pilot cases have been chosen to represent the three climatic areas of the Sudoe territory (oceanic, Mediterranean and high mountain)	Development of the methodology for collecting data from watershed headwaters; Definition of the methodology for the analysis of watershed headwaters data; Monitoring of the Veneno Claro basins in in Navaluenga (Ávila), Ribeira das Vinhas (Serra de Sintra, Cascais), Gave de Pau Amont and Nive (French Basque Country); Definition of action mechanism in the face of catastrophes	It is expected the creation of a model that can be replicated and scalable throughout the SUDOE territory for managing flash floods in headwaters of basins, which will include: Method of geomorphological and hydrological representation of the headwaters of the basin supported by GIS tools; Flood prevention plans adapted to climate change; Risk analysis tool through real-time data collection; Flood scenario projection tool with impact assessment; Protection plans in the event of flooding; Reconstruction plans updated to the techniques of restoration of historic buildings; Recommendations to increase resilience	http://www.inundatio.eu/

Project	Objectives	Description	Activities	Results	Websites
SAPYRA Financing: INTERREG V-A Spain - France - Andorra (POCTEFA) 2014-2020 Target: Landslide Location: Spain, France, Andorra	The objective is to reduce the intensity and frequency of the avalanche phenomena that threaten the Pyrenean accesses in Andorra and France	The project stems from the need to improve access between France and Andorra and seeks to promote the sustainable development of the border territory between Spain, Andorra and France	The project is carried out in three phases: Technical studies; Implementation; Mounting The project also uses three interventions: Active protection - to prevent avalanches Passive protection - to deflect avalanches warning devices Activities to finish the project: Identification of landslide exit zones based on the analysis of the topographical characteristics of the corridor; Prioritization of the outlet areas to be treated according to the frequency and intensity of historical landslides observed in the corridor (50 years); Dimensioning of the structures and their height according to the nivological context of the corridor	The H4 corridor is the most important work of the project, avalanche risk prevention work was carried out between Hospitalet and Andorra by the H4 Sapyra Project; Environmental study in the work area; Projected new protection works in the H2 avalanche corridor on the RN-20; Installation of battens in corridors Pe9 (Porté Puymorens) and Pan13 (Puerta), where about 400 ml are installed	http://sapyra.com/?lang=fr https://www.facebook.com/sapyra2017.2020/ https://www.youtube.com/channel/UCKY-GUHicYG6xXmM1B3QlJw

Project	Objectives	Description	Activities	Results	Websites
PIRAGUA Financing: INTERREG V-A Spain - France - Andorra (POCTEFA) 2018-2020 Target: Climate change Location: French–Spanish–Andorran border	The main objective of the project is to improve the adaptation of territories to climate change	The Pyrenees, a mountain range stretching from the Atlantic to the Mediterranean is particularly vulnerable to climate change. PIRAGUA addresses the characterisation of the hydrological cycle in the Pyrenees in order to improve the adaptation capacity of the territories to the challenges imposed by climate change and to support the investment aimed at adapting water resource management to climate change	Territorial and organizational approach: Coordination of information, tools and conceptual framework for the integral and cross-border management of water resources; Technological approach: Different technological challenges (simulation tools and scenarios, etc). The case studies deal with innovative adaptation actions in specific contexts of water and land management	PIRAGUA will provide results on the scale of the Pyrenees (2 global studies and 1 common strategy), as well as results on a local scale (7 case studies). It will associate the local and regional stakeholders with the basin organizations, so that their results are likely to benefit the whole territory	https://www.opcc-ctp.org/en/piragua https://twitter.com/opcc_ctp

Project	Objectives	Description	Activities	Results	Websites
TERRISC Financing: 75% FEDER 2002-2006 Target: Mass movement Location: Six sub-basins belonging to the hydrographic basins of the Alvoco river and the Pomares stream, located in the municipality of Arganil, in the municipality of Oliveira do Hospital and in the municipality of Seia	This project aimed to study agricultural terraces and assess their degree of degradation, in order to provide each municipality in the study area with elements that can enable them to justify and act in the revitalization of these regions	From the need to revitalize a set of traditional agricultural structures, an ambitious project emerged within the Mediterranean countries, to make known the importance of terraces. Agricultural terraces are structures that allow man to develop agricultural activities in the most inhospitable places. At the same time, they prevent the triggering of earth movements on slopes, through soil permeability	Experimentation and inventory of six hydrographic basins, spread over the municipalities of Oliveira do Hospital, Arganil and Seia. The inventory of the terraces was carried out using military maps from the Instituto Geográfico do Exército, aerial photographs from 1958 and orthophotomaps from 2004, which allowed the vectorization of the terraces to be carried out using the ArcGis 9.1 software. Erosion plots were also installed, where samples of material from the runoff were periodically collected, which were subject to laboratory treatment. Each plot has a standardized area of 2.5 m2. The main components of the erosion plot are a collection chute that stores the solid material, a scale limnigraph and a totalizer, capable of storing 30 liters of runoff water. Finally, meteorological stations were installed in each of the municipalities, with continuous readings, at 30-minute intervals	The project presents the following management measures: Prevention: Immediate reforestation of perimeters under public administration, favouring native or edaphoclimatically adapted species; Compartmentalization of space through the introduction of forest management (DFCI infrastructure) throughout the area; Encouraging private landowners to reorganize and clean their forests. Preservation: Creation of a professional masonry training course; Restoration of some built heritage; Development of routes of ethnographic interest; Olive oil routes with the recovery of mills; Mountain gastronomy routes, through the valorisation of regional products; Identification of the main trails travelled in the past by shepherds with their cattle. Itinerary: A set of tourist routes was developed that include the Protected Landscape of Serra do Açor and the Serra da Estrela Natural Park. This route is intended to encourage tourists to travel along these paths and thus contribute to revitalizing these regions and boosting the local economy	https://www.uc.pt/fluc/nicif/Projetos/Internacionais/terrisc/Metodologia

Project	Objectives	Description	Activities	Results	Websites
Montado-Adapt Financing: LIFE Porgram 2014-2020 Target: Climate change Location: Spain and Portugal	The main objective is to mitigate the consequences of climate change, increasing the sustainability at an economic, social and environmental level	LIFE Montado-Adapt is a project to promote the adaptation of the *Montado/Dehesa* system in Portugal and Spain. The project support the owners and managers of land in the implementation of the Integrated Land Use (ILU)	The process of development of the Integrated Land Use has 11 steps: (1) Evaluation of pilot areas; (2) Definition of indicators and current situation; (3) Development of the ILU systems; (4) Training of owners/partners; (5) Implementation of ILU in the 12 pilot areas; (6) Cooperation considering market; (7) Replication - Development of ILU in other interested properties; (8) Implementation of certifications in the pilot areas; (9) Marketing for products coming from the ILU; (10) Evaluation of results; (11) Recommendations to public policies and widespread dissemination	The 1st group of expected results consists in: Establishment of Integrated Land Use systems on 1250 hectares; a 10% improved presence of indicator species for bird species and butterflies and a restored plant diversity and structural complexity matching habitat requirements for the Iberian Lynx; at least 8 viable income sources for domestic and international markets, 150 Euro per hectare (or 300%) farmer income increase, an employment increase of 1 FTE per 10 hectares and an overall IRR increase to at least 6 %; Carbon sequestration increase of 1 ton CO_2-e per hectare. The second group of expected results consists in: Established/Inclusion of self-supporting commercial company; 11 project partners trained as promoters; Signed at least 10 cooperation agreements with commercial partners; Preparation of Group Certification Process; Created synergies with public and private entities; Created networks for dissemination	https://www.lifemontadoadapt.com/index.php https://www.facebook.com/lifemontadoadapt/ https://twitter.com/lifemontado

Project	Objectives	Description	Activities	Results	Websites
AMDRYC4 Financing: European Union LIFE Program 2017-2022 Target: Climate change Location: El Moralejo (Caravaca de la Cruz), Xiquena (Lorca), Nogalte (Lorca), Corvera (Murcia)	The main objective is the promotion of resilience to dryland agriculture climate in Mediterranean areas and its sustainable, intelligent and integrated management, as a basic tool for adapting to climate change based on ecosystems (EbA) and strengthening its mitigating role as carbon sinks	LIFE AMDRYC4 presents a new approach to promote natural solutions for the adaptation to climate change of dryland agricultural systems in the Mediterranean area.	The project actions contemplated in the project are carried out in 4 experimental plots located in different points of the Region of Murcia: a) Preparatory actions; b) Implementation actions; c) Monitoring of the impact actions; d) Communication and dissemination of results; e) Project management	Some expected results: Guidelines for the application of accountability methodologies for carbon and ecosystem services for climate change mitigation; Carbon sequestration models; CO_2 sequestration activities related to management of dryland farming soils in the Mediterranean area increased at the rate of 20 tonnes, achieving a total removal of CO_2 estimated at 1 000 tonnes during the project; Twenty companies and institutions voluntarily implementing measures of calculation, reduction and offsetting their carbon footprint; Voluntary agreements catalysing an offsetting market for carbon and ecosystem services; Reduced soil loss by 9-48 tonnes per year	http://lifeamdryc4.eu/en/ https://www.facebook.com/LIFEAMDRYC4/ https://twitter.com/LIFE_AMDRYC4

Project	Objectives	Description	Activities	Results	Websites
GREENRISK4ALPS Financing: INTERREG Alpine Space 2018-2021 Target: Multi-hazard Location: Kranjska Gora (Solvenia), Val Ferret (Italy), The Southern Wipptal (Italy), Oberammergau, Bavaria (Germany), Gries am Brenner/Vals (Austria), and Parc des Baronnies (France)	GreenRisk4ALPs project aims to overcome conflicts and resistances with new risk mitigation alternatives and science-based communication support; to implement innovative ecosystem-based risk management for natural hazards and to create protective forest books	GreenRisk4ALPs facilities risk-based protective forest management as part of an integrated and ecosystem-based natural hazard risk management in the Alpine Space	Main activities WP1 - PRONA: New tools on Protective forest and natural hazard assessment: The goal of this activity was to collect, review and summarize the available research and information on protective forests and their management and to discuss the interactions between climate, forest and natural hazards changes; WP2 - ACTINA: Actors involvement and network analysis: The objectives were to provide the socio-economic foundation for an ecosystem-based risk management in the Alpine Space by considering the increase of risks from natural hazards; WP3 - DORA: Decision oriented risk assessment: The main objective of DORA was to introduce an innovative ecosystem-based risk mitigation concept; WP4 - ACRI: Acceptance raising for ecosystem-based risk control measures: To increase the awareness of political, economic, and social factors for ecosystem-based solutions for risk mitigation and management on multiple levels; WP5 - RIGOR: Risk governance support: To provide recommendations and concepts for improving harmonized and efficient ecosystem-based natural hazard risk governance in the Alpine Space	WP1 - The main output is the PROTECTIVE FOREST ASSESSMENT TOOL (FAT) - a new decision support tool for risk-based forest management; WP2 - The outcome is an Alpine-wide map of decision structures of involved and relevant actors; WP3 - One of the results is the risk analysis and the strategy prioritization; WP4 - Road map for a multiple actor and decision targeted information process; WP5 - A summary presentation of concepts for overcoming national barriers and constraints of ecosystem-based risk management as well as our two PROTECTIVE FOREST BOOKS	https://www.alpine-space.org/projects/greenrisk4alps/en/home

Project	Objectives	Description	Activities	Results	Websites
RISC_ML Financing: INTERREG V-A Spain - Portugal (POCTEP) 2014-2020 Target: Multi-hazard Location: Rivers Miño and Limia in Spain and Portugal	RISC_ML aims to better understand the Miño-Limia international river basin district, improve drought management mechanisms and establish an early warning system to assess the real risk of flooding	Greater knowledge of the international hydrographic demarcation, the establishment of mechanisms for the joint management of droughts and early warning against floods will allow greater preparation and response capacity in the territory against them	1) Analysis of the basin at the geographical and hydrological level; 2) Drought plan for the international demarcation of Miño-Limia; 3) New early warning system against floods in the international demarcation; 4) Basin control system and natural retention measures against flooding	Activity 1 New mapping of the international demarcation Hydrological modelling for the international demarcation considering climate change for the periods 2011-2040, 2041-2070 and 2070-2100 Modelling of water resources management in the river basin district Activity 2 Databases of drought indices on meteorological data measured in situ and another based on products derived from satellite images Reliable indicator system fully adapted to the area of study and design of state indexes Joint technical drought plan for the entire International Demarcation of Miño-Limia Activity 3 Improvement of available data Modelling and station database Flood early warning system for the entire International Demarcation Activity 4 Real-time hydrometeorological and water quality monitoring stations with communication systems in the Miño-Limia river basins New communications and data storage system for the international demarcation Projects for natural retention measures in the face of floods	http://risc-ml.eu/

Project	Objectives	Description	Activities	Results	Websites
URBAN KLIMA 2050 Financing: European Union LIFE Program 2019-2025 Target: Climate change Location: three main Basque cities, as well as in other urban and rural municipalities (Spain)	The strategy proposes actions aimed both at adaptation, making changes in the territory, towns, infrastructure, etc. in order to mitigate the consequences of climate change, and at climate change mitigation, proposing measures that will reduce greenhouse gas emissions	Urban Klima 2050 is the Basque Country's most significant climate action project for the next few years. This project operates in the three main Basque cities, as well as in other urban and rural municipalities (Spain) and it will have an impact on 7.234 km2 on 2.164.311 people	Analyse: Review of the KLIMA 2050 strategy and roadening the climate risk analysis in the Basque Country; Define: Establishment of guidelines for planning; Integration of climate change into territorial and urban planning; Integration of climate change into sectorial policies Act: Pilot projects at three levels of intervention: 1) Design and implement Nature-Based Solutions (NBS) at the municipal level and implementing seven pilot projects to improve resilience in the local area, and also pilot projects on different sources of renewable energy; 2) Implementing NBS in several rivers in all three territories to prevent future flooding 3) Implementing tools to prevent risks in coastal areas and a pilot project in Zarauts; Conducting a strategic analysis of the current condition of seaports in the Basque Country and their climate risk; Empower: Driver the commitment and empowerment of the population; Promoting the empowerment of the administration; Manage: Building structures for climate governance	One of the results was the inventory, cartography, classification and description of the NBS. The catalogue includes: 79 interventions in urban and suburban parks, streets, squares and streams, on a surface of 440 ha. Some of the most frequent actions are: tree-planting streets and squares, the application of sustainable gardening techniques, the creation of lamination ponds and avenue channels, the installation of orchards and urban forests, the conditioning of green itineraries. Potential map of NBS of Donostia/San Sebastian; Study of electric and bicycle-specific mobility - Nervión Linear Park and Zadorra Green Route; Analysis of the state of the art on empowerment and commitment of the population	https://urbanklima2050.eu/eu/ https://twitter.com/urbanklima2050/ https://www.youtube.com/channel/UCChNumkLxNIAPevv681uJ5Q

Project	Objectives	Description	Activities	Results	Websites
CANOPEE Financing: POCTEFA INTERREG 65% of FEDER co-financing 2016-2019 Target: Climate change Location: Pyrenean forests (France and Spain)	The main objective is to ensure, the long-term future of the current and future goods and services provided by the forest ecosystems in the Pyrenees	This project provided forest managers and owners and institutional officials with a series of indicators regarding the impacts of climate change on Pyrenean forest stands: monitoring of the phenology of the various forest species found in the Pyrenees, changes in defoliation and distribution	OBSERVE: understand the effects of climate change on Pyrenean forests and use this knowledge as a decision-making tool; DIAGNOSE: changes in the distribution of forest species found in the Pyrenees and diagnosis of the vulnerability of Pyrenean forests with respect to climate change; ACT: propose and implement appropriate measures to help vulnerable areas adapt to the effects of climate change.	Improve our understanding of the effects of climate change on Pyrenean forests as a decision-making tool; Develop tools for diagnosing the vulnerability of Pyrenean forests with respect to climate change; Put together a set of forestry adaptation measures to cope with climate change in the most vulnerable areas	https://www.opcc-ctp.org/en/canopee https://twitter.com/opcc_ctp
SUSTAINHUTS Financing: European Union LIFE Program 2016-2021 Target: Climate change Location: The 12 mountain huts linked to SustainHuts are located in Spain (6), Slovenia (3), France (1) and Italy (1)	This project aims to reduce CO_2 emissions in natural environments acting in huts by implementing novel and original renewable energy based solutions	Sustainable project improves the sustainability of mountain refuges, through the integration of renewable energies in 12 huts of 4 European countries	Preparatory actions; Purchase/lease of land; Implementation actions (no actions in SUSTAINHUTS); Monitoring of the impact of the project actions; Communication and dissemination of results; Project management	Expected results: To achieve a 20% improvement in energy efficiency, a reduction of carbon dioxide emissions of 10 tonnes per year and hut, as well as nitrogen oxides in 0.06 tonnes per year and hut. It is also expected to reduce in up to 15 per year the helicopter flights required to supply the fuel to the huts	http://sustainhuts.eu/

Project	Objectives	Description	Activities	Results	Websites
eFIRECOM Financing: Co-funded by ECHO - Humanitarian Aid and Civil Protection 2015-2016 Target: Wildfires Location: Interface areas from the Mediterranean region (Spain, France, Tunisia, Algeria)	eFIRECOM aims at enhancing the resilience of citizens to wildfires, through effectively promoting and increasing awareness and participation on the culture of risk with updated knowledge and best practices.	In the Mediterranean region, social vulnerability and the cost of civil protection actions are intensified by the increasing risk of forest fires affecting urban and peri-urban areas due to land use changes and climate change	Review on tools and best practices on wildfire risk communication; Specific development of communication programs and tools per each target audience and regional context; Knowledge capitalization and transfer tools	Development of a communication toolkit for the capacity building of citizens and communities towards wildfire risk prevention, adapted to three target audiences: i) Communities and municipalities, ii) Scholars, youths and their teachers, iii) Journalists and media professionals. Edition and dissemination of operational and strategic recommendations for the improvement of the communication on risk and reduction of social vulnerability to wildfires in Mediterranean areas, transferred to the relevant authorities	http://efirecom.ctfc.cat/?lang=em
PREFER Financing: European Community's Seventh Framework Programme ([FP7/2007e2013]) under G. A. nr. 312931. Target: Wildfires Location: Portugal, Spain, France, Italy and Greece	The main purpose is to set up a space-based service infrastructure and up-to-date cartographic products, based on remote sensing data, to support the preparedness, prevention, recovery and reconstruction phases of the wildfires in the European Mediterranean	Reports on the state of Europe's forests indicate that the broad Mediterranean area is systematically affected by uncontrolled forest fires whit a negative mid-to-long term prospect because of Climate Change. In this scenario, the need to improve the the intelligence support to wildfires prevention is widely relevant	The products developed were based on the exploitation of data from the Copernicus space infrastructure, and the integration of different data types from a variety of sources, such as earth observation, digital terrain models, socioeconomic data, meteorological data and in-situ data	A set of cartographic tools in Mediterranean Europe: Preparedness/prevention service phase: Fuel map, fuel reduction map, prescribed fire map, daily fire hazard map, seasonal fire hazard map, vulnerability map and economic value, seasonal risk map. Recovery/reconstruction service phase: Post-fire recovery vegetation map, damage severity map, 3D fire vegetation volume loss map, burned scar map	https://cordis.europa.eu/project/id/312931

Project	Objectives	Description	Activities	Results	Websites
LIFETEC Financing: European Commission within the LIFE programme. Target: Wildfires Location: Portugal and Spain	LIFETEC aims at improving forest fire fighting using Electronic and Communications Technologies to reduce the detection time of forest fires and to improve the efficiency of the fighting forces ensuring communications and geolocation	Early detection of forest fires and reliable and robust communication and geolocation systems between firefighting brigades and between those brigades and coordination centres are fundamental to ensuring rapid and efficient intervention that minimizes not only the damage caused by fires but also the cost of extinguishing them	Real-time monitoring of atmospheric refractivity was carried out by using measurements provided by the meteorological radars in Cuntis, in Galicia, operated by Meteogalicia, and in Arouca, in Portugal, operated by the IPMA. Several prototypes have been developed of the TETRA-based communications and location system. Other communications systems are not needed (telephone networks, Wi-Fi, etc.). The firefighters of the brigade in the Deza and Tabeirós districts of Terra de Montes have tested the prototype of the geolocation system that has been developed	A method for the early detection of forest fires by weather radars A management system based on TETRA and Android for the real time geolocation of firefighting resources	https://lifetec.uvigo.es/en/layman-report/

Project	Objectives	Description	Activities	Results	Websites
OPEN2PRESERVE Financing: Project financed 75% by the European Regional Development Fund Target: Wildfires Location: Portugal, Spain and France	The main objective of the OPEN2PRESERVE project is to connect current interdisciplinary scientific knowledge with technology and practical operation, in order to implement and assess combined techniques that guarantee the preservation of the ecosystem services linked to open spaces with high natural value	The project proposes starting eight regional pilot experiences based on the combination of guided herbivory and initial techniques to reduce fuel through controlled burns. All the experiences seek to offer innovative solutions that guarantee the economic feasibility of the commitment and can serve as an example and training for the execution of similar initiatives at local and regional level	Samplings for the calibration of surface vegetation (phytovolume) Drone flights to measure the phytovolume of the shrub mass before controlled burning Phytovolume sampling in the field Detailed monitoring of soil and vegetation and control of the state of growth and welfare of grazing animals during the experience Equine in directed grazing monitored by GPS	The traditional management of domestic herbivores in western Pyrenees, characterized by a mixed grazing of sheep, cattle and horses, with limited animal guidance and stocking rates ranging from 1 to 3 LU·ha−1· 6 months−1, is adequate to preserve the high diversity and ecological value of grasslands, preventing the cascade of divergent degradative processes that occur in the total absence of herbivory	https://open2preserve.eu/en/presentacion/

Project	Objectives	Description	Activities	Results	Websites
MIXFORCHANGE Financing: LIFE Programm Target: Climate change Location: Spain	The main aim of the Project is to contribute to the adaptation to climate change of European Subhumid Mediterranean mixed forests by increasing their resilience, ensuring their conservation and enhancing their productive, environmental and social functions	The silviculture method developed during the project has been applied on 164 ha of mixed sub-humid Mediterranean forests: holm oak forests, chestnut forests, oak forests and pine forests, in four geographical areas in Catalonia (northeast Spain)	A total of 27 Actions will be implemented, from Preparatory to Management and project progress monitoring activities. Implementation of innovative management schemes in forests dominated by Quercus ilex subsp. ilex, Castanea sativa, oaks (Quercus petraea, Q. pubescens, Q. canariensis) and Pinus sp, in a total of 164 ha. Developing new tools to improve the economics of Subhumid Mediterranean forest management. Tools to integrate the adaptation of Sub-humid Mediterranean forests to climate change into the policy and legal framework. Vulnerability models, technical and policy guidelines, review, and adaptation of legal framework. Evaluation of the ecological and silvicultural effects of the innovative forest models, and of the socioeconomic impact of the project	Training and capacity building actions Ecological, dasometric and socioeconomic assessment methodology Climate change vulnerability maps A series of actions aimed at promoting the adoption of the silvicultural principles developed in the project in new areas and forests: Technical manual - Adaptive and close-tonature management in mixed sub-humid Mediterranean forests (2022) Protocol for the ecological assessment of the demonstrative silvicultural interventions Protocol for the silvicultural assessment of forest interventions Protocol for standing timber quality assessment of valuable broadleaf species (2020)	http://www.mixforchange.eu/en/about-the-project/actions/

Project	Objectives	Description	Activities	Results	Websites
RISK-AQUASOIL Financing: Co-financed by the European Regional Development Fund Target: Multi-hazard Location: Portugal, Spain, France, Ireland, The United Kingdom	The RiskAquaSoil project aims to develop a comprehensive management plan for risks in soil and in water to improve the resilience of the Atlantic rural areas. Through transnational cooperation, the Project partners will fight the adverse effects of climate change, especially on agricultural lands	The Atlantic Area presents high exposure to climate change. Increased intensity and frequency of storms, altered hydrological cycle and changes in temperature and precipitation patterns have implications for the agriculture sector. However, there are still huge uncertainties in the way climate change will directly and indirectly affect agricultural and food systems. The project will contribute to a better coordination for the detection, risk management and rehabilitation for rural territories, associated to risks of natural, climate and human origin. It will also ensure articulation with policies	A study of Iberian media coverage on climate change: This study was conducted through four main steps regarding its design: 1) definition of a research equation, 2) definition of a time frame, 3) selection of most relevant news, and 4) quantitative content analysis Analyse in depth 1609 news published between 2017 and 2018 in five European countries Monitoring program: implemented in catchments with sizes between 20 km2 and 160 km2 in areas 60%–99% burnt. For each catchment a gauging point was selected near the mouth of the river. These 5 gauging points were assessed monthly, starting one month after the fire, in November 2017, and ending in June 2018. In each campaign stream water was sampled for laboratory analysis and in-situ physical-chemical proprieties were measured	A national framing – especially focused on the severe drought experienced in both countries and its subsequent impacts on agriculture – a non-democratic debate and a non-proactive discourse characterized the Iberian news. 2017 rural fires in Portugal caused a burnt area, greater than 400 ha, affected the characteristics of surface waters and noticeable water changes in turbidity, aluminium, iron and manganese were accessed. The European media tends to report climate change by using distant (e.g., future-focused) and outcome (e.g., threatening messages) framings, based on non-resilient, scientific, and political narratives, whilst overlooking the role of civil society on adapting to climate change	https://www.riskaquasoil.eu/pt/

Project	Objectives	Description	Activities	Results	Websites
MIDMACC Financing: LIFE Program Target: Climate change Location: Spain	Promotes adaptation through the implementation and testing of different landscape management measures to meet climate change related challenges in marginal mid-mountain areas of Spain (La Rioja, Aragón and Catalonia), while improving their socioeconomic development	The project is developed in La Rioja, Aragon and Catalonia, covering diverse bioclimatic conditions from the subhumid Mediterranean of the Pyrenees to the submediterranean mid-mountains of the Iberian Mountain Range. Adaptation measures are implemented in pilot areas of the three regions with diversity of environmental and socioeconomic characteristics that facilitate transfer capacity of results to other mountainous regions from southern Europe	Risk prevention in Requesens, Catalonia: The scrubland has been cleared, the trunks and branches have been extracted and the logging residues have been removed. Subsequently, a mixture pasture seeds has been randomly sowed to recover pastures under the forest area and an old pasture field (about 3 hectares) has been recovered Risk prevention in La Garcipollera, Aragón: different assays will be carried out over 4 years: (i) different cows number will be introduced in the different plots; (ii) soil measurements will be taken before and after extensive livestock activity; (iii) vegetation samplings will be carried out also before and after extensive livestock activity; (iv) seasonal rainfall simulations; and (v) temperature and humidity and soil moisture will be continuously measured in the different plots. Adaptation measures in the vineyard, Catalonia: use of different agronomic practices such as green soil coverage, slope management (terraces) or training systems, while maintaining a high level of competitiveness and quality. In Catalonia, this pilot experience is carried out in three vineyards belonging to Celler Espelt (Roses, Alt Empordà), Celler cooperatiu d'Espolla (Espolla, Alt Empordà) and Llivins (Llívia, Cerdanya)	Forest management for fire risk prevention in Requesens, Catalonia and La Garcipollera, Aragón Scrubland clearing in Aragon and La Rioja Vineyard assays in La Rioja and Catalonia	https://life-midmacc.eu/

Project	Objectives	Description	Activities	Results	Websites
POLYFARMING Financing: A project co-financed by the LIFE Program of the European Commission Target: Climate change Location: Spain	The objective of the project is to demonstrate the interest of a new plurifunctional agro-silva-pastoral integrated management system as an alternative of profitable management to fight against the problem of the abandonment of agriculture in Mediterranean mountain areas and the environmental (soil degradation, vulnerability to climate change, loss of biodiversity) and socio-economic consequences (loss of productive capacity of the territory) that this abandonment is producing	The project is concreted in the start-up of a pilot farm, an 80-hectare farm located in the region of La Garrotxa, 40 km north of Girona (Catalonia, Spain). Currently, thanks to the co-financing of the LIFE program of the European Commission, the Polyfarming system, which combines the resources of the forest, livestock and crops to recover fertile soil, is implemented in Planeses to restore the farm activity.	Intensive controlled grazing: the meadow is divided into plots of a similar size and the animals are moved every day from the plot they are in to another one that is at the optimum grazing point. Agrosilviculture: combining fruit trees and orchards with pastures and animals. Cultivated plants are accompanied by weeds that, when cut, are left in the soil to decompose and thus improve soil fertility. Training actions for producers: Free manual, informative videos and replication sessions Dissemination and communication: Social media, news, and events organized by Polyfarming	After three years of applying the regenerative model in the Planeses orchard, the results indicate that the farm orchard is able to sequester up to 30 times more CO_2 per year than the conventional model: and grazing also increases CO_2 capture threefold compared with natural pastures. In three years, the organic matter in the soil of the orchard multiplied by two and and the capacity to retain water increased by up to 20%. The Polyfarming project pilot farm, Planeses, was an abandoned farm before implementing the regenerative model. Today it is a project that eight people work on and has recovered the farm's agricultural and livestock activity. Polyfarming project offers a free manual and downloadable sheets so that any producer can apply the different techniques proposed. Polyfarming has also produced informative videos of the Polyfarming system and the techniques it applies Training courses: The organisation of these training courses is carried out by the two partners of the project, CREAF and PLANESES	https://polyfarming.eu/visita-virtual/?lang=em

ANNEX III – GOOD PRACTICES IN DISASTER RISK MANAGEMENT IN THE SUDOE REGION

DRM activities	Types of natural hazards				
	Wildfires	**Flooding**	**Landslides**	**Mass movement**	**Rockfall**
Mitigation	Prescribed burning Livestock grazing Guided grazing Wildfires prevention plans Improvement of priority forest fire prevention infrastructures Forestry Management Plan Communication toolkit for the capacity building of citizens and communities towards wildfire risk prevention Controlled burns Guided herbivory (equine and ovine livestock)	Plans for prevention and emergency management Flood risk index	Analysis of the topographical characteristics Construction of a sediment retention basin Identification of the frequency and intensity of historical landslides observed Afforestation and experimental vegetation	Periodic collection of runoff material	Guidelines (sustainably valorise rockfall protection forest ecosystems services)
Preparedness	Wildfire risk map Training of operators and technicians on the use of fire in prevention and suppression Database of the history of wildfires Early detection of forest fires through meteorological radars Mapping different wildfire products in Mediterranean Europe	Watershed monitoring Training and commitment of local communities and farmers Early warning systems	Terracing techniques, with the establishment of vegetation, together with a drainage system	Mass movement risk index Inventory and analysis of the existing tools for risk management	Rockfall risk map Large-Scale Rockfall Modelling
Response	Management system for real-time geolocation of resources available for firefighting.			Inventory of terraces	
Recovery	Forestry Management Plan				

ANNEX IV – PRACTICES TO FIGHT CLIMATE CHANGE

Strategy	Some benefits	Reference
Diversify plant production by alternating agricultural crops with forest crops	Resilience into agricultural systems: Greater ability to suppress pest outbreaks and to buffer crop production from the extreme events	Lin, B. B. (2011). Resilience in agriculture through crop diversification: adaptive management for environmental change. BioScience, 61(3), 183-193.
	To fight against soil degradation and desertification; to reduce greenhouse gas emissions	Martin-Gorriz, B., Maestre-Valero, J. F., Almagro, M., Boix-Fayos, C., & Martínez-Mena, M. (2020). Carbon emissions and economic assessment of farm operations under different tillage practices in organic rainfed almond orchards in semiarid Mediterranean conditions. Scientia Horticulturae, 261, 108978.
	Crop diversification is a cost-effective method to build resilience into farming systems for environment change	Alcon, F., Marín-Miñano, C., Zabala, J. A., de-Miguel, M. D., & Martínez-Paz, J. M. (2020). Valuing diversification benefits through intercropping in Mediterranean agroecosystems: A choice experiment approach. Ecological Economics, 171, 106593.
Improve soil fertility through green manuring, mycorrhization	To reduce losses of soil organic matter, compaction and lower soil erosion rates	Almagro, M., de Vente, J., Boix-Fayós, C., García-Franco, N., Melgares de Aguilar, J., González, D., ... & Martínez-Mena, M. (2016). Sustainable land management practices as providers of several ecosystem services under rainfed Mediterranean agroecosystems. *Mitigation and adaptation strategies for global change*, *21*(7), 1029-1043.
Marketing for products coming from the pilot areas	Producers have the opportunity to sell their own products in local markets. In Spain, an economic analysis showed that organic farming was 36% more profitable when selling products in conventional markets	Pardo, G., Perea, F., Martínez, Y., & Urbanoa, J. M. (2014). Economic profitability analysis of rainfed organic farming in SW Spain. Outlook on Agriculture, 43(2), 115-122.
Product certification to international standards	Due to the absence of mineral fertilizers, the carbon footprint of vegetal organic products is 16% lower compared to conventional plant products, therefore, in the European Union, the promotion of certified food products is consistent with climate change mitigation	Bellassen, V., Drut, M., Antonioli, F., Brečić, R., Donati, M., Ferrer-Pérez, H., ... & Diallo, A. (2021). The carbon and land footprint of certified food products. Journal of Agricultural & Food Industrial Organization, 19(2), 113-126.

Strategy	Some benefits	Reference
Modelling, quantification and monitoring of the transformative impacts caused by agricultural practices	According to a study developed in Spain, the monitoring of soil organic carbon (SOC) makes it possible to assess adaptation to climate change, as the SOC can be used as an indicator to assess regional adaptation practices	Antón, R., Arricibita, F. J., Ruiz-Sagaseta, A., Enrique, A., de Soto, I., Orcaray, L., ... & Virto, I. (2021). Soil organic carbon monitoring to assess agricultural climate change adaptation practices in Navarre, Spain. Regional Environmental Change, 21(3), 1-15.
Guidelines for local climate planning in the Pyrenees	Identification of good practices related to the inclusion of climate change at the local level and recommendations that they help and facilitate the integration of climate change in the development and application of both regional and local policies in the Pyrenees	https://www.opcc-ctp.org/sites/default/files/documentacion/opcc-a_prueba_de_clima-es_2.pdf
Strengthening of technical skills and training in climate change	Educational activities, writing and art to teach about climate change for all ages to raise awareness of the effects of climate change Actions to encourage communities to take responsibility for climate change	https://urbanklima2050.eu/en/urban-klima-2050-educates-the-population-about-climate-change-with-educational-activities-for-all-ages/new/75/
System for monitoring the impacts of climate change	Consolidate existing and future knowledge regarding climate change and disseminate climate change information in different formats	https://urbanklima2050.eu/en/climate-change-hub-observation-and-monitoring-system/action/26/
Design of a complete hydrogen cycle production based on renewable energy (production by electrolysis of water, pressurized storage, and power production by fuel cell).	Improve energy efficiency, reduce CO_2 emissions per year as well as NOx	http://sustainhuts.eu/project/
Protocols for tree quality classification	This protocol is a tool to quickly assess the potential of a tree at different vital stages to generate quality timber	http://www.mixforchange.eu/docs/2022_06_Layman%20report%20MixForChange-EN.pdf
Implement Nature-Based Solutions in rivers and at the municipal level	Increase biodiversity and ecological connectivity, optimise water management, improve soil fertility, increase permeable surface, improve ecosystems services and bring nature closer to citizens	https://www.vitoria-gasteiz.org/docs/wb021/contenidosEstaticos/adjuntos/es/28/11/92811.pdf
The use of cows, chickens and rabbits with controlled daily movement	The animals have a very healthy diet while improving soil biodiversity and fertility with their excrements	https://polyfarming.eu/resources/livestock-resources/?lang=en

Strategy	Some benefits	Reference
Experiences in organic agriculture with waste from local compost	Using olive mill waste compost with sprinkle irritation as sustainable alternative for rice crops under Mediterranean conditions, improving the soil's properties, increasing the water efficiency and reducing weed pressure	Peña, D., Fernández, D., Albarrán, A., Gómez, S., Martín, C., Sánchez-Terrón, J., ... & López-Piñeiro, A. (2022). Using olive mill waste compost with sprinkler irrigation as a strategy to achieve sustainable rice cropping under Mediterranean conditions. *Agronomy for Sustainable Development*, *42*(3), 1-17.
	Use of agro-waste is a source of nutrients and an alternative to reduce the use of external input in intensive horticulture system	Carricondo-Martínez, I., Falcone, D., Berti, F., Orsini, F., & Salas-Sanjuan, M. D. C. (2022). Use of Agro-Waste as a Source of Crop Nutrients in Intensive Horticulture System. Agronomy, 12(2), 447.
Forest management for fire risk prevention	One of the strategic forest managements is the use of goats, aimed at firebreak areas, to promote grazing in the forest and control fuel biomass, which can contribute to reducing the risk of fires and, consequently, to mitigating climate change.	Pareja, J., Baraza, E., Ibáñez, M., Domenech, O., & Bartolomé, J. (2020). The role of feral goats in maintaining firebreaks by using attractants. *Sustainability*, *12*(17), 7144.
Introduction and/or optimisation of vineyards in mountain areas	The combination of minimum tillage with plant strips in vineyard showed to be more valuable strategy in soil control than unique minimum tillage, averaging a reduction of soil erosion and runoff of 36 and 39%, respectively	Cárceles Rodríguez, B., Zuazo, V. H., Rodríguez, M. S., Ruiz, B. G., & García-Tejero, I. F. (2021). Soil Erosion and the Efficiency of the Conservation Measures in Mediterranean Hillslope Farming (SE Spain). *Eurasian Soil Science*, *54*(5), 792-806.
Pasture recovery through scrubland clearing and introduction of extensive livestock farming	Clearing is an appropriate way for spatial reorganization in marginal mountain areas and it does not require excessive investment. Furthermore, following clearing, the landscape increases in heterogeneity	Lasanta, T., Nadal-Romero, E., Errea, P., & Arnáez, J. (2016). The effect of landscape conservation measures in changing landscape patterns: a case study in Mediterranean mountains. *Land Degradation & Development*, *27*(2), 373-386.
Agricultural practices: self-management of mountain orchards, biofertilizer, microorganisms, biochar, FRW technique, crops on a bed of trunks	Biochar and crops on a bed of trunks, offer the possibility of multiplying by 2 the amounts of soil organic matter and promote a carbon sequestration. In addition, the applied techniques improve the capacity of retention of rainwater in the soil	https://polyfarming.eu/objective-and-actions/?lang=em

Strategy	Some benefits	Reference
Monitoring and adaptation of forests to climate change	A wildfire monitoring system is an emergency management tool for helping the authorities reduce human and economic losses due to wildfires disasters	Bielski, C., O'Brien, V., Whitmore, C., Ylinen, K., Juga, I., Nurmi, P., ... & Rossi, C. (2017, December). Coupling early warning services, crowdsourcing, and modelling for improved decision support and wildfire emergency management. In *2017 IEEE International Conference on Big Data (Big Data)* (pp. 3705-3712). IEEE.
Promoting of mountain agriculture by means of vineyards	Monitoring network monitoring variables: physical and chemical soil properties and soil moisture, soil microbial biodiversity; vineyard production and quality; rainfall and weather simulations to analyse the effects of adaptive vineyard establishment and agronomic practices in vineyards in La Rioja and Catalonia.	https://life-midmacc.eu/2020/12/23/deliverable-10-monitoring-protocol-of-action-c3-promotion-of-mountain-agriculture-by-means-of-vineyards/
Adapt-mounted Platform	The farmer obtains a support sheet and video describing the way of implementation, the reason for its application, the contribution of the measure to adaptation to climate change or an assessment of its cost for each adaptation measure to be applied	https://sigm.lifemontadoadapt.com/

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