Policy Briefings

BASQUE CENTRE FOR CLIMATE CHANGE
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FLOOD RISK MANAGEMENT: WHAT ARE THE MAIN DRIVERS OF PREVENTION?

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Key Points

- *In a changing and unstable climate, climatic flood risk will increase: more intense and more extreme events would be more frequent. Higher climatic risk will turn into higher socio-economic risk, unless we implement appropriate adaption measures to prevent the risk.*
- *Spatial hydro-economic approaches are widely used to estimate the risk and is a strong basis to elicit flood damage drivers to target prevention policy. Then, locally identified risks must give rise to prevention measures adapted to the local socio-economic, environmental and hydrological reality.*
- *Flood warning alone cannot prevent the risk. Emergency and divulgation plans should enter in the equation of risk prevention in the institutional set of measures.*
- *Infrastructural measures of defense have been an historical answer to manage the risk. In a changing climate their efficiency to alone protect goods and lifes has been questioned. Environmental measures are designed to recover natural dynamic of rivers. They can provide the flexibility required to adapt to uncertain environments.*
- *Flood risk adaptation measures must involve both the private and public sectors to reduce vulnerability and exposure. With a higher climatic risk, financial insurance might become costlier. Self protection measures, designed to reduce the probability of suffering damages due to the flood can be promoted and supported by the institutional sector via diagnostic of vulnerability of the private sector.*

A warmer climate, with its increased climate variability, will increase the risk of flooding. Indeed, with a warmer climate will increase evaporation and the intensity of water cycling, and a warmer atmosphere can hold more water vapor and has a higher energy potential. As a consequence, rainfall would be more intense and associated extreme events are expected to be more frequent. Such changes are not far according to future projections.

Several studies reveal that such modifications have already been observed: the frequency of exceptional floods has increased during the twentieth century. Moreover, other studies have revealed that the role of anthropogenic activities on the modification of flood risk cannot be ruled out. In a study relative to the flood events occurred in Wales and England in autumn 2000, climatic simulation models revealed that the twentieth-century anthropogenic activities increased the climatic risk by more than 20%.

Such an increase of the climatic risk would increase the risk on our activities and life unless we adapt to manage it. An increase in the flood hazard, i.e. the probability of occurrence of potentially damaging flood events would increase the socio-economic risk of flood and the potential damages. Our objective here is to illustrate on which drivers of flood risk we can act in order to reduce the socio-economic risk. The analysis is based on the assessment of the flood risk in the city of Zaragoza and downstream, along the Ebro river (Spain).

When we think about the potential damage we can suffer from a flood event, various drivers cross our mind: the timing and the volume of rainfall, the velocity of the flows, the water depth, the efficiency of the emergency system, the capital accumulated in our houses, the type of economic activity, our capacity to protect our goods and reduce their susceptibility to the flood or our capacity to protect our life. In the Jucar river basin, in the south east of Spain, the flash flood episode of September 2012 tragically killed nearly a dozen people. The circumstances of their death are various according to the newspapers that covered the event. Some of them died carried away by the waves, other drowned inside their cars, and in their houses. Some were more vulnerable than others due to their age or to cardiac disease and could not save their life. Therefore, elements of people vulnerability like age and pathologies are some drivers that water managers have to deal with in the estimation of the human risks in the face of climate change.

The estimation of the flood risk in terms of economic and human health risks would give valuable information to managers and individuals to manage such risk. To pretend achieving the Zero-risk is a utopia; uncontrolled circumstances, scientific and intrinsic uncertainties relative to climate driven events remain present but the reduction of this risk can significantly be achieved with efficient prevention measures based upon spatial assessment of the risk. Hydro-economic approaches propose to organize and structure these natural, human and economic drivers in order to estimate the potential damages and the risk. These models are widely used for flood risk assessment. In Europe, the major rivers like the Rhin, the Rhône or the Loire have designed tools for the assessment of the socio-economic risks. Moreover, these hydro-economic approaches can be integrated to spatial cost-benefit analysis or multi-criteria analysis in order to help decision makers to take relevant decisions.

Behind the Risk: Hazard, Exposure and Vulnerability

The **flood risk** is a product of flood hazard and the negative consequences of flooding. The **flood hazard** characterizes the nature of the flood: the volume of water, the depth of water, the velocity of flows, and the spatial and also temporal dynamics. Analysis of the characteristics of past events helps to estimate the probability of occurrence of a flood with given characteristics and the average time that elapses between the occurrence of a certain flood event and the next event of the same magnitude (called the return period[1]).

The study of the **consequences of a flood event** requires combining hydraulic and hydrologic information together with other factors that can be prone to economic analysis such as exposure and vulnerability. The exposure analysis identifies the elements at risk: the rural, the urban and the human elements. Among the urban elements at risk are the residential and non residential properties, the public infrastructure, the transport network, etc. The rural elements refer for example to areas with human interventions, forestry and agriculture. However, the fact that these elements are located in the floodplain and are exposed to the risk does not necessarily mean they will suffer negative consequences. The vulnerability analysis determines the potential of these elements to be harmed by the flood. The vulnerability of the elements depends upon how much they are exposed to the hazard and how much susceptible they are to the hydraulic characteristics of the flood. How much an element is susceptible? This depends upon its preparedness to the flood, its capability to cope with and to recover from the event.

The flood risk is then the result of linking the negative consequences of each potential flood event with the annual probability of overcoming such event (also called exceedance probability). It is represented in a damage-probability curve or flood-risk curve.

Spatial flood risk assessment in practice

In the PREEMPT project, we have analyzed the flood risk in the Ebro river basin, Spain. The case study area covers the municipalities of Zaragoza, Pastriz, Alfajarín, El Burgo del Ebro, Nuez del Ebro and Villafranca del Ebro (Figure 1). The total population in these municipalities is about 680,000 inhabitants almost all located in Zaragoza (98%) but with a heterogeneous density of population and different degrees of exposure to the flood.

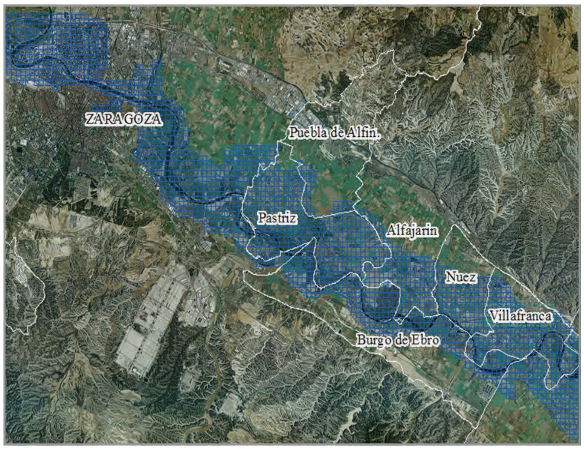

Figure 1: Case study area. In blue cells, the exposition to a 500 years

To illustrate the flood risk in this area we propose to focus on the urban and human elements at risk. Six return periods have been analyzed: 5, 10, 25, 50, 100 and 500 years. The hazard information of each return period has been overlaid with the land uses of the area in order to estimate the elements exposed to a given potential flood. Then, the vulnerability of the elements exposed is estimated as a function of the water depth and adjusted by susceptibility factors. The land uses analyzed are the commercial, industrial, warehouse, sport, leisure and tourism, health and public infrastructures.

The **economic impacts** analysed in the urban area are the direct damages to the residential and the non-residential sectors. The direct damages estimated are the cost of cleaning, the cost of repair of building and infrastructures, the damage to the inventory of houses, the stock, the fixtures and fittings, the movable equipment and the services. The total potential damages (the risk probability curves) for the municipalities of the case study area are illustrated in Figure 2.

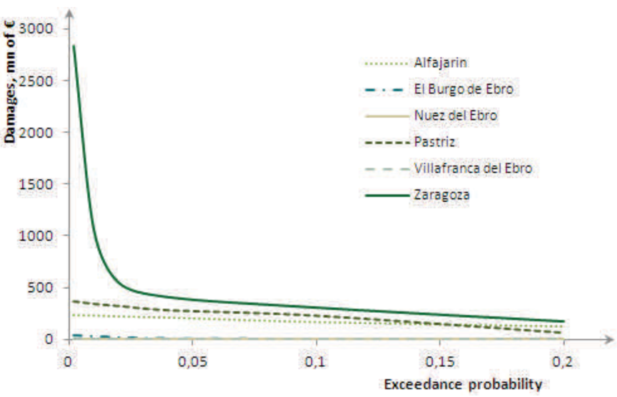

Figure 2: Risk-probability curves in the case study area

One can see that Zaragoza, the main economic pole of the area, suffers the larger total damages. However, an analysis by sector and municipality shows that the downstream municipalities of Pastriz and Alfajarín will bear globally the larger residential risk. For floods with higher probability of exceedance, more frequent and with smaller flooded areas, Alfajarín suffers the larger damages. Then as the flood return period is getting larger, Pastriz suffers the larger damages. Finally, for exceptional floods the largest residential damages are located in Zaragoza.

As a consequence, the differences in flood risk estimates between municipalities suggest that flood risk prevention policies should be adapted to the socio-economic and to the hydraulic and hydrological reality of the local urban environment.

1. In hydrology, to the return periods are associated probabilities of exceedance: the events with small return periods have large probability of exceedance. A flood with a 10 years return period has a probability of exceedance of 0.1, a flood of 500 years return periods has 0.002 probability of exceedance.

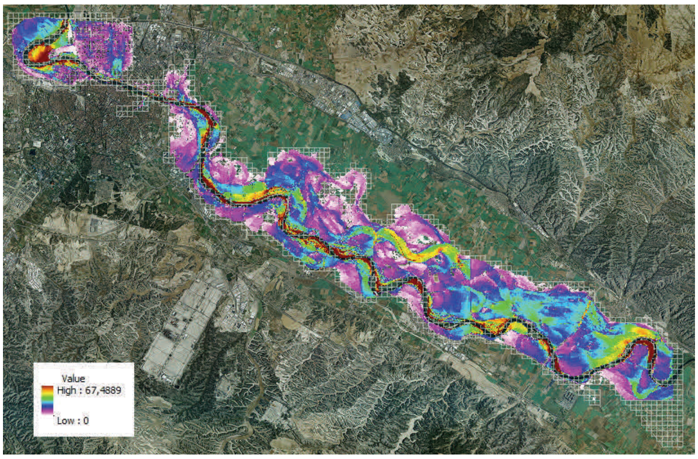

Figure 3: Hazard rating index of the 500 years return period.

The **health impacts** are measured in terms of potential death, injuries and stress generated by a given flood event. How many people can suffer injuries or can die due to a flood event? This depends upon the capability of the population to avoid the wave (defined as the people vulnerability), upon the flood warning system, the speed of the onset, the habitat type (the area vulnerability) and the velocity of the flows and the water depth (the hazard). The hazard variables can be synthesized in a hazard rate index[2]: the higher the index the higher the hazard associated to the event (Figure 3). The index shows that the more dangerous areas are those combining higher water depths and higher velocity of water flows. Areas of high hazard rate can then be identified in the space. Prevention policies and emergency plans can integrate such information to give more targeted recommendations to citizens.

In the Ebro and in Zaragoza, the flood warning system is relatively advanced. Flood can usually be forecasted in advance because of the geographical situation of the city. The alert can generally be emitted with two days of anticipation. The area is thus less vulnerable than areas exposed to flash floods. The vulnerability of people depends upon the age structure and the incapacities of the population; elder people are less able to escape as well as disabled or long-term sick people. Our estimation combined elements of area vulnerability, people vulnerability and hazard. It reveals that the number of injuries would vary from 13 people with probability 0.2 to 39 with probability 0.02 and 96 with probability 0.002. Almost all of them would be located in Zaragoza, where one founds the larger vulnerable population.

Flood risk prevention: complementarity and coordination of measures

The measures water managers can implement to prevent flood risk can be classified into four categories: the institutional, the infrastructural, the environmental and the socio-economic measures. **The institutional measures** refer mainly to the flood alert system, the security and norms of reservoirs and dams, the land use plans and the emergency plans. In the Ebro river basin an automatic hydrologic alert system (SAIH- Sistema Automático de Información Hidrológica) monitors the Ebro river and its main tributaries in real time. Such a monitoring system improves the flood warning system and contributes to reduce the area vulnerability and the health impacts as noticed previously. However flood warning alone cannot prevent the risk. The design of emergency plan of Civil Protection and municipalities would provide guidelines to people to apply protection measures and reduce their exposure. Finally, divulgation of flood risk maps and emergency plans, education to flood risk reduction as for earthquakes disasters will contribute to the success of risk prevention policies. For example, in Germany during the 2002 flooding events, two thirds of the affected people were not aware of living in flood risk areas. The Zero-risk will not be avoided but the risk can be significantly reduced with the coordination of alert, emergency and divulgation plans.

The **infrastructural measures** are the civil engineering measures of defense towards floods. Dams and dikes have been the traditional measures of protection and regulation of rivers. The storage capacity of the reservoir system has a significant role to contain water flows and stock. In the Ebro river basin, during the flood of winter 2003, the 28 main reservoirs stored more than the double of water they usually store in normal periods. The Yesa reservoir in the river Aragon outflowed 150 m3/s and then 100 m3/s when the inflow was 250 m3/s. The reservoirs of Yesa and Itoiz contributed to absorb the flood wave significantly in the sub basins of the Irati and Aragon rivers.

In the flood risk curves shown in Figure 2, one can see that the risk suffered in the city of Zaragoza is relatively moderated for small floods and becomes much larger as the hazard increases. This characterizes places protected by dikes. Dikes protect the elements at risk for a given return period. When the return period is exceeded, the dikes do not contain water flows anymore and the damages increase suddenly. In the more extreme scenario, dikes can break and generate more devastating flood waves.

2. Adapted from the UK Department for Environment, Food and Rural Affairs (DEFRA).

The efficiency of these strong infrastructures to contain water has been questioned by some authors in the face of climate change where flood characteristics of a given return period would become more uncertain. In this context infrastructural measures may therefore not be sufficient to protect the element at risk as their design would have expected it. In the European Union, a shift of policy orientation has been made in the beginning of the XXI century with the Water Framework directive (2000/60/EC) and the Floods directive (2007/60/EC) to recover a good ecological status of rivers. Others European policies, like the Common Agricultural Policy and the Rural Development plans have also indirect impacts on ecological status.

Therefore **environmental measures** are being implemented in river basins. 600 environmental actions have been referenced in Spain according to the Ministry of Agriculture, Food and the Environment. These measures consist in recovering the natural dynamic of rivers, improving the flowing of water with operation of residuals elimination, river bed cleaning and forestation of river banks. These measures are coordinated in a national strategy with respect to restoration of rivers (Estrategia Nacional de Restauración de Ríos), launched in 2005 in order to minimize the risk of floods. For example, downstream the Cinca river in the Ebro river basin it has been decided to eliminate a secondary dyke of protection and to recover the natural vegetation of the river bank. These measures have helped the river to recover its natural dynamic and to have more space, to reduce the risk of break of the principal dyke and to recover the soil absorption capacity thanks to the forestation of the riverbanks with riparian species.

The **socio-economic measures** are mostly directed towards the involvement of the private sector in the prevention of the risk. Nevertheless they are not disconnected from the institutional prevention of the risk. Both the development of insurance products and self -protection measures reduce risks. The insurance system reduces the size of the damage suffered ex-post and covers all the sectors of the economy, from the agricultural sector to the citizens. However, in the face of increased climatic risks, one can expect an increase in the risk premium and such an increased cost of insurance would reduce individual welfare. Alternative solutions can be developed; self-protection measures can be promoted. They are designed to reduce the probability of suffering damages and to reduce the vulnerability of the activity. Land use and crop choices by farmers, location of firms in the flood prone areas, technical measures like elevation of the factors of production or goods of consumption are private decisions any individual can act on to reduce risks. However, the more informed individuals are about the flood risk, the more efficient will be their decisions. Involvement of insurance companies, water managers and others partners of firms could help private firms to guide their decisions via a diagnostic of vulnerability. In France, such an initiative has been launched for the reduction of the flood risk in the Loire river basin, in which the actions of institutional water managers, insurance companies and firms is coordinated to reduce the risk.

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