



Flood Risk Management Plans in Volcanic Islands: Analysis, Discussion, and Lessons Learned in the Canary Islands

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Abstract

Floods are risks arising from natural phenomena such as torrential rainfall over short periods or rising sea levels. In limited territories, like islands, these phenomena reduce geographical space and have severe environmental and economic consequences. The Canary Islands (Spain) is a territory where numerous floods have occurred throughout history. The regional authorities have undertaken Flood Risk Plans as part of the Hydrological Programme for the archipelago. Climate change and the Canary Islands' orography make them prone to adverse weather phenomena like heavy rains and the gradual disappearance of coastal territories due to wave action and progressive rising sea levels. These factors have prompted this review of Flood Risk Plans in the Canary Islands, Spain. Furthermore, an assessment of the archipelago's hydrological and orographic conditions has been conducted to contextualize the islands' situation regarding flood risks. The results obtained indicate that there is a need for greater control through hydrological planning to minimize the impacts of episodes of torrential rains. In addition, studies related to extreme wave events should be improved to size maritime infrastructures correctly. A lack of preventive actions has been detected, involving: (i) assessment and prevention of floods using computer models and simulations, (ii) actions in eroded areas of basins, (iii) cleaning up watercourses, (iv) assessment of hydraulic infrastructures that cross watercourses, such as crossing works, bridges, speed bumps on tracks or agroforestry roads,

and (v) effective coordination for the planning, management, and performance of hydrological and forestry projects between the Forestry and Hydraulic Authorities. Flood effects also increase after large forest fires, especially if action is not taken immediately after the fire by building barriers with burnt material and masonry dikes. Due to the real risks posed by Flooding in the Canary Islands, which has caused historical problems in the archipelago, the Regional Administration has created a "Flood Risk Plan" for each of the islands, where the primary information has been collected. This plan includes the following aspects: selection of the potentially floodable and high-risk areas of the hydrographic basins; evaluation of risks derived from runoff; delimitation of flood zones; selection of potentially floodable coastal areas; studying climate evolution; studying the influence of climate change on sea levels and other aspects considered relevant in the case of coastal and rainwater flooding. Risks have been classified as river flooding, flash flooding, and flooding due to the sea. Civil works must also be conducted to channel ravines to allow the natural flow of water. Wire meshes should be placed on the unstable slopes of the islands to trap small rocks that may fall after episodes of heavy rains. Moreover, urban planning needs to consider areas at risk of flooding to take the appropriate measures. Finally, the most crucial factor is that all the public authorities are aligned and pursue a common goal so that water, coastal, and urban planning can help minimize flood risks.

Keywords

Flood risk · Canary Islands · Planning · Water resources · Volcanic

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1 Introduction

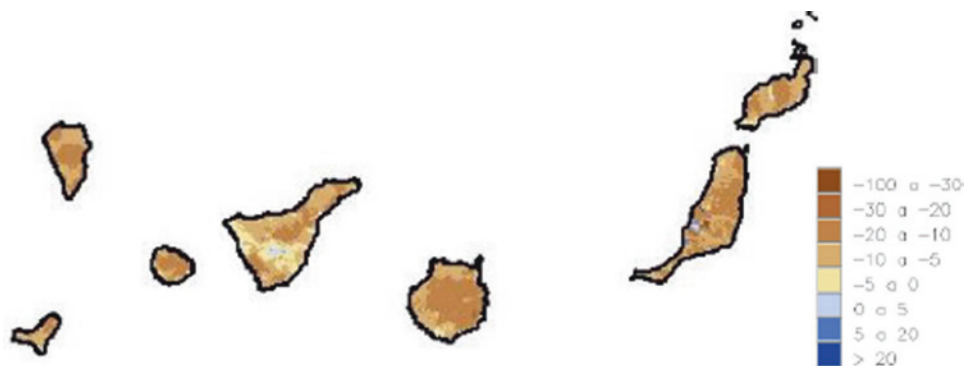
Hydraulic planning on an island can be considered when it has sufficient extension or territory to generate its water resources, and therefore, these resources can be planned and managed (Loucks & van Beek, 2017). However, this definition would not fit small islands that cannot sustain a continuous population settlement due to the absence of stable water resources.

One of the unique characteristics of the rainfall regime in the Canary Islands is its intensity and concentration over a short period. This means that there must be effective territorial planning to avoid episodes of flooding, which have previously occurred in the archipelago (the Canary Islands consist of the following islands: La Palma, El Hierro, La Gomera, Tenerife, Gran Canaria, Fuerteventura, and Lanzarote). Therefore, each island has created its flood plan to take measures against rain floods.

2 Materials and Methods

Climate models are numerical representations of climate systems based on the physical, chemical, and biological properties of systems' components, their interactions, and feedback processes. For example, the Spanish Centre for Public Works Studies and Experimentation (CEDEX) has developed, based on the results of the Special Report on Emissions Scenarios A2 (SRES) (IPCC, 2014), plans in which a downward trend in precipitation in the Canary Islands is projected from 2011 to 2040 (Fig. 1). Another threat facing the archipelago is the rise in sea level, since according to the Spanish State Agency for Meteorology (AEMET), through the IPCC-AR5 allocation (AEMET, 2017), the overall average trend in sea level rise in the Spanish Atlantic-Cantabrian area is estimated at 3.6 mm/year between 1993 and 2010, is occurring. If this trend continues, the islands will be faced with the risk of flooding from the sea, which will be particularly important in areas with limited geographical space.

Fig. 1 Variation of precipitation (%) in 2011–2040 with the control period for the average scenario A2 projections. *Source* Hydrological Plan of Tenerife (CIATF, 2019)



In the case of Macaronesia (Azores, Madeira, Savage Islands, Canary Islands, and Cape Verde), several meteorological phenomena converge, causing torrential rainfall. Most of the time, floods are formed in forest basins in the highland areas of the islands (Leandro et al., 2013). As a result, the ravines quickly become overloaded, and flow velocities are substantial and must flow into the sea.

3 Results

In the Canary Islands, three scenarios cause flooding.

3.1 River Flooding

This scenario includes flooding caused by overflowing ravine beds in episodes of heavy rain. From a hydrological point of view, a significant problem threatens oceanic islands: the enormous annual rate of erosion generated, especially on islands with little vegetation. This process is related to island erosion, which is part of their life cycle but can be accelerated by the loss of vegetation cover and the progressive abandonment of traditional agricultural systems, uncontrolled grazing, urbanization, and, finally, the progressive salinization of soils that directly affects water resources (Santamarta, 2011).

Due to the historical flooding caused by ravine overflows, numerous hydraulic works known as “ravine channeling” have been carried out in the Canary Islands. These works have managed to minimize the effect on the population by providing a space through which runoff water can flow following its natural course. This has meant that on islands with less relief, such as Lanzarote and Fuerteventura, this problem has been brought under control. On the islands with higher ease, these works have also managed to minimize damage from river risks.

3.2 Flash Flooding

Sometimes, very intense rainfall in a short period causes all the precipitation to become runoff. This can lead to localized flash flooding where the rain occurs, leading to severe property damage (Hosseini et al., 2021). The islands with the highest exposure to this risk are the most populated ones, as having more urbanized (and therefore less porous) areas increases the flooding risk in cases of extreme rainfall. Thus, the islands that may be most affected by flash flooding are Gran Canaria and Tenerife. After these, the western islands, i.e., the islands of La Palma, El Hierro, and La Gomera, are also more prone to this phenomenon due to their rugged terrain.

3.3 Flooding Due to the Sea

The climate change we are facing has severe consequences for the planet, such as the melting of the poles causing the sea level to rise. As a result, there are many predictions of global land loss and even the disappearance of low-lying islands (Lazrus, 2012). For example, many coastal population centers and maritime defense works could be threatened in the Canary Islands. Therefore, we might say that the islands risk losing coastal territory due to rising sea levels and extreme wave phenomena.

4 Discussion

The region of Macaronesia consists of a series of five archipelagos in the North Atlantic. These archipelagos have in common a series of climatic, geological, and environmental factors that result in similar characteristics regarding vegetation and water resources (Hughes & Malmqvist, 2005). Furthermore, torrential rains cause identical damage on all the islands of Macaronesia, including erosion, loss of fertile soil, damage to agriculture and infrastructure, and water pollution (Sanchez-Moreno et al., 2014).

Urban management is crucial in minimizing damage from torrential rains since towns should not become natural channels for runoff water because, if so, they are at risk of suffering severe injury in the event of flooding. However, although this aspect is now being considered in both the urban and hydrological spheres, there are still threatened neighborhoods in natural basins. This situation has been experienced in Cape Verde, the Azores, and the Canary Islands.

Other studies focusing on the vulnerability of coastal territories on the islands have shown on the island of Pico (Azores) that the entire coast presents a high to moderate

risk of damage mainly due to extreme waves (Borges et al., 2014). This is also a risk in the Canary Islands, especially in specific areas, which have historically suffered flooding from intense waves. Much of their tourism and economic activity is in the Macaronesian islands in coastal regions. Thus, these areas' risks are a severe blow to the island's economy and way of life. Therefore, flooding must be anticipated by the authorities to minimize any damage.

Finally, it is necessary to protect vegetation cover on the islands since its existence favors the resistance of soils to torrential rains and has a buffer effect on such episodes. Therefore, it is necessary to take care of the vegetation cover, especially in summer, when it becomes prone to fire.

5 Conclusion

In the Canary Islands (and throughout Macaronesia), rain and coastal flooding have been recurrent throughout their history. The potential harm to the population and damage to infrastructures has led the Canary Island authorities to establish Flood Risk Plans against these phenomena, seeking to minimize the impact of floods when they occur. These plans are essential since they gather all the available information on these phenomena and prepare the population and the authorities to face them. Therefore, urban planning managers must follow the recommendations for coastal towns and those located in areas that could be flooded in the event of torrential rains. Indeed, by the provisions of the Strategy for Disaster Risk Reduction and Management promoted by the United Nations (UNISDR), resilient cities must have a series of keys to be adequately prepared for adverse weather events.

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