JOURNAL OF MARITIME RESEARCH

Vol XI. No. I (2014) pp 11–15

ISSN: 1697-4040, www.jmr.unican.es

Resilence of Territories to Extreme Stream Flooding

C. Rolo[1,*] and M. de Azevedo[2]

ARTICLE INFO

Article history:
Received 14 January 2014;
in revised form 22 January 2014;
accepted 04 March 2014.

Keywords:
Flooding, Municipal Scale, Resilence, Risk Management

ABSTRACT

The risks associated with climate change represent a challenge to the resilience of the territories, in particular those that result from extreme hydrological phenomena or potential sea level rising, leading to flooding. While inevitable natural phenomenon, the occurrence of floods can threaten the safety of persons, goods and the environment, so it is essential to reduce the associated risks and consequences and to alleviate the negative effects through mitigating measures. This framework leads to the necessity of evaluation the effects of flooding, the zoning of endangered lands and the quantification of risks. These aspects act as indicators of potential consequences associated with different flood scenarios, so it is mandatory to establish flood risk management plans, which define protection levels and identify integrated prevention measures, without neglecting environmental issues, namely soil protection, land use planning and nature conservation. In the water resources planning and territorial management tools, namely the Municipal Master Plans it is critical the delimitation and zoning of areas prone to flooding, corresponding to different recurrence rates, as the essential basis to the planning process of land use, to enhance the resilience of the territories. As case study, is presented the the delimitation of flooding areas in Almeirim municipality.

1. Introduction

The risks associated with climate change, including those resulting from extreme hydrological phenomena or the possible mean sea level rise, leading to floods, may put at threat the functional balance of those systems and represent a challenge to the resilience of the territories. The concept of resilience has diversified and come to have more than one meaning, and the resilience perspective began to influence fields outside ecology. In recent years the concept of resilience has been introduced in flood risk management (De Bruijn and Klijn, 2001).

The occurrence of floods, while natural phenomenon, can jeopardize the safety of persons, goods and the environment, so it is essential to reduce the risk and the consequences that are associated, by mitigating negative effects through prevention and mitigating measures (Decree-Law no. 115/2010 of 22 October). On the other hand, omissions in the planning process and pressures for the use of marginal lands have led to more aggravated situations. In this framework it is necessary to evaluate the effects of floods; for that the areas prone to flooding should be delimitated and the risks must be quantify. These factors are indicators of potential consequences associated with different flood scenarios (high probability, to periodicity less than 100 years; average probability for frequency exceeding 100 years; and, low probability, to extreme phenomena). It is fundamental to establish flood risk management plans, which define levels of protection and prevention, integrated measures identify to mitigate risk, not forgetting the environmental issues secured in the Water Law (Law no. 58/2005, of 29 December), including soil protection, land use planning and nature conservation.

The Water Law, in what concerns protective measures against flooding, establishes the duty of delimitation of flood prone areas, vulnerable to floods, in the water resources planning instruments and in territorial management. In a preventive perspective, endangered by floods areas are considered as areas of

[1]Assistant Professor. University of Algarve. Campus of Gambelas - Faculty of Sciences and Technology. 8005-139. Faro. Portugal. E-mail address: cmantunes@ualg.pt. Tel. +351966376087. Fax +351289800066

[2]Associate Professor Aggregate. Instituto Superior Técnico. Avenida Rovisco Pais 1, 1049-001. Lisboa. Portugal. E-mail address: m.azevedo.coutinho@ist.utl.pt. Tel. +351966709969. Fax +351218418156.

[*]Corresponding author. E-mail address: cmantunes@ualg.pt (C. Rolo)

risk, to be integrated in the National Ecological Reserve, for the mitigation of natural hazards.

This work intends to analyze how concepts such as resilience, risk, vulnerability and mitigation relate themselves, in the context of flood risk management, evaluating simultaneously the role of planning instruments, particularly at the municipal level, in the promotion of resilience of the territories, to extreme water events, and the character of the population adaptive capacity (Vis et al., 2001).

In terms of water resources, namely in municipal plans, the delimitation and zoning of flood areas are essential for different frequencies of occurrence, because they are fundamental for the planning and land management process planning, and induce the resilience of the territories. As a case study, the delimitation of flood areas, corresponding to the frequency of occurrence of once in 100 years (return period of 100 years) for the municipality of Almeirim is presented.

The developed map represents the areas potentially subjected to centennial flooding, constituting a fundamental instrument, because it shows a conditioning factor to soil use and occupation. It works as element of consciousness and alert for the population and supports the decision-making process, thus contributing to increase the resilience of the territory of the municipality of Almeirim.

2. Conceptual Framework

2.1. Resilience in the context of flood risk management

The word resilience derives from the latin "resilio", which meaning return to a previous state, rebound, recoil. It is a concept arising from physics, and refers to the property of a body to regain its original shape after suffering shock or deformation.

Although the concept of resilience was been for a long time of domain of ecology sciences (Holling, 1973), the review of the literature showed that in nowadays there exist more definitions and types of resilience, for example social resilience, engineering resilience (Adger, 2000; Dauphiné and Provitolo, 2007; Folke, 2006). De Bruijn and Klijn (2001) has been introduced the concept of resilience in flood risk management.

The definitions of concepts have important implications in the choice of methodologies and tools as well as in the results of vulnerability assessments and resilience of territories.

The resilience being the ability of a system to absorb disturbance and reorganize itself, while subject to adverse requests, keeping the bulk of its functions, structure, identity and mechanisms (Holling, 1973; Walker et al., 2004), it is considered that the planning and land-use management is a tool which allocating the various functions and uses to territorial units, can enhance losses and damage reduction, contributing to risk management and to the consequent increment of its robustness.

It is measured by its resistance and rapidity of return to equilibrium (Pimm, 1991). So the resilient territories while less vulnerable, are more prepared to deal with disruptions and changes, so it is essential to adapt them, as well as frame populations for different scenarios. Adaptability, as component resilience, is one of the factors favouring resilience promotion.

The mitigation of the adverse effects, while risk prevention measure and the reducing the territories' vulnerability to extreme phenomena, such as floods, constitute methods of risk management, which should include the analysis of different scenarios of flood incidence (high probability, to periodicity less than 100 years; average probability for frequency exceeding 100 years; and low probability to extreme phenomena).

Resilience, while attribute of a system, manifests itself as a tolerance capacity to a security threshold which is considered critical. Recognizing that threshold, measures and actions can be proposed and established, related by land planning instruments, assessing the distance between the system state and its holding capacity, and then keeping the system in a controlled condition.

It is important to consider on the resilience concept in communities' accommodation to changes and alterations of territories, in a multidisciplinary approach, considering the territory as a complex system susceptible to threats. To adopt an integrated perspective on territorial approaches, involving local communities is the best approach at this scale (Serre et al., 2013). This allows a closer approach to the reality and the ability to act in due time and an interaction with agents of different backgrounds (stakeholders); however, this requires a multilevel governance system for effective decision-making.

2.2. Land planning tools and risk management

Land planning policy is based on a territorial management system organized in three levels - national, regional and municipal - and takes place through a body of action instruments (Law no. 48/1998, of 11 August, as amended by Law no. 54/2007, of 31 August).

At the national level, the National Programme for Land Planning Policy defines the model for territorial development of the country, in the long term, considering the risks and vulnerabilities as components of territorial model, giving priority to the prevention and management of risks, pointing to, among others, the risks of floods and inundations. In this framework, the preventive management of risks is considered mandatory in other levels of management, imposing the assessment and prevention of factors and situations of threat, and the implementation of measures to mitigate their effects.

At the regional level the different types of threats are defined and according to the objectives and criteria for each type of plan, the areas of danger, compatible uses, in these areas, and the measures of prevention and mitigation of risks must be identified.

The Municipal Master Plan is a management tool, with binding nature, through which the municipality integrates and articulates the guidelines established by the territorial management instruments of national and regional levels in its development strategy and spatial organization model in the municipality, namely in terms of land-use options, preventing the occupation of areas of greater susceptibility to threats. The Municipal Master Plan is also a reference tool for other municipal plans, and in particular to the urbanization plans and the detail plans.

It should be noted that the administrative boundaries do not restrict the impact of risks, so, the preventive approach, multi-

Figure 1: The study area in Portugal and Almeirim municipality

Source:Authors

disciplinary, must assume supra-municipal character, i.e. at the level of the inter-municipal land-use planning.

Finally, it should be referred that some of the objectives of the National Ecological Reserve (Decree-Law no. 116/2008 of 22 August, as amended by Decree-Law no. 239/2012, of 2 November) is to prevent and reduce flood effects, contributing to adaptation to climate change and for the security of people and goods. Areas threatened by floods, while areas for the prevention of natural risks, are integrated in National Ecological Reserve, who has to be delineated in conditioning' maps of the Municipal Master Plans.

In this framework, it is considered essential to develop municipal flooding maps, because the delineation and zoning of these areas, for different flooding frequencies, constitutes an essential tool for risk management and, consequently, to improve the resilience of the territories to flooding.

3. Municipaly of Almeirim - the Case-Study

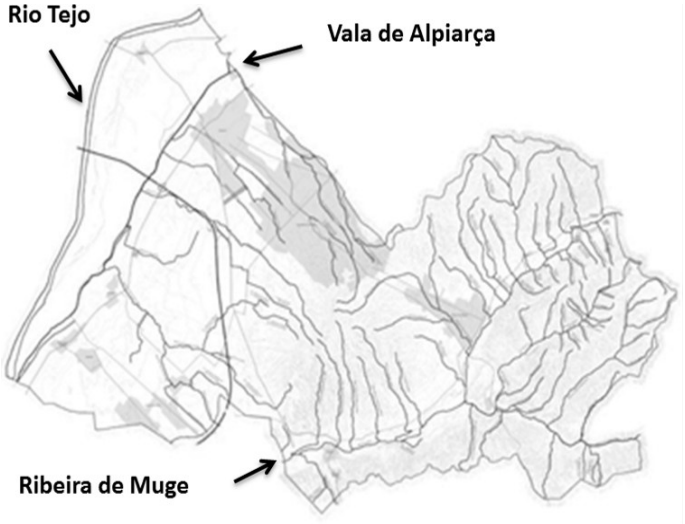
3.1. Study area

The study area is the municipality of Almeirim, with four parishes (Fazendas, Raposa, Benfica do Ribatejo and Almeirim), located approximately about 70 km from Lisbon (Figure 1).

For a case study the municipality of Almeirim was adopted, because it is an area in the alluvial plain of the Tagus river with drainage problems and very prone to flooding. Although flooding was a very frequent phenomena in this area recently there is less awareness of the population. This municipality, with an area of approximately 222 km^2, belongs to the NUT III-Lezíria do Tejo and is part of the catchment area of the river Tagus, covering the sub-basins of the streams ribeira de Muge and vala de Alpiarça (paul or ribeira de Ulme), as show in Figure 2.

The river catchment of ribeira de Muge covers the eastern area of the municipality, including almost all of the parishes of Fazendas and Raposa, having as main tributaries the streams of vale de João Viegas, vale de Figueira, vale das Casas and Calha do Grou. The watershed of vala de Alpiarça covers much of the parishes of Benfica do Ribatejo Almeirim and a small part of the parish of Fazendas, having as main tributaries the vala do Meio and the streams of Vale da Fonte Moça, Falhão, Vale da Mina and Vale da Pataia.

Figure 2: network in Almeirim municipality



Source:Authors

3.2. Material and Methods

Fieldwork was carried for the study and the information available was collected and analysed. In particular the following elements were used:

- Military maps 1: 25,000 scale, from Instituto Geográfico do Exército;
- Topographic maps 1: 10,000 scale;
- Master plan for Tejo's river catchment;
- Management plan for Tejo's river catchment;
- Rainfall and hydrometric data;
- Corine Land Cover maps;
- Geological and soil cover maps;
- Survey of water courses, flood marks, land occupation, geomorphological, soil and topographic characteristics in the municipality.

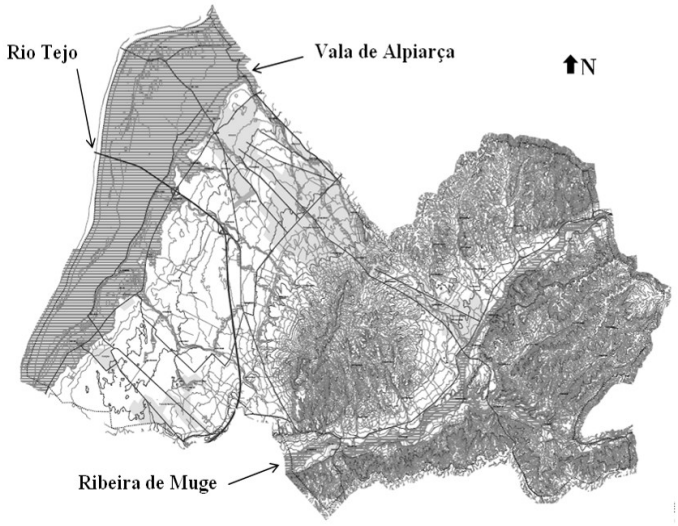
The analysis of hydrological conditions was made considering the different characteristics of the zones of the municipality of Almeirim. The type of occupation of the territory, the geomorphologic features, topographic and soil characteristics of the municipality and the information available about flooding (records of historical events) were considered.

The modeling of the flow conditions were simulated using one-dimensional model, HEC-RAS (US Army Corps of Engineers, 2010), for variable regime, based on the estimated flow discharges for a return period of 100 years, the corresponding hydrographs, the digital terrain model and, as boundary conditions, the water levels of 12.16 and 9.97 m (water levels for the flood of 1979, respectively in Porto da Courela and Benfica do Ribatejo).

Figure 3: Flood of 1979 - registry of water levels

Source:Authors

Figure 4: Flooding area map for the municipality of Almeirim



Source:Authors

For the validation of the results obtained with this simulation, a comparison was made with the flooding marks. In Figure 3 shows some examples of flooding marks, registered in 1979, namely in Porto da Courela (rural area) and in Almeirim (urban area).

For the delimitation of areas threatened by flooding the most unfavourable water levels resulting from the comparison of model results with maximum water levels, registered in 1979, were adopted (Tapada - 12.07 m; Almeirim - 11.87 m; Mouchão de Santa Marta - 9.98 m).

3.3. Results and Discussion

The delimitation of the areas threatened by floods, for the municipality of Almeirim, is represented in Figure 4

The analysis of Figure 4 shows that the flood areas in the municipality of Almeirim focus essentially on lowland zone, located between the vala de Alpiarça and the Tagus river, where the land is almost flat, and the alluvial valley of ribeira de Muge. These areas occur primarily in rural land, where agriculture is predominantly the land use and where the losses and risks are not as high as it would be in urban areas.

In what concerns human-induced changes, over time, the drainage network has remarkable differences between rural and urban land. In rural areas some of the water courses have suffered significant changes due mainly to stream constriction inherent of pressure from cropland (i.e., the planting of vineyard). In urban space most water courses that flow across the urbanized land were artificialized, and in many reaches they have been covered, increasing locally the frequency of flooding, for periods of intense rain showers.

4. Conclusions

Recently, the resilience focuses upon the vulnerability of physical structures to natural disasters, forecasting the risk of catastrophic events and their social and economic implications. So, in this context new strategies must be envisaged for managing risks and be considering spatial and territorial aspects of resilience in local and regional development and planning.

The mapping of flood areas is considered crucial at municipality level, because the delineation and zoning of flooding areas, for different return periods, constitutes an basic tool in the process of land use planning, as it represents a limitation factor to soil use and occupation. It works, also, as a sign of awareness and warning to the population, and as a tool for risk management and support of the decision-making process, thus contributing to the increase the resilience to flooding.

Assessing a critical resilience threshold, in a territory, while a complex system and susceptible to threats, can lead to the establishment of measures and actions, framed to land planning tools. This threshold provides a measure of the difference between resilience, while a system attribute to support impacts, and its own holding capacity, ensuring it greater vulnerability and preparedness to cope with disruptions and changes.

It should be noted that the major constraints on the water courses are the result of adjacent land use pressures, both in rural or urban areas, designed primarily to provide larger space for occupation by different uses and that, and that the covering of water courses, in urban areas, lead to decrease the resilience of the territory, for flooding events.

Land planning approaches must present an integrated and multidisciplinary nature, involving local communities, because it is the level that best meets its reality, provides greater opportunity to act and which is closer to agents of different kinds (stakeholders). The process must be also associated with a system of multi-level governance of effective decision-making.

A resilience flood risk management strategy must considers measures to reduce the impacts of flooding, such as the design of warning systems and evacuation plans and the application of spatial planning and building regulations . Resilience strategies may also include measures to accelerate the recovery after a flood, e.g. compensation regulations and insurances (Vis et al., 2003).

In the study case the flood areas occur mainly in rural land, predominantly with agriculture and the potential losses and risks are not as high as it would be in urban areas. The human-induced changes, over time, created remarkable differences in

the drainage network for rural and urban land. As, in rural areas some water courses suffered significant constriction, inherent of pressure from cropland, in urban space a high degree of artificiality is observed, and even in some drainage reaches the channels were covered, leading to greater frequency of flooding and decreasing resilience.

References

Adger W. N. (2000) Social and ecological resilience: are they related? *Progress in Human Geography* 24 (3), 347-364.

Dauphiné, A. and Provitolo, D. (2007) La résilience: un concept pour la gestion des risques. *Annales de Géographie* 654 (2), 115-125.

De Bruijn, K.M. and Klijn, F. (2001) Resilient Flood Risk Management Strategies, *Proceedings of the IAHR congress*, 16-21 September, Beijing China, 450-457.

Folke, C. (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16, 253-257.

Holling, C. S. (1973) Resilience and stability of ecological systems. *Annual Review of Ecological Systems* 4, 1-23.

Pimm, S.L. (1991) *The Balance of Nature? Ecological Issues in the Conservation of Species and Communities.* Chicago: University of Chicago Press.

Serre, D.; Barroca B. and Laganier, R. (2013) *Resilience and Urban Risk Management.* London: Taylor & Francis Group. ISBN 978-0-415-62147-2.

US Army Corps of Engineers (2010) HEC-RAS River Analysis System ? User's manual. Institute for Water Resources [online]. Hydrological Engineering Center. Davis. Available from: http://www.hec.usace.army.mil/ [Accessed 6 December 2013]

Vis M.; Klijn F. and Van Buuren, M. (2001) *Living with floods: Resilience strategies for flood risk management and multiple land use in the lower Rhine River basin.* Delft: NCR.

Vis, M.; Klijn, F.; De Bruijn, K.M. and Van Buuren, M. (2003) Resilience strategies for flood risk management in the Netherlands. *International Journal of River Basin Management* 1(1), 33-40.

Walker, B.; Holling C. S.; Carpenter, S. R. and Kinzig, A. (2004) *Resilience, adaptability and transformability in social?ecological systems. Ecology and Society* [online]. Available from: http://www.ecologyandsociety.org/vol9/iss2/art5/. [Accessed 20 November 2013]

Legal Appendix

- Decree-Law no. 115/2010. "D. R. 1ªSérie" 206 (10-10-22) 4757.
- Decree-Law no. 116/2008, "D. R. 1ªSérie" 162 (08-08-22) 5865.
- Decree-Law no. 239/2012, "D. R. 1ªSérie" 212 (12-11-02) 6308.
- Law no. 48/1998. "D. R. I Série-A" 184 (98-08-11) 3869.
- Law no. 54/2007. "D. R. I Série-A" 168 (07-08-31) 6074.
- Law no. 58/2005. "D. R. I Série-A" 249 (05-12-29) 7280.