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Floods on the Spanish Mediterranean coast in the current climate change context: guidelines for its analysis and management. Study in the basin of the Piletas stream (Málaga)

1. GLOBAL CHANGE AND NATURAL RISKS IN THE MEDITERRANEAN REGION

Interest in natural hazards in Europe has grown in recent years due to legislative changes that have taken place. A decade ago they were hardly considered in environmental and urban regulations, but today they are a priority objective in European policies. The main milestone is the European Directive 2007/60/EC, relative to the evaluation and management of flood risks, which has gradually transposed into the laws of the different EU states a series of considerations on the adaptation of territorial management policies. Furthermore, the European Commission highlights the importance of natural hazards in the Mediterranean region, as well as the need to strengthen knowledge of how torrential floods operate. And this need can be appreciated if we observe the results of the modelling in coastal basins of Mediterranean areas, where there is a notable mismatch between the flooding resulting from the hydrological-hydraulic analysis and the real flood. An example of this was the flood in Rincón de la Victoria, in the province of Málaga, in 2004, in which small river basins caused runoff much higher than expected, as well as other risks. For this reason, the empirical analysis of one of these basins, that of the Piletas stream, has been incorporated into the general characterization of the region carried out in this work.

The main reason for the current interest in the subject is the context of Global Change. The rapid territorial and urban alterations suffered in the region in recent decades, together with climate change, play a very important role,

both due to their repercussions on floods and other risks, as well as the awareness achieved in the population. Climate change generates scenarios, present and future, in which the natural risks of the Mediterranean region are growing and will grow even more in the coming years.

The main starting hypothesis of this paper is the need to refocus the study of flooding from a territorial perspective, overcoming traditional sectoral approaches. This implies assuming three main conditioning factors: the close interrelation with anthropic action, the need to incorporate the study of solids by water erosion into the flood flow, and the need to also study the causal areas, and not only the risk receptors.

The experience gathered by previous papers or by observation of floods in recent years show us basins that function with a close spatio-temporal interrelation and frequent synergies between natural and anthropic behaviours. They also show that the causative areas are more important than the receiving areas from a preventive vision of risk.

Furthermore, the incorporation of soil particles by river erosion into the flow in the basins of the Mediterranean coast explains a good part of the differences in the behaviour of the floods that occur here compared to those in other river basins. Mediterranean basins, mostly torrential in behaviour, produce and evacuate large amounts of sediment in a very short time, and this means that the flow carries a significant proportion of solid load, in addition to damaging infrastructure or triggering landslides.

All these particularities, or the very conception of risk as a holistic and territorial phenomenon, justify an area

of research that fully fits with the science of Geography. Based on this, the main objective of this paper is the territorial, morphological and functional characterization of the river basins of the Spanish Mediterranean coast in relation to the risk of flooding. And also, the identification of solutions to improve the analysis of hazards in the specific case of the space considered.

2. METHODOLOGY

The identification of the determining aspects of the risk of flooding and associated risks on the Spanish Mediterranean coast has been carried out considering the main factors and processes that control the risk in the geographical area. Both physical aspects and functional features have been considered. This work has been done on a double scale. First, the region as a whole has been observed, resorting to bibliographic analysis, and subsequently, the above has been validated in a representative river basin of the region. Lastly, a series of guidelines are identified to improve the analysis of hazards and management in the region.

Concerning physical conditions, the factors and elements of the climate have been considered, with special incidence in the torrential rainfall, the fluvial morphology, the hydraulics and flood zone and the associated hazards, mainly water erosion and hillside landslides. And in relation to the anthropic aspects, the functional and morphological changes have been taken into consideration due to the evolution of the settlement and land uses. Special attention has been paid to the resulting urban patterns and processes of littoralization and urban sprawl, as well as the impact of new farming techniques. To quantitatively support the above, pluviometric analyzes have been carried out in the study river basin, considering the maximum daily rainfall for different return periods, runoff studies, flow analysis and studies of soil particle production by water erosion. For the latter, global values and specific values for a specific rainfall event have been considered. Similarly, the evolution of the urban pattern and land use in recent decades has been analyzed.

The modified rational method has been used for hydrological analyzes, and the HEC-RAS model for hydraulics. The morphological analysis of channels and alluvial forms has been carried out with photointerpretation and fieldwork, also using geological and edaphological cartography and digital elevation models. And for water erosion studies, the revised universal soil equation (RUSLE) and the modified universal soil equation (MUSLE)

have been used. In the latter case, the return period of 500 years has been used, which in Spain is used in urban planning to delimit the flooded area. For the study of the urban pattern, information on urban planning provided by the local administration has been used, as well as orthophotographs.

3. CONCLUSIONS: GUIDELINES FOR THE SPECIFIC ANALYSIS OF FLOOD IN THE TERRITORIAL MANAGEMENT OF MEDITERRANEAN REGIONS

In conclusion, a series of guidelines are obtained to improve the analysis of floods and their management in the region. At the technical and administrative level, there is an absence of regulation that deals with the phenomenon from a territorial point of view and considering causes and effects, that is, places of origin and appearance of the hazard. In regions such as the Mediterranean, with their particular characteristics, this is especially necessary.

Fundamentally, the hydrological-hydraulic model required by the administration for urban planning should be reviewed. This has shown its ineffectiveness, which has led to the requirement of oversizing the flow through the use of parameters much higher than the real ones. Thus, in addition to considering a return period of 500 years in Spain, compared to the usual 50 or 200 years in other countries, a series of conditioning factors are incorporated into the analysis of the runoff threshold to raise the resulting flooding. But still, these floodings are often smaller than the real flood that results when stormy events occur. For this reason, the analysis of the hazard fluctuates between the overestimation and the underestimation of the overflowing water according to the area or stream considered, with a very high degree of error and uncertainty. Thus, it seems necessary to readjust the analysis of flooding in Mediterranean areas. And according to the characterization seen, said readjustment should include important aspects such as the associated hazards, mainly soil erosion and landslides. These hazards are conditioned bidirectionally and synergistically with each other, feeding back and producing important differences in the extension, speed and depth of the flood with respect to the resulting inundation through the traditional hydrological-hydraulic study. Quantifying the soil particles in the flow would be a main aspect, and it could be done by using the MUSLE formulation (Modified Universal Soil Loss Equation) and its transformation into volume.

This cartographic improvement should also incorporate areas that emit or cause a hazard, such as, for example, areas where flow dynamics change abruptly, infrastructures with the possibility of undermining or collapse, precarious buildings in floodplain areas or possible sources of contamination. This also reinforces preventive management in addition to the analysis of the hazard. Likewise, the systemic and associated functioning of all these processes, both from a spatial and temporal point of view, should be considered. These additions would improve the knowledge and the real magnitudes of the flood in the spatial context of work. This would be very useful both in urban planning and subsequent management.

In addition, considering a preventive approach, the analysis and monitoring of changes in land use should be a priority to diagnose trends in runoff and soil erosion processes. In this way, it is possible to act early in the face of natural risks. The advancement of geographic information technologies facilitates increasingly complex analyzes at more ambitious scales. This makes it possible to improve territorial management and planning and to obtain conclusions that can and should be reached by local and regional administrations to build territories that are increasingly safe and resilient in the face of natural risks.

The methodological and normative adaptation of the Mediterranean coast fits with the objective set by the European Commission to develop guidelines for the analysis of hazards and risk in specific regional areas. The geographic variety and territorial contexts make the development of generic planning instruments and measures useless. Besides, other important legislative requirements would be applied in this way, such as those set out in articles 6 of Directive 2007/60/CE of the European Parliament, and 8 and 9 of *Real Decreto 903/2010 del Ministerio de la Presidencia del Gobierno de España*, of evaluation and management of flood risks, which indicate the need to consider the areas with high content of transported sediments and debris flows, and potentially polluting facilities. These aspects are not considered at present.

The importance and validity of the subject require continuing to work on it from the conceptual field and, especially, from the methodological field. As has been seen, the European Commission insists on this, and almost verbatim these requirements have been transferred to state and regional legislation, with clearly marked compliance dates and objectives. However, the normative changes required for compliance with European guidelines have not yet been made.