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Housing bubbles and the increase of flood exposure. Failures in flood risk management on the Spanish south-eastern coast (1975–2013)

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Abstract

In recent decades, there has been a significant increase in economic losses caused by flood events on the coastal region of south-eastern Spain. The increase of extreme rainfall events forecast by the climate change models is currently not reflected in the statistics which suggests that the principal cause is due to the exposure experienced within the past 40 years. Consequently, it is interesting to evaluate the effect of urban growth in flood-prone areas and the role played by government institutions in mitigating the increase in exposure. For this study, the cadastral information and the hydrological modelling data for the return periods of 10, 50, 100 and 500 years were used. This allows high-resolution spatial–temporal results to be obtained that show one of the most significant growths in exposure in Spain and Europe, as well as the low efficiency that risk mitigation measures have had.

Introduction

Throughout the 20th century, social and economic improvements in developed countries and the massive implementation of 'structural' measures have both allowed an increase in safety levels and a significant reduction in fatalities caused by floods (Doocy *et al.*, 2013). However, in recent decades, there has been an increase in physical and economic losses (WMO, CRED and UCL, 2014) that raises serious concerns in society. There are a number of explanations for this issue. One of these is associated to the growing influence of anthropogenic climate change which predicts an increase in extreme weather events (Mills, 2005; Höppe and Grimm, 2009; Coumou and Rahmstorf, 2012). Other studies indicate social factors as being mainly responsible for the destruction caused by heavy rainfall events (Changnon *et al.*, 2000; Easterling *et al.*, 2000; Bouwer *et al.*, 2007; Barredo, 2009; Neumayer and Barthel, 2011; Barthel and Neumayer, 2012).

Climate change projections may explain the rise in flood losses; however, these shouldn't be considered yet (Bouwer, 2011). According to Kundzewicz *et al.* (2014), there are strong variations in precipitation for the regional and sub-regional scale that reduce confidence in trends. For example, most research in Southern Europe, particularly in the Mediterranean area (Benito *et al.*, 2005; Gallego *et al.*, 2011; Benito and Machado, 2012; Cortesi *et al.*, 2012) concludes that there is no trend showing a correlation between increased heavy rainfall events and increased flood events in recent years. According to IPCC (2014), there is low confidence in anthropogenic climate change affecting the frequency and magnitude of fluvial floods on a global scale. In other words, this increase in flood events is not completely related to the higher frequency of heavy rainfall. However, this correlation is likely to become more significant in the future.

To illustrate the aforementioned, a spatial example can be seen in the study area. In the southeast of the Iberian Peninsula, we see an increase in economic losses within the last 40 years due to flood events (Gil-Guirado *et al.*, 2014a), despite the fact, as has been mentioned previously, that current climate conditions have remained relatively stable. It seems that the socio-economic growth and the rise of housing construction (Gaja, 2008) have led to an increase in vulnerability and exposure which are mainly responsible for those losses. Furthermore, this situation will probably become more precarious if some climate forecasts are met [IPCC, 2014; AEMET (Agencia Estatal de Meteorología), 2015], and if the economic model fails to adopt efficient adaptive measures (Berkes and Folke, 1998) (vid. Figure 1). Therefore, it is interesting to focus attention on social factors either within the present or future scenario in order to minimise the potential consequences and improve the adaptation.

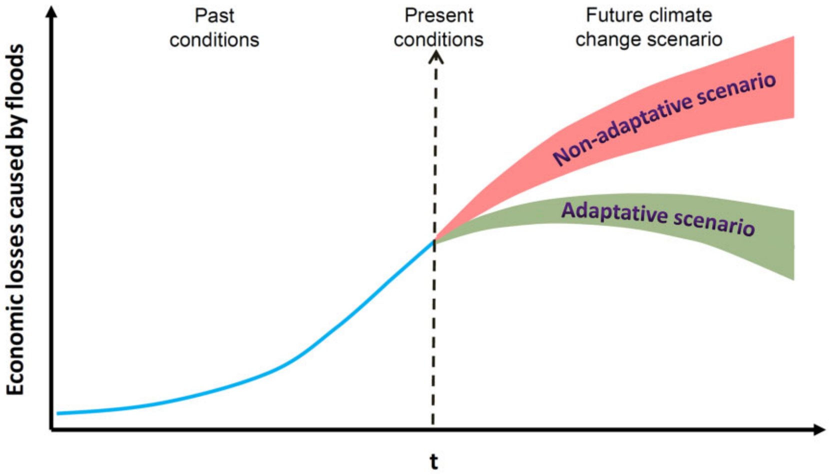

Figure 1 The economic impact of floods on different scenarios of adaptation. Source: Own elaboration.

These societal factors represented by vulnerability – i.e. the capacity of a society to deal with the event (Kron, 2005) or the susceptibility to harm (IPCC, 2014) – forces us to consider this concept influenced by a wide range of social, economic and cultural factors which, to date, have not been completely considered therefore making the quantitative assessment of future trends difficult (IPCC, 2014). Nevertheless, there are variables which show the growing influence of global vulnerability today, one of these being institutional vulnerability. This can be defined as rigid institutions which use obsolete legal framework measures to mitigate exposure in hazard areas (Wilches-Chaux, 1993). An example of how institutional vulnerability contributes to the increase in economic losses and fatalities can be seen in Raschky (2008), who demonstrates how government institutions around the world are largely responsible for losses caused by natural hazards. In this sense, local and regional governments are primarily responsible for controlling exposure in the hazard areas through a legal framework. Thus, we consider exposure – i.e. the population and the value of assets at risk from flooding (Kron, 2005; IPCC, 2014) – to be dependent on a legal and regulatory framework. From this, we can deduce that greater institutional vulnerability is related to increased exposure.

Therefore, the objective of this paper is twofold: first, through a high spatial–temporal resolution evaluation, to show the increased exposure in flood-prone areas on the Spanish Southeastern coastal region (Alicante and Murcia). In recent decades, this region has seen unprecedented population and economic growth resulting in a significant increase in the occupation of flood-prone areas. Second, to demonstrate qualitatively that this increase is related to the poor management of flood-prone areas by government institutions and the regulations adopted by them, i.e. increased institutional vulnerability. To do this, the effectiveness of a catalogue of spatial and urban planning measures is analysed, with particular attention to the flood risk management strategies (FRM) which have been applied over the study period.

Spanish Mediterranean coastline, a risk area

From the second half of the 20th century, economic growth in Spain has been reflected in the disproportionate increase of construction despite fluctuations and crises (Burriel, 2008; Gaja, 2008). In this coastal region, the improvements in the economic conditions and social progress did not take into account the physical factors. Therefore, exposure and flood events (Gil-Guirado *et al*., 2014a,b) produced a dramatic rise in economic losses (Barredo *et al*., 2012).

To understand this better, we need to analyse the evolution of urban development of the study area. During the analysed period, the region's average urban growth rate was highly effected by the significant demand in secondary holiday homes by Spanish, and predominantly, foreign tourists (Burriel, 2008). Between 2001 and 2011, the number of central and northern Europeans who settled in provinces along the Mediterranean coastal region increased by 481%. This means a total amount of 477 325 new inhabitants, significantly surpassing the Spanish population growth which increased by 110.5% for the same interval (INE, 2013). The arrival of these new residents between 1970 and 2013 triggered a 233.34% increase in new residential properties and a total increase of 317% (including non-residential properties, e.g. industrial, commercial, business) [DGAVS (Dirección General de Arquitectura, Vivienda y Suelo) 2014]. In order to have an idea of the consequences of such a phenomenon on a national scale, 43.9% of buildings constructed and

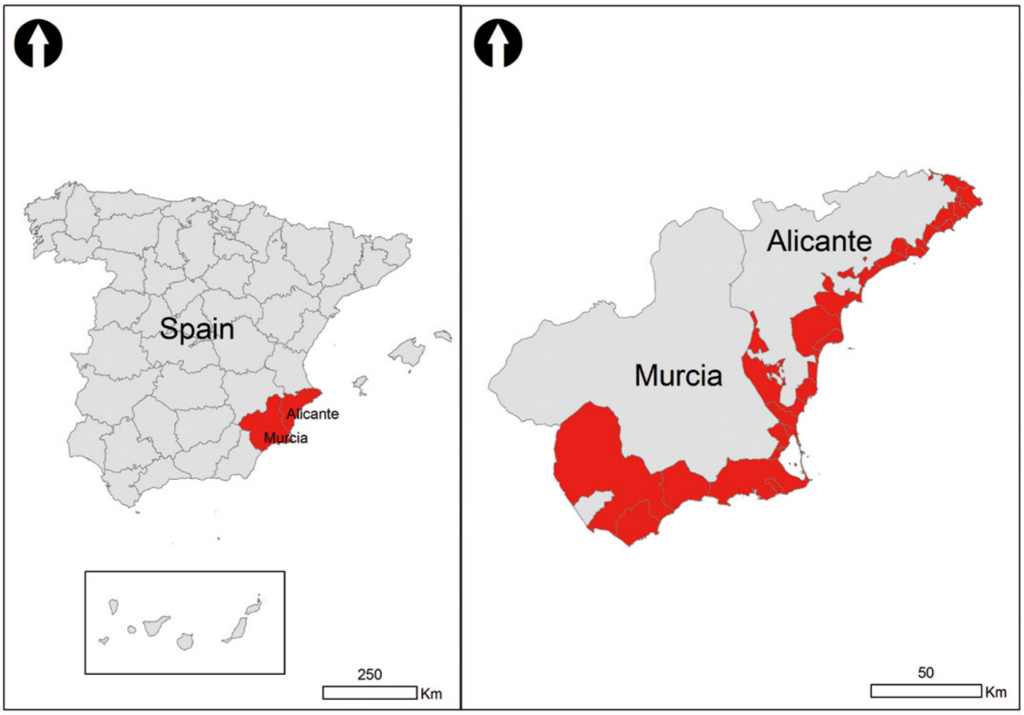

Figure 2 Study area. Alicante and Murcia provinces and their coastal municipalities.

40.7% of the total area developed occurred on the Mediterranean coastline.

The construction of residential buildings along the coastal region of Alicante and Murcia (vid. Figure 2) is even more significant. Before the economic crisis of 2008, Alicante was placed in third position in the national ranking behind Madrid and Barcelona and ahead of provinces with higher populations, e.g. Valencia and Málaga. In fact, if we consider the significance of this phenomenon in Alicante and Murcia together, this geographical area of less than 5000 km^2 (4.611 km^2) would be ranked second just behind Madrid.

This increase in construction makes the coastal region of Alicante and Murcia a perfect example of urban growth and the existing close relationship between the increase in flood exposure and economic losses. Recent research for the study area shows how exposure and the number of flood events have risen in parallel and exponentially for the period 1960–2013 (Gil-Guirado *et al.*, 2014b). According to the authors, 191 flood events took place in the study area between 1975 and 2013, a rate of 4.9 floods per year, whereas the rate was 2.2 floods per year for the period 1960–1974.

Using this scenario, we can study the urban development trend in flood-prone areas, thus enabling us to understand the process of three main questions: (1) increase of exposure, (2) effectiveness of land management and flood risk mitigation measures related to institutional vulnerability, and (3) increase in economic losses due to an increasing frequency of flood events.

Methodology and sources for exposure assessment

In order to assess exposure to floods, it is necessary to consider two essential components of the risk function in a spatial context: the physical or hazard component and the human component (Cardona *et al.*, 2012). The first was obtained from information included in the National Mapping System of Flood Hazard Areas (SNCZI in Spanish) [MAGRAMA (Ministerio de Agricultura, Alimentación y Medio Ambiente), 2014] which is the official cartography of the Ministry of Agriculture, Food and Environment for river network management, risk prevention and territorial planning. This source follows the principles of Directive 2007/60/EC (European Commission, 2007) and uses the results of hydrological modelling (vector format for area and raster format for depth) for the following return periods: 10 year (RP10); 50 years (RP50); 100 years (RP100); and 500 years (RP500). From this, we were able to create flood hazard maps for the selected study area.

Regarding the human component, buildings as cadastral parcels[1] were taken into account following the methodology proposed by García (2013). This information was obtained from the headquarters of the General Directorate of Cadastre database up to May 2013 [MHAP (Ministerio de Hacienda y Administraciones Públicas) 2014]. Cadastral

[1]Parcel is the maximum disaggregation unit used in this paper and corresponds, generally, to each building located on the ground.

information is divided into shp-type spatial files and its metadata. Records from both digital documents are linked using a cadastral identifier which enables the age of each building to be associated to each plot. This allows us to create the exposure map using the intersection of the two main components, hazard and building, and to determine the locations exposed to potential floods.

Despite the high quality of data, our analysis has had to take into consideration a series of limitations associated with the nature and characteristics of such sources. With respect to cadastral metadata, the same parcel can have more than one building, each with a different construction date. In these cases, the year of the oldest building was selected and the assumption was made that it had not been demolished or replaced by a newer building. The problem here was that it could underestimate the number of parcels for the earliest years of the study period. Therefore, we have calculated the error for the exposed and non-exposed buildings as shown in Table 1.

Additionally, as mentioned in similar papers (Koivumäki *et al.*, 2010; Jongman *et al.*, 2014), due to the absence of hydrological modelling prior to the ones used in our analysis, it is assumed that flood-prone areas of the return periods have remained stable over time. However, in the geographical area analysed, anthropogenic transformations of river courses have been significant and will have probably altered flood-prone areas in that period (Bochet and García-Fayos, 2004; Hooke, 2006; Symeonakis *et al.*, 2007).

Table 1 Error percentage of parcels containing more than one building and total number of cadastral parcels from study area, differentiating between exposed and total parcels

	Total parcels > 1 building	Total parcels	% Error
Total	11 509	196 811	5.85%
Exposed	1 355	26 457	5.12%

Source of the information: Own working.

Results

Increase to flood exposure in the Murcia and Alicante coastal region

Since 1975, the year of the Dictator Francisco Franco's death and the beginning of the democratic transition, urbanised areas and the number of properties have cumulatively grown in the flood-prone areas of this region.

In relative terms, the results are impressive. For the period analysed, the increase in properties is 347% (< 1975 = 100), i.e. an annual growth rate of 8.9%. However, what is remarkable is the fact that the increase in properties in flood-prone areas has been bigger than in non-flood prone areas (273%) (vid. Figure 3). Regarding the area occupied by constructions in flood-prone areas, the increment values are significantly lower (368%) than values in non-flood prone areas (442%) (vid. Figure 4). However, they are still very high figures that give us an idea of the accelerated process of urban expansion and of the laxity in the application or generation of measures for the mitigation of flood risk.

If we analyse every year in detail, Figure 5 allows us to distinguish two distinct periods, 1975–1993 and 1994–2013. The first one is preceded by the oil crisis of 1973. Despite the great impact of this event in Spain, its effects on property development in the study area were minimal because of the

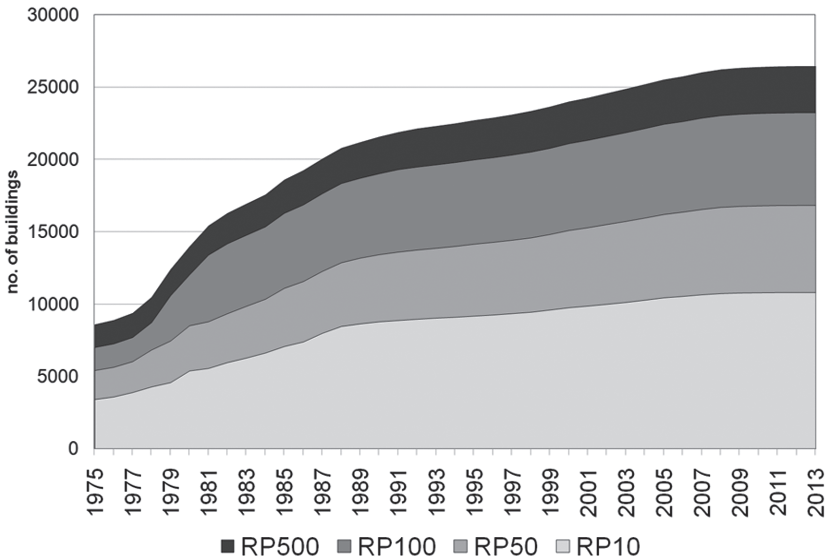

Figure 3 Aggregate trend of number of buildings constructed in flood-prone areas for different return periods.

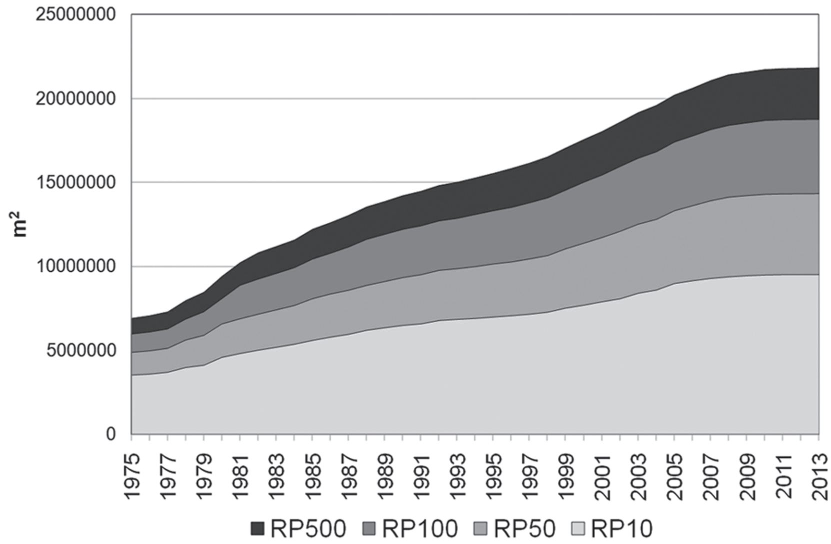

Figure 4 Aggregate trend of built-up areas in flood-prone areas for different return periods.

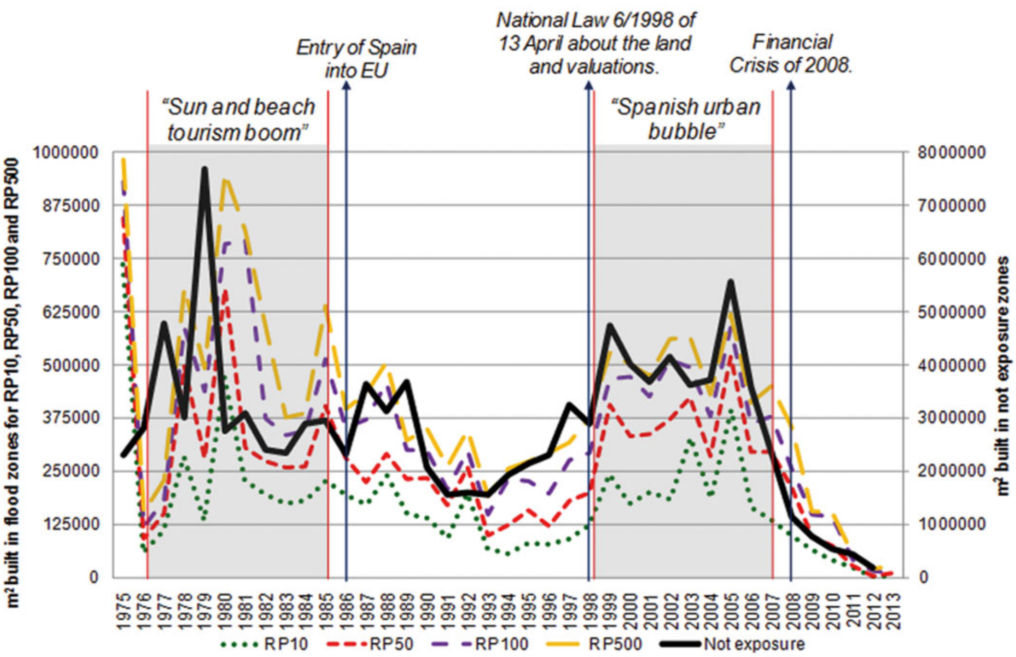

Figure 5 Evolution of urban development in flood-prone areas over different return periods.

housing demands created by an increase in national population and more significantly, residential tourism. This has resulted in dramatic urban growth in both flood-prone and non-flood prone areas since 1977. Another significant factor that contributed to this growth was Spain's entry into the European Union (1986). This had a noticeable impact on the tourist areas and municipalities of the studied area (Harrison, 2006). Between 1975 and 1980, 35 618 new properties were built, of which 6361 (17.8%) were in flood-prone areas (vid. Figure 5). This means an annual average exposure rate (the speed at which flood-prone areas are occupied) of 0.61% in all the return periods, and a maximum of 1.9% for RP10 (vid. Figure 6), i.e. the highest return period value of the whole series.

Between 1980 and 1993 the rate of urban development decreased to 0.1% for all return periods (vid. Figure 7). In fact, the year 1993 marked the beginning of another great economic crisis and the end of the first period. Nevertheless,

Table 2 Summary of the total area and buildings constructed and exposed for different periods of return (m² and n° properties)

	Total (Non-exposed and exposed)		RP10		RP50		RP100		RP500	
Year	Area	N° properties	Area	N°Pro	Area	N°Pro	Area	N°Pro	Area	N°Pro
< 1975	39 086 259	69 943	2 792 619	2 942	4 034 979	4 697	5 055 485	6 187	5 936 462	7 617
1975–1993	69 914 504	90 922	4 051 103	6 079	5 822 607	9 169	7 822 049	13 466	9 087 743	14 692
1994–2013	59 278 456	35 946	2 667 616	1 772	4 467 618	2 966	5 900 844	3 611	6 813 211	4 148
Total	168 279 219	196 811	9 511 338	10 793	14 325 204	16 832	18 778 378	23 264	21 837 416	26 457

Source of the information: Own working.

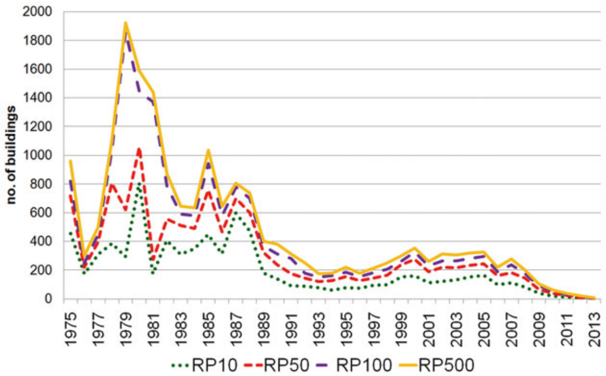

Figure 6 Evolution of the number of buildings constructed in flood-prone areas for different return periods.

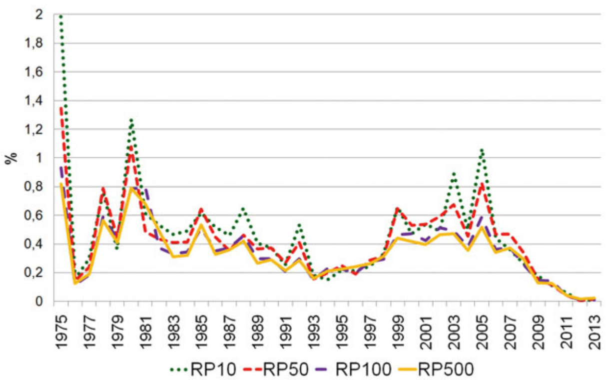

Figure 7 Evolution of the percentage of built-up surface areas in flood-prone areas for different return periods.

it had already begun to show signs of slowing down in the mid-1980s. Together with economic factors, this decrease could be attributed to the first effective flood mitigation measures. These structural solutions, which will be analysed later, were widely demanded by the public due to the high number of flood disasters which occurred during the 1980s on the Spanish Mediterranean coastline (Serra-Llobet *et al.*, 2013).

The beginning of the second growth period in 1993 saw a decrease in construction due to the Spanish economic crisis as well as an increase in the occupation of flood-prone areas in some municipalities. Between 1994 and 1997, a progressive increase took place. However, 1998 marked a new phase of indiscriminate building activity contributing again to the increase of buildings in flood-prone areas. Between 1998 and 2006, 2644 new buildings were constructed, with an annual building rate in flood-prone and non-flood areas similar to the building rate of the previous 'property boom'. To understand the magnitude of this phenomenon, we can look at the liberalisation that took place when the 1998 Land Law was approved by national government (Jiménez, 2009). For example, the availability of land for property development for some municipalities of the study area, e.g. Torrevieja, was exhausted in a period of 15 years.

The overall result of this 'housing boom' over the past 39 years (vid. Table 2) is the integration of the river courses into urbanised zones, and therefore, the progressive rise of exposure and flood risk.

This can be seen by the relative distribution of buildings in the different return periods with regard to the total amount. Figure 8 shows that, up until recent years, occupation of flood-prone areas has taken place mainly in the RP10 area. This alarming trend can be explained by the fact that the study area is densely occupied by ephemeral channels. These types of natural water channels which remain dry for long periods of time, intermittently experience flash floods caused by extreme precipitation events. Unfortunately, these hazardous characteristics are not perceived clearly (Llasat *et al.*, 2008) and encourage buildings to be located on banks near flood beds, thus blurring the original layout of the water channel course.

Finally, Figure 9 shows the trend in the proportion of built-up surface area in zones affected and unaffected by floods. There is a variability which adjusts itself to the already mentioned periods of crisis and growth. Nevertheless, exposed area data show a decrease which is greater than the non-exposed area, although this is not a significant difference as the decrease is small. This decrease is related to two factors: first, the intense occupation of flood-prone areas in the first period compared to the second period data; and second, the legal restrictions which limited the occupation of these hazard zones (the 1998 and 2008 land laws and

Figure 8 Percentage of built-up area in each return period.

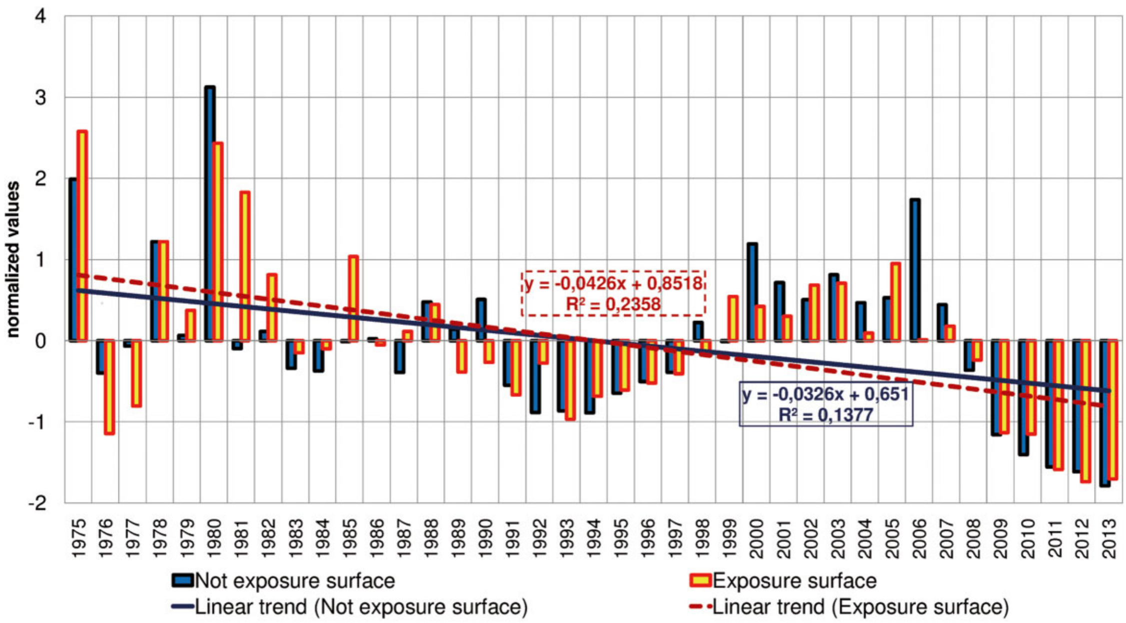

Figure 9 Evolution of normalised values of built-up surface areas in exposed and unexposed flood hazard area.

regional plans for FRM may have had some effect on this.). Figure 10 shows two examples of the increased exposure between 1981 and 2013 in the study area.

Evidence of mitigation measures effectiveness

The increase of flood disasters in the Alicante and Murcia coastal regions in the last four decades has resulted in the implementation of more effective flood risk mitigation measures. These include emergency management, structural and non-structural measures. In general, they have all been successful in reducing the number of fatalities, which was previously high. However, the economic losses have continued to increase, even with minor rainfall events, therefore adding uncertainty as to their effectiveness. To evaluate the measures and their effectiveness, we

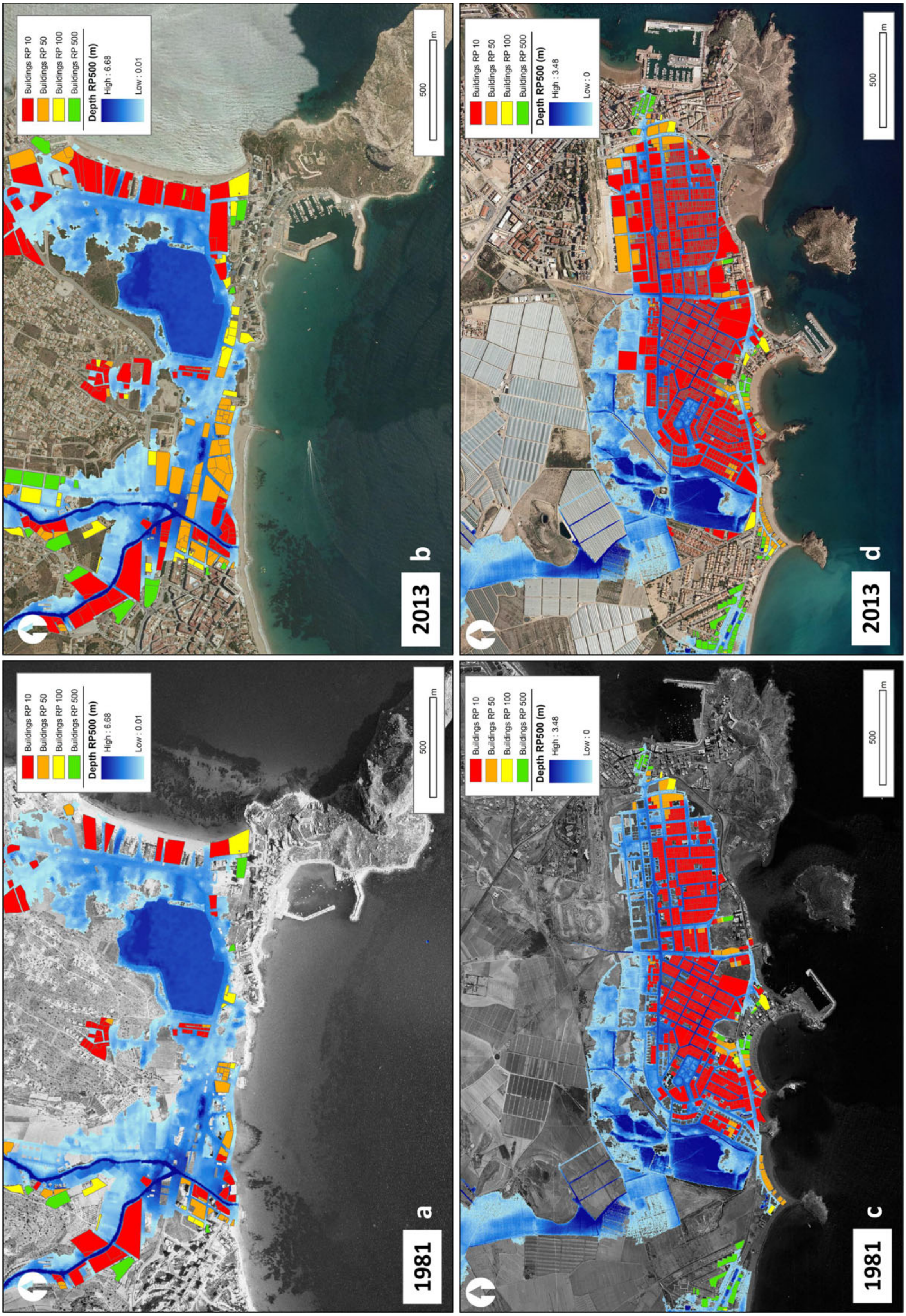

Figure 10 Increasing exposure in two selected places of the study area between 1981 and 2013. Images a and b are from Calpe (Alicante); c and d, Mazarrón (Murcia).

Table 3 Effectiveness of flood risk mitigation measures in the Alicante and Murcia coastal region

Type of measure	Flood risk mitigation measure	Scale	Degree of effectiveness
Emergency management	Regional Civil Protection plans against flood risk (Murcia, 2007; Valencia, 2009)	Regional	High
	Municipal Civil Protection plans	Local	High
Structural	Flood defence plan of Segura river (1987)	Regional	High (Although it creates a sense of false security)
	Anti-flood plan Alicante city (1999)	Local	High (Second phase not yet developed)
	Performances in Benipila and Hondón watercourses (Cartagena) (2008)	Local	High
	Channeling works in urban coastal areas	Local	Medium (The design does not adapt to different types of rainfall)
Non-structural	National Mapping System of Floodable Areas (2013–2014)	National	High. This is the first national mapping for flood risk areas.
	Land Law 2008	National	Medium. For the first time, municipalities are required to elaborate a flood risk mapping in order to delimit non-suitable land for urbanization. Very slow implementation.
	Valencia territorial strategy (2012)	Regional	Low. No action has been initiated.
	Murcia Coastline Land Management Plan (2004)	Regional	Low.
	Territorial Action Plan on Flood Risk in Valencia (2002)	Regional	Medium. Occupation of flood-prone areas has slowed down.
	General urban planning	Local	Low. They have not prevented land occupation of flood-prone areas. Slow introduction of 2008 Land Law measures.
	Risk education	Regional/Local	Low. Introduction of subjects on natural risks in primary and secondary school education curriculum.

Source of the information: Own working.

consider their typology and performance scale, as shown in Table 3.

The emergency management plans, dependent on regional or local civil protection institutions, have been very effective. This measure has had a major influence on the reduction of fatality losses in the study area. These are highly effective measures which have been well integrated with the activities of different government bodies, emergency services and civil protection organisations.

The most important structural measure implemented was a flood defence plan for the Segura River. This plan consisted of the lower part of the river being channeled and the construction of storm rainwater tanks. In the case of Alicante city, a flood protection plan was approved after the occurrence of major floods (September 1997). This involved the channeling of the main ephemeral channel that crosses the municipality. Additionally, the similar measures have been implemented in the rest of the study area, especially after extreme precipitation events. In general, structural measures have had limited effectiveness despite the decrease in extreme precipitation events. This is confirmed by the increase in the frequency of flood events and economic loss statistics (Gil-Guirado *et al*., 2014b).

Non-structural measures related to land management have generally had a low level of effectiveness in this coastal region. The only positive aspect has been the production of an official mapping for flood risk (The National Mapping System of Floodable Areas, used in this paper) in adherence to the terms established in the Directive 60/2007/EC. The remaining land management and planning measures (regional and local) which affected the study area, have to date, failed to prevent the occupation of flood-prone areas. The ineffectiveness of controlling the occupation of flood-prone areas can be better understood by looking at two land laws referenced in Table 3. First, the 1998 National Land Law (article 9), which stated for the first time that any official documentation identifying a land area as a 'natural hazard zone' would be classified as a 'non-urban' area and the rest would be classified as land for building development. At the time, very little of this type of documentation existed allowing local municipalities to take advantage, and therefore, approve the occupation of flood-prone areas. However, in 2008 this changed when a new land law was passed [MV (Ministerio de la Vivienda), 2008], which stipulated the creation of risk maps in order to control urban expansion into flood-prone areas. Nevertheless, the success of this law is still not clear due to it being recently passed. Second, on a local scale, the only plan that has slowed down the occupation of flood-prone areas is the Action Plan on Flood Risk in the Valencia Region (PATRICOVA in Spanish). Since its approval, 1284 reports (risk and floods) have been produced and 7300 ha. of occupied flood-prone land (previously classified 'urban') has been reclassified as 'non-urban' in the Alicante province (Olcina, 2010). Meanwhile, in 2004, the Region of Murcia's Coastal Land Management Plan was approved. However, this regional plan had a minimal effect as demonstrated by Pérez *et al.* (2014).

Another non-structural measure to reduce flood risk is the addition of a risk education programme to primary and secondary school educational curriculums. As the measure was only recently adopted, its effectiveness is yet to be determined.

Discussion and conclusions

From these findings, we can draw four important conclusions. First, the significant increase in exposure is directly related to the economic conditions associated to two 'urban boom' periods (1978–1982 and 1997–2007). Up until the global crisis of 2008, this increase showed no signs of slowing down due to political decisions.

Second, considering there is no conclusive evidence that the natural increase in rainfall events is responsible for more frequent flood events (Benito *et al.*, 2005; Gallego *et al.*, 2011; Benito and Machado, 2012), we can deduce that the growth of flood risk within the study area is a result of an increase in both vulnerability and therefore exposure, rather than an increase in natural hazard activity. The results obtained from this study coincide with European Directive data (2007/60/EC) and Jiménez *et al.* (2014), which demonstrate that the increase in physical and economic exposure (i.e. the assets and values located in flood-prone areas) is one of the main contributing factors for flood events becoming more frequent and destructive. These results are also consistent with a study which uses a similar methodology in the Netherlands (Jongman *et al.*, 2014) and with several studies of areas in Europe which have adopted the land use analysis methodology (Lugeri *et al.*, 2006; Radojevic *et al.*, 2013; Rojas *et al.*, 2013; Früh-Müller *et al.*, 2014). However, it is important to highlight that the increase in urban growth in flood-prone areas along the coastal region of Southern Spain is significantly higher than in any other country within Europe (Burriel, 2008).

Third, little is known regarding the contribution made to risk mitigation by structural measures since their implementation. Although with hydrological and hydraulic modelling, we can spatially determine the safety threshold provided by structural measures, we cannot assess their impact as we have no modelling data before they were constructed. However, what we can know for certain, according to several authors (Calvo, 2001; Saurí-Pujol *et al.*, 2001), is that areas which experienced flood disasters in the past now have defensive systems which provide an acceptable safety threshold. At the same time, there has also been a recent and intense occupation of new areas which have been traditionally affected by floods, and therefore has increased exposure. This represents a risk migration, clearly explained by White (1973), and highlights the significant spatial and temporal limitations of structural measures (Ghanbarpour *et al.*, 2013; Taki *et al.*, 2013).

Fourth, there has been a significant failure of the flood mitigation measures. Taking land management and urban planning as an example, the number of properties and the built-up surface area within flood-prone areas have increased to 255.02% and 258.35% (1975 = 100), respectively. These are alarming figures when considering the legislation which exists to specifically protect these types of areas (RP50). In fact, it is interesting to note that the return period where building construction has taken place more intensively is RP10. From this, we can understand how local and regional government fails with regards to land management and urban planning due to a lack of understanding or negligence, which in turn contributes to increased institutional vulnerability. A probable explanation for this is the significant influence which economic interests have on government authorities (Romero *et al.*, 2012) leading them to ignore the risk of occupying land exposed to flood hazards.

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