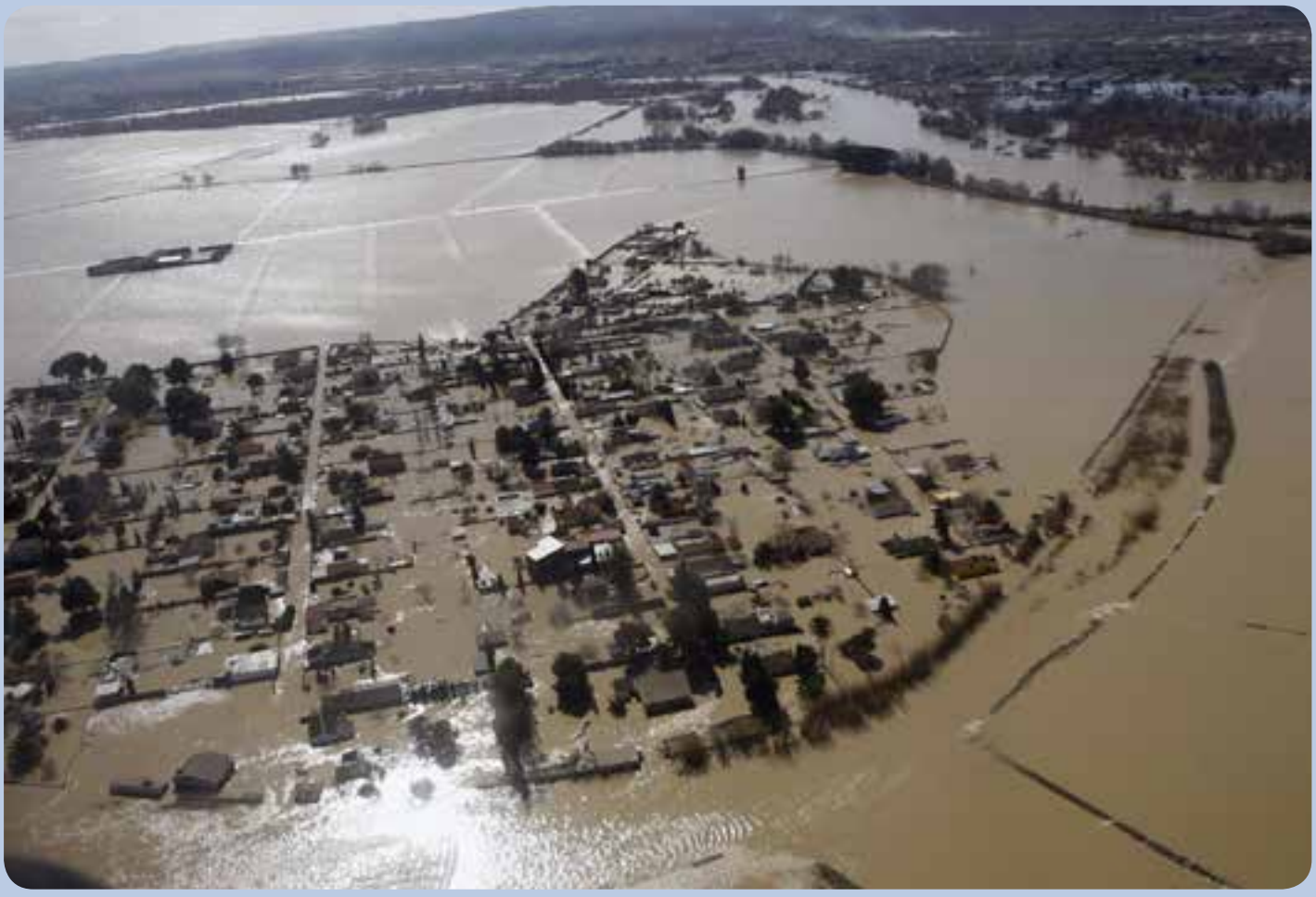
# The Effects of Climate Change on the Risk of Floods in Spain



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# Introduction

Floods in general are events associated with more intense rainfall than average that produce the inundation of areas generally free of surface water, such as urban and industrial areas and agricultural fields. The risk of flooding emerges from the combination of two factors: on the one hand, the occurrence of more intense rainfall (danger) and, on the other, the existence of goods and people that may potentially become affected by being in flood areas, temporary riverbeds and other hazardous areas (vulnerability). Clearly, facing the same risk of flooding (the same intense rainfall), the final risk will be very different depending on the degree of vulnerability, that is, the population and goods exposed, which depends on the type of use of that space and the existing territorial ordination model.

Floods are the most common type of natural disaster in Europe. During the 1998-2002 period, according to the European Environmental Agency, floods represented 43% of all the catastrophes taking place in Europe. Floods have an important economic and social impact and, most importantly, involve the loss of human lives.

Floods and droughts represent the most important natural hazards in Spain, given their socioeconomic relevance and their frequency, beyond other dangers such as strong winds, hail storms, avalanches or seismic events. The three main areas of flooding risk in Spain are the Basque Country, the Canary Islands and above all, the Mediterranean coast, which has 75% of the maximum daily rainfall events in Spain.

The most dangerous flood events are sudden rises in minor river beds, due to the loss in human lives they bring about. These sudden rises, caused by torrential rainfalls, are particular frequent on the Mediterranean Coast and the Canary Islands.

Floods represent extreme events linked to unusually intense rainfalls, extreme events that, according to the available forecasts, will be significantly altered by climate change. What are the trends of change we expect to see in Spain due to climate change? Are the necessary measures to adapt to the new situation being implemented?

In the following sections we are going to synthetically analyse what the climate change models and scenarios say about the case of Spain with regard to these extreme events. We are going to review the recent trends in flooding patterns, the response by governments and public administrations, and the proposals by Ecologists in Action to adopt more ambitious public policies to adapt to climate change and its related flooding risks.

# The expected impact of climate change on floods in Spain

The IPCC reports indicate an increase in the intensity and frequency of extreme events and, specifically, floods. Different authors point to a foreseeable increase in extreme events across Europe stemming from the global change. It is estimated that the contribution of climate change to the economic cost produced by natural disasters will substantially increase in the future, due the greater intensity and frequency of extreme events in many regions.

In the case of floods, it is complicated to make forecasts for several reasons. On the one hand, they are events that take place in short periods of time with low frequency, about which climate models generate uncertain results. On the other hand, floods are influenced by non-climatic factors such as demographic factors, changes in use, and transformation of the fluvial plains. Consequently, there is not a strong consensus about whether the occurrence and magnitude of these flood events have increased due to climate change, a question that is still subject to great uncertainty.

Nevertheless, the fifth IPCC report indicates not only a decrease in rainfall, but also an increase in its irregularity in the coming decades in the intermediate latitudes, where Spain is located. Despi-

te the fact that all these quantitative projections regarding the frequency and intensity of flood events are questionable, it is estimated that the number of days with a large amount of rainfall could increase, given that the global change may intensify the water cycle, increasing the frequency of floods in many areas in Europe. These floods, especially the sudden unleashing of intense rainfalls (flash-floods), will probably be more frequent all over Europe, especially in the South of the continent, where these flash-floods could increase by 70% by the end of the century.

In the case of the Iberian Peninsula, there is no consensus about the expected changes in extreme rainfall that can be expected for the distant time scenario of 2070-2100. However, maximum rainfall in 24h, which can cause rising rivers and floods, could increase by 5% on the entire Peninsula by 2050.

Moreover, the possible synergy between different effects produced by climate change could exacerbate the risk of floods. This is the case of forest fires. The models not only predict an increase in temperatures in the summer, but also a reduction in spring rain. All this points to more severe atmospheric conditions, which would translate into a greater number of fires, more intense fires, and a larger area burned. For example, in the Llobregat basin (Catalonia), an increase in forest fire frequency is expected, which would destroy the vegetation and alter the soil properties, producing an increase in run-off of 30%, which could increase flood events during intense rainfall.

In addition, an increase in the risk of coastal flooding is expected. For example, the available research indicates that the risk of flooding on the coast of Bilbao in the 2050-2100 period could triple the current expected sea level extremes.

Finally, the scenarios of changes in the use of soil also indicate that, in the future, the tendency toward an increase in soil sealing will continue, an increase stemming from the accelerated urbanization process. The increase in housing areas, in the absence of a careful territorial ordination, will continue to present a growing occupation of flood zones, increasing the number of goods and people that could be affected during a flood episode.

To sum up, the risk of floods will continue to increase in the future due to a dual effect of climate change: on the one hand, climate change will foreseeably increase the frequency of intense rain and flash-flood events (increase in the risk of flood); on the other hand, the change in the use of soil, the other component of the global change, will increase the exposure of goods and people to floods (increase in vulnerability).

# Recent flood trends in Spain

The observation of rainfall in the Mediterranean region does not allow us to reliably ascertain whether the number of days with intense rain has increased, due the reduced number of days when these types of rainfall take place. However, the impact and damage produced by floods has increased significantly. The risk of flooding is greater at the beginning of the 21st century than it was twenty years ago. This increase in the flood risk is not as related to the increase in torrential rainfall events, about which there is no clear evidence, as it is to the increase in vulnerability, or exposure to risk, even though the climate change models also predict an increase of the former in the future.

Why has the vulnerability to floods increased in recent decades? Damage due to floods is increasing, mainly due to poor land management, through three fundamental mechanisms:

i) The increase in water resistant surfaces due to urban developments, so that water flow increases. As a result, with the same rainfall, the frequency and severity of the flood events increases.

ii) Secondly, the floodable areas are increasingly occupied by buildings and other infrastructures. Facing similar floods, the exposure to risk (vulnerability) is greater, and therefore the damage to goods and people also becomes greater.

iii) Finally, infrastructures like roads and artificial slopes interrupt and disorganize natural drain networks, and so the water is forced to alter its flow, thus affecting previously flood-free spaces.

As a result, in the whole of the Spanish territory, and especially in the Basque Country, Canary Islands and the Mediterranean coast, the risk of floods is greater at the beginning of the 21th century than it was twenty years ago.

In recent decades numerous flooding events have taken place, such as those affecting the Mediterranean coast (1982, 1985, 1986, 1987, 1989, 2000 2005 and 2007), the Basque Country (1983) and the Southern and Central Peninsula (1995 and 1996). Some especially catastrophic floods in terms of the loss of human lives took place in the Arás Canyon in Biescas (Huesca), due to a deluge that caused 86 deaths in 1996, and the floods in Alicante and Cerro de Reyes (Badajoz) in 1997, causing 37 deaths. In the same way, other important flooding events should be mentioned, such as those in Tenerife in 2002, Catalonia in 2005, and the Mediterranean coast and Andalusia in 2007.

The catastrophic floods in Biescas and Badajoz perfectly illustrate why the damages caused by floods are increasing. In the case of Biescas, the tragedy occurred because the public administration allowed a campsite to be built in the debris cone of the Arás Canyon in the Pyrenees. This misguided licence was based on the false security offered by the channelling of the canyon and the numerous contention dams build in its basin. In fact, these more than 30 contention dams made the damage significantly worst because the flash-flood swept them away, along with the materials held in them. In the case of the flood in Cerro de Reyes in Badajoz, the agrarian transformations disorganized the draining networks, hillocks, and channelling of the Rivillas river, reducing the volume of drainage space for the river; most importantly, the flood areas were occupied by homes, factories and infrastructures. In addition, some obstacles to the water flows were created, such as bridges that were not adapted to the flash-flood water level.

Faced with these risks derived from climate change, which are going to worsen in the future due to climate change and the changes in land use, are the necessary measures being adopted in Spain?

# The Administration's response

The Spanish administration has not implemented true strategies to adapt to the increase in the risk of floods. Applying these strategies requires accepting that floods are a natural risk that cannot be eliminated (they will continue to take place with greater frequency and intensity due to climate change). Therefore, we need to modify our life styles and production styles in order to adapt to the occurrence of these extreme events.

Despite what we might think, the conception of floods as a natural phenomenon to which we must adapt, rather than as an anomaly to be overcome, is not recent. It was held by many traditional societies and production systems. Riverside populations have historically adapted to the risk of floods by reducing vulnerability, that is, exposure to them. In fact, the historical centres of villages are the areas that experience the least flooding because most of the inhabited spaces tended to be located in higher areas or outside the rivers' flooding plain, mouths of streams, and canyons and other high risk areas.

However, once more, as in the case of droughts in the 20th century, the public administration implemented a new strategy, leaving behind this historic adaptation strategy and moving toward a new conception that it is possible to avoid floods through hydraulic works such as dams, channellings, hillocks, contention dikes and dredging. A clear example is the Plan for the Prevention of Flash-Floods in the Segura Basin (1977), focused on the construction of channels and lamination dams. We can also mention urban channellings and diversions, as in the Plan in the South of Valencia.

These hydraulic works have distorted the public's perception of risk and given rise to a false sense of security that has favoured the occupation of floo-

dable areas, increasing the exposure to risk and the vulnerability of the population and their possessions. Moreover, waterway channelling produces complex and negative flood consequences downstream because it allows more energy and speed in the flash-flood waters, increasing their erosion power and destruction capacity. As a result, these hydraulic works not only have not managed to stop floods, but paradoxically, in many cases they have increased their risk, which shows the failure of this strategy.

To the occupation of floodable areas, we can add other effects of bad land ordination: on the one hand, more water resistant soil increases surface runoff and damage due to floods, especially in urban spaces, and on the other hand, the construction of new infrastructures (roads, slopes) cut into and disorganise the draining networks, worsening the damage caused by intense rainfall.

In addition to being counterproductive because of generating a false sense of security that ends up increasing risk, hydraulic works are not very useful against floods. The available studies show a continuous increase in economic damage due to floods, despite the increase in structural measures (dams, dikes, breakwaters). The water reservoirs have a very limited capacity to layer the great floods due to the incompatibility of this layering function and other uses of these infrastructures, such as hydroelectricity, water supply or agriculture. Spain, in spite of having the highest number of dams per person in the world and the largest amount of infrastructures, experiences increasing damage due to floods.

The construction of contention dikes or hillocks placed too close to the riverbed is equally inefficient, and if they break during a flash-flood there can be a real threat to people's lives. Finally, dredging does not solve any problems because sediments settle and take the place of the materials removed in a very short time. On the other hand, these hard flood interventions have a serious environmental impact because they break the morphodynamic balance of the river, eliminating sediments, degrading the natural vegetation, and destroying habitats.

Despite everything we have mentioned, after a catastrophic flood, the public administration, instead of communicating rigorous and contrasted information about the cause of the floods to the population, and about the measures that have to guide risk management, tends to promise (as occurred with the flood in the Ebro river in February and March 2015) more investments in dredging and other hydraulic works.

The European Flood Directive, passed in 2007, establishes that floods cannot be avoided, but their effects can be minimised. Confronting the inefficiency of the classic hydraulic works, this directive advocates for the territorial ordination of flood areas, and for the re-naturalization of the flood plains for the layering of flash-floods. Complying with this directive, risk management plans have been designed in each hydrographic zone, and they must be definitely approved in December 2015. These plans include some efficient measures, but in general we still lack clear support for measures involving territorial organization. At the same time, we detect incoherencies in the measures included in the hydrological plans, and, on many occasions, hard interventions based on hydraulic works with great environmental impact and dubious efficacy continue.

# Ecologists in Action proposals for better adaptation to and preparation for floods

Faced with the misguided policies applied up to now, adapting to and preparing for floods in the Climate Change perspectives requires the application of several principles:

- **Adaptive management**: it is not possible to avoid floods, but we can adapt to them, in order to prevent and minimise their adverse effects.

- **Principle of precaution**: It is necessary: i) to assume sensible scenarios of Climate Change (in contrast to the temptation of optimistic sce-

narios) and ii) incorporate uncertainty into planning and decision-making, so that the greater the uncertainty is, as in the case of future episodes of intense rainfall, the further the risk thresholds must be pushed in decision making. This means that floodable ground must be defined using criteria that emphasize uncertainty as well as safety (lower risk of exposure to floods).

Adequate flood risk management cannot be based on the failed strategy of hydraulic works that produce a false sense of safety; instead, it must include the general application of the precaution principle, especially given the uncertainty about the frequency of future events and to recover the adaptation to these natural phenomena through good territorial organization. Furthermore, the risk is particularly high for sudden flash-floods that take place in small river basins with a large flow concentrated in a short period of time (hours), leaving no margin for a response. This makes it even more necessary to have a strategy to avoid risk though territorial ordination, leaving all areas susceptible to receiving fast-floods free of constructions and installations, the most rational, sensible and sustainable risk reduction measure in the medium and long term.

At the same time, river overflows are essential for the geomorphological dynamics and ecological health of rivers, given that they provide naturally important services to society, such as maintaining the natural fertilization of agricultural lands, contributing to biodiversity, eliminating invasive species, bringing sand to beaches and sediments and nutrients to river deltas, and creating fertilization sources for coastal fishing areas. Therefore, we do not need to avoid floods, but rather minimise their negative effects by giving space back to the rivers.

Alongside the territorial organization, the management of the river area constitutes another great measure for efficient and sustainable management of the flood risk. The river area, formed by the river itself and adjacent floodable spaces of enough width, would act as an expansion zone for the overflows through processes of damming and infiltration, dissipating the energy of flash-floods and, therefore, their erosion capacity. There is no better insurance for the riverside population than substituting a phenomenon, the flash-flood, with another one with less negative effects, overflow, in areas where it creates less damage and gives maximum benefits. Moreover, the river area makes it possible to conserve and recover the hydrogeomorphic dynamic, obtaining a continuous riverside corridor that guarantees ecological diversity, complies with a good ecological state, favours the filtering of contaminants through the restoration of groves as "green filters", and improves and consolidates the riverbed landscape.

Adequately managing the river area requires, among other interventions:

i) Recovering streams and riverside woods that contribute to dissipating the energy of the floods.

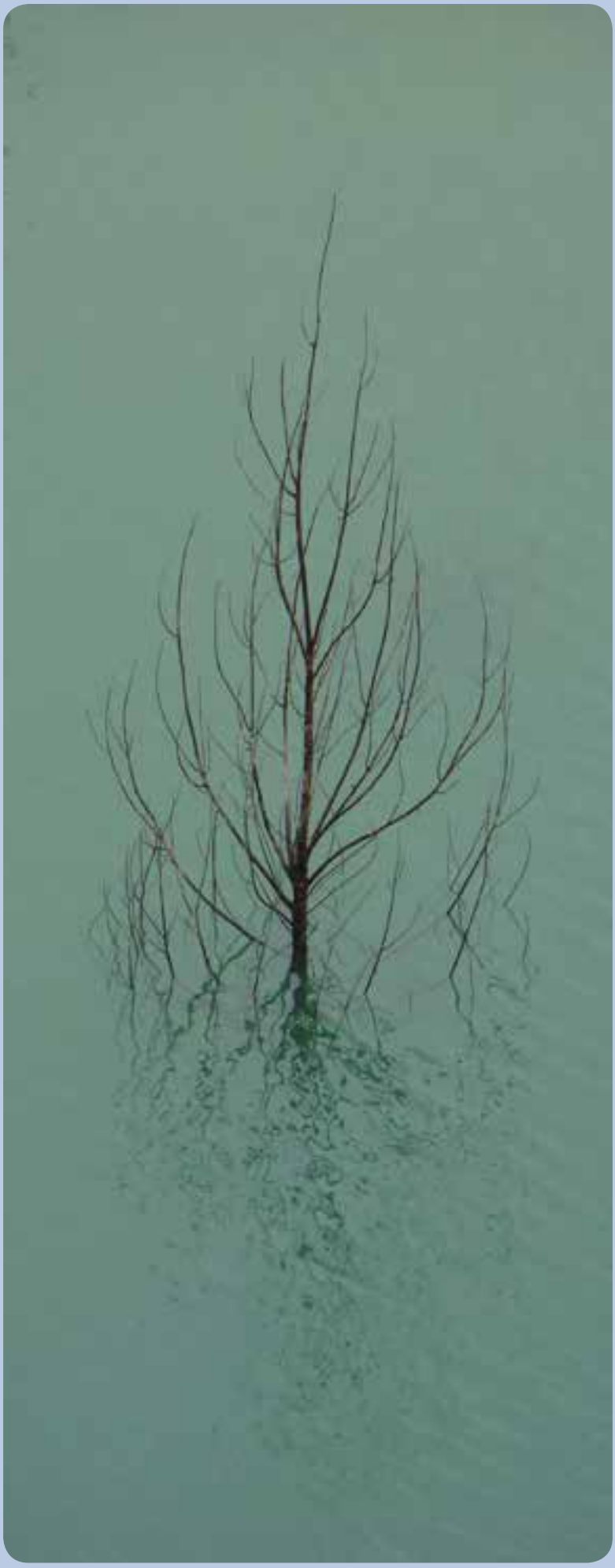
ii) Removing and setting back dikes and hillocks to expand the flood smoothly and later allow emptying when the river level comes down, reducing the destructive capacity of the flash-flood waters downstream.

iii) Adapting to using floods. This implies i) revising the municipal urban organization plans and other instruments of territorial organization, impeding transformation to uses incompatible with floods; ii) In the flood plains, favour the persistence of natural and agricultural uses compatible with floods. The traditional agricultural uses of these plains favour the laminating function, and so they must be supported by measures such as eco-conditioned subsidies, effective agricultural insurance, "proximity" marks and quality or other formulas.

iv) Apply compensations and insurance systems to farmers who see their harvests affected.

Finally, an integral strategy in dealing with these floods must include education in uncertainty and in the culture of risk. It is fundamental to count on the riverside inhabitants developing educational programs, social communication and recruitment to allow the modification of the public perception of rivers and the role of floods, with the certainty that only a well-informed society will support the adequate management of river areas.

With the adoption of these measures, we could substantially reduce the effects of floods and flash-floods, which, as a result of Climate Change, are occurring and will occur with greater frequency in our country.



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