Comprehensive Flood Risk Management – Klijn & Schweckendiek (eds.)

City, climate change and floods. A contribution to the urban resilience study

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Keywords: *Urban Resilience, Climate Change, Flood Risk, Urban Planning, Flexibility, Adaptive capacity.*

ABSTRACT: According to the most recent climate change scenarios, regarding greenhouse gases anthropogenic emissions, the frequency and intensity of extreme precipitation events will increase in mid-latitudes. These changes of climate regime might raise the number of floods in those regions, increasing the devastating effects in societies and environment.

For the Iberian Peninsula, the majority of studies indicate a rainfall decrease during the winter months and an increase during the summer; however more frequent and concentrated extreme events of precipitation are expected in some parts of the Peninsula. This paper presents the main methodology and first finding of a PhD research that has as one of its objectives, the assessment of extreme precipitations on climate change scenarios in the Metropolitan Area of Lisbon – Portugal- as a way to gather the necessary information to evaluate the resilience of at least two urban areas. For the propose of this paper the focused study area is one of Lisbon's suburbs – *Cacém* – located in the middle of a stream that has historical events of flash floods.

The approach of resilience assessment, in this context, is based and adapted from previously validated and published methodologies, which can be subdivided in historical approach, creation of a conceptual model of the system and future alternative system regimes. To evaluate the specific case study one methodology is used, developed in the project "Sustainable Land Use Policies for Resilient Cities" (SUPER-CITIES), under the scope of the Urban-Net European Network on urban resilience. This study developed a comprehensive assessment methodology, based on urban planning evaluation.

1 INTRODUCTION

This article is part of an ongoing PhD research integrated within three major investigations. The first one was held between 2008 and 2010 and is called "Sustainable Land-Use Policies for Resilient Cities" (SUPER-CITIES) developed under the scope of the Urban-Net European Network; the second is called "Floods and Flood Risk Maps in Climate Change Scenarios" (CIRAC), developed in collaboration with the Portuguese Insurance Association, and finally, the third is called "Urbanized Estuaries and Deltas. In the search for comprehensive planning and governance. The Lisbon case." under development and supported by the Portuguese Foundation for Science and Technology. (FCT).

The objectives of the PhD research consists on assessing the impacts of climate changes within the Lisbon Metropolitan Area and evaluate the resilience of at least two urban areas located it two different catchments. Those areas, as well as the northern part of Lisbon Metropolitan Area, are characterized by small catchments were flash floods are common and a result of a couple of hours of precipitation, occurrences with flow rates of approximate 5 and 10 $m^3/s/km^2$ (Santos and Miranda 2006).

2 CLIMATE CHANGE AND MODIFICATIONS IN EXTREME RAINFALL EVENTS

Some Portuguese winters tend to be extremely rainy. This includes situations of torrential rain regimes in some areas. In recent years two episodes were exceptionally severe in the study area.

The winter of 2010 was one of the wettest, according to records of several weather stations throughout Portugal, as well as the wettest winter ever recorded in Lisbon with an annual total precipitation of 1598 mm. This corresponds to the highest value registered since the observations started in the Geophysical Institute - Lisbon weather station (Instituto de Meteorologia 2010). Not only this was the rainiest year but also the winter with most rain ever registered, i.e. between December 1st 2009 and March 31st 2010 the precipitation recorded in Lisbon was 958.6 mm, corresponding to the maximum value observed between 1865 to 2010 (Figure 1). At the same time it was verified that the number of days with rain was below average (Vicente-Serrano, Trigo et al. 2011).

Two years before, on February 18th of 2008, the same weather station recorded a maximum daily precipitation of 118 mm. Other stations in the Metropolitan Area of Lisbon such as *Loures* (137.6 mm), *Lisbon/Benfica* (150.3 mm), *Caneças* (116 mm) and others, also recorded very high values of precipitation for that day, but the time series are not as long as in Geophysical Institute. Note that this atmospheric episode had about 6 hours of duration (Moreira, Silva et al. 2008).

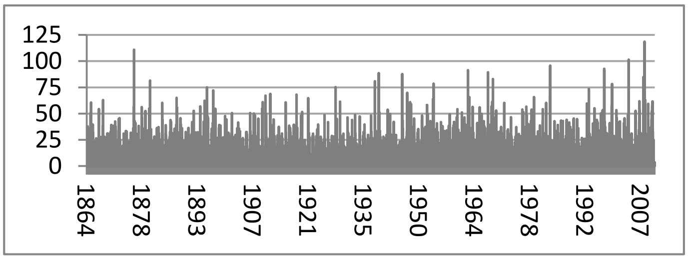

Figure 1. Precipitation between 1865 and 2010 registered by the Geophysical Institute station. Source: Geophysical Institute - Lisbon

These two episodes do not translate into climate change is a reality. We can't even conclude that this is a tendency in the climate of the area, but it can be a beginning of something.

Same authors argue that change in rainfall have a direct relationship with temperature, being accepted by the scientific community, that increases in rainfall in middle latitudes that are around 6% for each 1.8 ° C rise in surface temperature (e.g. Kharin, Zwiers et al. 2007).

According to generic climate change scenarios, the frequency and intensity of extreme precipitation events will increase in middle latitudes regarding greenhouse gases anthropogenic emissions (Groisman, Knight et al. 2005; Min, Zhang et al. 2011).

Recently, some studies concluded that climate warming is already causing extreme weather events that affect large areas of the north hemisphere. This is formally identified as a human contribution to the observed intensification of extreme precipitation events (Min, Zhang et al. 2011; Pall, Aina et al. 2011). These same studies also prove that the previous climate models, may have underestimated the observed trend in extreme rain, which imply that is possible that climate change may be the cause for doubling the risk of severe floods events (Min, Zhang et al. 2011; Pall, Aina et al. 2011), namely through more frequent river floods, urban inundations and other similar hazards.

But the study of climate change isn't a new field and some conclusions can be retrieved from literature. The changes in precipitation, namely in extremes is usually assess by the calculation of return periods for a given precipitation values. This is done for past and present situations and compared with the return period of future climate change scenarios under analysis. A return period consists in the average interval between events of the same magnitude. This kind of approach was applied to global climate models and concluded that "the probability of heavy daily precipitation increases by more than 50% in many locations" all over the world (Hennessy, Gregory et al. 1997).

Those studies were also done for specific areas, catchments or countries all in different parts of the globe, although with different conclusions (see e.g. Park, Kang et al. 2011; Eum and Simonovic 2012).

The majority of studies related to climate change accomplished to or covering Portugal, show a small rainfall increase in the warmer months, decreasing in some models, the global precipitation in general and during the winter (Santos and Miranda 2006; Bladé, Cacho et al. 2010). Although it is expected that episodes of intense rainfall will be more frequent and concentrated in time for some Portuguese areas (IPCC 2007; MAOTDR 2009; IPCC 2011). The Metropolitan Area of Lisbon is in a transition zone between the middle latitudes and a more Mediterranean climate, where uncertainties in climate change scenarios related to extreme precipitation are more significant (Hennessy, Gregory et al. 1997; IPCC 2011; EEA 2012).

As we know, the future projections related with Climate Change are defined through greenhouse gases emissions scenarios, based on future assumptions of demographic, economic and technological evolution. Subsequently, subdivided into four major families commonly identified as A1, B1, A2, B2 which integrate information contained in about 40 evolution scenarios (IPCC 2000).

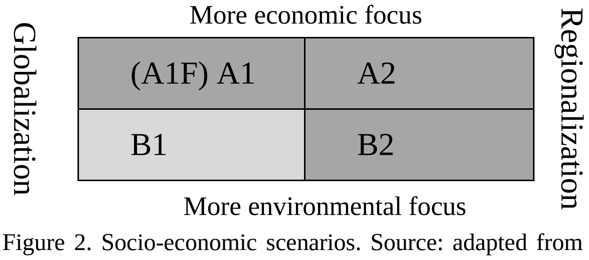

Figure 2. Socio-economic scenarios. Source: adapted from IPCC 2007

The general circulation models (GCMs) are obtained with information on emissions of greenhouse gases in each of those scenarios. The GCM's have global climate information (e.g. temperature, atmospheric pressure, cloudiness, humidity) for different future periods. This information is generally aggregated into a grid with a spatial resolution of 300x300 km horizontally and with a multilevel vertical grid (Santos and Miranda 2006).

The scenarios defined by GCMs create great difficulties of analysis for relatively small areas such as the Metropolitan area of Lisbon and obviously, the catchments under analysis. These difficulties are even more significant in places where the geography of the region is responsible for specific phenomenas such as orographic rainfall event (Santos and Miranda 2006). To overcome this difficulty, the GCMs are regionalized for a smaller horizontal resolution ranging from 30 to 50 km or even for a specific meteorological station (Lopes 2008).

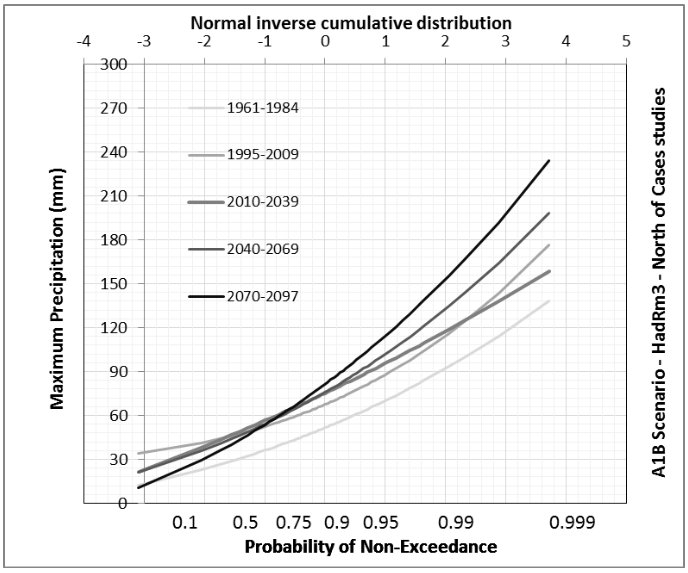

Figure 3. Pearson III distribution adjusted to regionalizes HadRm3 – A1B climate change scenario for the study area. We see an increase tendency of maximum precipitation for different recurrence intervals in the 2040 -2069 and 2070-2097 periods. Source: own production.

In this PhD, the Regional Climate Model is used, developed by the Met Office Hadley Centre (HadRM3) with projections at the medium emissions scenario A1B, complemented with two statistical base regionalization obtained from the GCM HadCM3 scenarios (A2 and B2).

For the Lisbon Metropolitan Area, and more specifically for the first study area (Figure 4), other regionalizations are already available for some socioeconomic scenarios (Aguiar and Domingues 2009; Aguiar 2010). Nevertheless, the available information is insufficient for this study since it lacks the necessary detail in daily rainfall values. This information is fundamental to evaluate and identify the future extreme rainfall characteristics and the respective return periods necessary for hydrological modeling of floods (Santos and Miranda 2006). With this objective, it was developed by the Climate Change Impacts Adaptation and Mitigation research group (www.sim.ul.pt/cciam) a statistical base regionalization obtained from the GCM HadCM3 scenarios. This work was developed within the project "Floods and Flood Risk Maps in Climate Change Scenarios", and the A2 and B2 socioeconomic scenarios were analyzed. The initial results suggest that for the study area, the return periods of rainfall are decreasing in B2 and A1F scenario (see Figure 3). The results of the regionalization for extreme precipitations will be analyzed under this PhD, using a partial-duration series approach for data provided from dynamic downscaling A1F and statistical downscaling A2 and B2 available for the study area as mentioned.

Figure 4. Location of *Cacém* in *Barcarena* catchment. The first case study area under analysis in Metropolitan Area of Lisbon (in white the *Jardas* or *Barcarena* stream). Source: own production.

3 EVOLUTION OF RESILIENCE CONCEPT

The resilience concept was originally defined as a "measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling 1973).

Timmerman (1981) was one of the first authors that defines the concept of resilience, providing a direct link between climate change and society. Later on, this connection was done through the integration between ecology and society, which defines a socio-ecological system. For this author resilience appears as a capacity of a system to adapt to stress or risk, as well as the ability of that system to quickly recover from those impacts.

More recently, Carpenter *et al.* (2006) define resilience as the ability to face adversity, determined by the magnitude of the transformation or exogenous disturbance that a system can experience without suffering a change of regime, taking into account the conditions, functions or specific processes of that system. This can be translated into the ability that a given system has to self-organize, build and increase their ability to learn and adapt.

Godshalk (2003) synthesizes the characteristics of a resilient city to different hazards were floods are included thought attributes, being redundancy, diversity, efficiency, autonomy, adaptability and collaboration.

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The project "Sustainable Land Use Policies for Resilient Cities", which is based on several sources, refer adaptability, capital building, complexity, connectivity, flexibility, recovery and transformability as the more relevant attributes to evaluate urban resilience (P. Pinho (coord), Martins et al. 2010). Based on this experience, the evaluation of urban resilience in the *Cacém* case study is analyzed through the flexibility attribute.

Golden (2000) defines flexibility "as the capacity to adapt across four dimensions; temporal, range, intention and focus. These dimensions define areas within which flexibility can be achieved. The extent of flexibility can be measured by its metrics; efficiency, responsiveness, versatility and robustness."

Related to climate change and resilience to flooding in urban areas, Djordjević et. al. (2011) refers several initiatives in this research field; namely the AMICE project – Adaptation of the Meuse to the Impacts of Climate Evolutions, the FRC – Flood Resilient City or the project FLOODsite (Figure 5).

4 METODOLOGY USED FOR URBAN RESILIENCE EVALUATION

The application of methodologies for assessing the resilience of socio-ecological systems applied to urban areas in an urbanism perspective is a relatively recent exercise. In this sense, the absence of many sources is proved, being almost unavoidable to use the information provided by Resilience Alliance (http://www.resalliance.org/), as one of the first research group that explores the dynamics of complex adaptive systems were urban resilience is included.

This research group proposes a strategy for evaluating resilience through sequential responses of several criteria, grouped into three main topics:

i) Definition and understanding of the system. This task consists on the definition of the area of analysis for a particular event. This implies the identification of the stakeholder's main concerns, , the recognition of major disturbances affecting the system, the identification of historical periods that have changed the system, the major policies and measures that were implemented, etc.

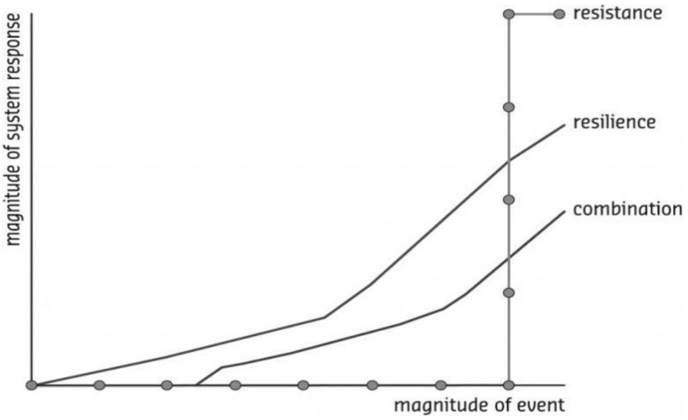

Figure 5. Representative scheme of the combination of factors of resilience with resistance factors. Source: FLOODsite 2009.

In this point of the assessment, the period between 1960 to present will be considered, resorting the identification and evaluation of policies and measures with direct or indirect influence to flood risk prevention and protection of streams and rivers (e.g. National Agricultural Reserve, National Ecological Reserve, River basin plans, National Strategies for Climate Change, Municipal Master Plans, etc.);

ii) Assessment of resilience. This step subdivides primarily in the development of conceptual models of the system and secondly in the definition of alternative systems regimes.

At this point, the hydrological modeling of the catchments under analysis and the assessment of flood risk, in the affected urban areas, is essential.

Risk analysis integrated with the conclusions from point i) will be the information needed to the definition of alternative regime systems.

According to Resilience Alliance consortia, at least two future alternative regimes of the system must be considered. In this study will be used three different climate change scenarios. As mentioned, the flood and risk analysis will be evaluated using A2, B2 and A1F regionalized climate change scenarios.

It's important to note that these scenarios are not a forecast but a future possibility under certain circumstances, allowing the evaluation of the processes and dynamics that can lead the system under study towards a particular trajectory (Resilience Alliance 2007).

iii) Finally, it proceeds to an enumeration of the implications verified for the management of floods of the system under evaluation.

Since this methodology has been successfully tested in some studies, although with different objectives, (see e.g. Ruth and Coelho 2007; Rescia, Pons et al. 2008) it will be used to assess the resilience, in this work, but with some adjustments arising from the effective application, as verified and previously tested in other projects (P. Pinho (coord), Martins et al. 2010).

4.1 *Historical approach*

When we try to understand Portuguese reality within an historic perspective, related to the topic of flooding three main moments of rupture of socio ecological systems can be observed.

The first is directly linked with the end of the dictatorial regime in 1974. This is a turning point since the floods with greater human and material losses in the Metropolitan Area of Lisbon happened in 1967 and this episode was masked by the regime. Few changes were made apart from some legislation concerning floodplains protection, although without any practical consequence (Rebelo 2008).

The study of floods and subsequent delineation of areas affected to this phenomenon started more systematically after the flash flood that affected the Lisbon area in 1983. This episode had significant economic and social consequences, being profoundly studied for several catchments (including the two principal case studies of this PhD - *Barcarena* and *Lage* streams). The first delineation area were construction was banned is defined only in 1986, although since 1971 the National Law provided that possibility. The catchment with the first area of protection was the *Lage* stream, located in the Metropolitan area of Lisbon (Saraiva, Correia et al. 1998).

Although, in that year, and in later years, the situation of floods in *Barcarena's* stream happened with consequences in *Cacém*, the floodplain area was not defined until the present. Recently, the entire downtown area of this city was renewed under the so called *Polis Program*, under a policy of environmental enhancement and city rehabilitation. This intervention includes the regularization of the *Jarda* stream and the creation of a retention basin among other modifications in the floodplain (MAOT 2000).

The period between 1983 and 1986 can be considered the second rupture period, since it definitely changed the way that National Authorities look at the flood phenomenon. . The Portuguese admittance to the European Union (EU) in 1986 can't be forgotten because it marks a paradigm shift in these issues. The framework for European Community action in the field of water policy (Directive 2000/60/CE) promotes a comprehensive and integrated protection and management of water resources and is an example of the importance of the membership of Portugal in EU.

Floods and flood risk are a growing concern of EU Institutions which have promoted several studies and established regulations around this subject (see e.g. Schmidt-Thomé, Kallio et al. 2006; EEA, WHO et al. 2008; Sec 2010).

The European Directive 2007/60/EC is one of the most important examples, being transposed into the Portuguese National law by Decree-Law 115/2010 approving the framework for the assessment and management of flood risks. This Decree-Law regards climate change as a factor to be taken into account in assessing the occurrence of floods.

Concerns about climate change are also growing in Portugal. This concern is illustrated by the approving of the National Strategy for Adaptation to Climate Change in 2010 (MAOTDR 2009). The period between 2007 and 2010 can be considered the third moment of rupture in the system because it is the first time that is obligatory to consider the risk of flooding in the studies and also the first concerns emerge concerning the impacts and adaptation measures related to climate change at a Political level.

4.2 *Creation of a conceptual model of the system*

In Portugal and especially in areas with high population density such as the Metropolitan Area of Lisbon, the planning structure is strongly marked by a top-down policy. The top-down structure means that the different levels of Planning are well defined and unfortunately the decision chain is highly rigid (the different levels of planning with preponderance in Portugal are the European one, although there is no actual EU competence for spatial planning but their influence is undeniable through sectorial policies and the National, Regional and Local or Municipal level). At different levels Portuguese governance has several agents and public organizations with urban management and water related competencies. There is also several overlapping jurisdictions which do not facilitate a decision, raising questions regarding governance issues (DGOTDU 2004).

Contrary to other European countries, the water and flood related interventions still have a perspective of flood defense, adopting structural measures such as river channel regularization or other engineering measures. Although other approaches like catchment management to increase water retention begin to appear, we are taking the first steps in the flood management and flood risk management areas (PNPOT 2007; Rebelo 2008).

4.3 *Future alternative system regimes*

Creating future alternative system regimes aims to realize the main changes that can be predictable in the study areas. This analysis will be conducted considering two key points. The hydrological modeling for different return periods in the present and at alternative climate change scenarios (A1F, A2, B2 as mentioned before) for two different periods (2050 and 2100). The hydrological modeling will be followed by flood risk assessment for these three periods with proper evaluation of the results. This evaluation has the initial assumption of stability in urban functions and built-up areas in order to simplify the analysis, assuming the uncertainty that this decision carries.

4.3.1 *Hydrological modeling*

The MOHID program will be used to perform the hydrological modeling, developed by the Marine

Environment & Technology Center of the Instituto Superior Técnico – TU Lisbon (www.maretec.org) and Action Modulers, (www.actionmodulers.pt). MOHID was initially created for the study and simulation of flows in coastal and estuarine waters (Neves 1985). Using mathematical models, this program is capable of simulating runoff, transport through the drainage network and the infiltration and saturated of soil (Trancoso, Braunschweig et al. 2009), being a typical 3D hydrodynamic model, in constant development.

The aim of this work is the evaluation of flash-floods with durations between 4 to 6 hours. To do so, the 2D hydrological modeling will be used which use the Green-Ampt approach. This option avoids the complexity associated with analysis of fluid dynamics in porous media, reducing substantially the time processing, being the most common form of flood modeling (See e.g. EXCIMAP 2007).

MOHID is an explicit model, i.e. for each period of time – *t*, the result depends on the conditions of the grid in *t-1*. As an explicit model it must hold into account that the time step must be below a certain time period, otherwise the simulation will produce inaccurate results. The time step adjustment should have in attention that during a time period, the volume of water out of a cell cannot be higher than the volume at the beginning of the time step.

To find the appropriate value for the time step it is crucial to consider the Courant-Friedrichs-Lewy condition, which is strongly influenced by the size of the grid cell implemented in the model (Altinakar, McGrath et al. 2009). Consequently, to guarantee the stability of the model with a given grid (x, y) it should be taken into account the formula described in (1) where μ is the velocity of wave propagation in water as a result of $\sqrt{g * h}$, being g the gravity (9.80665 m/s²) and h the water height. In the same formula Δx is the grid size in the x-axis, Δy is the grid size in the y-axis and C is the constant Lewy Courant-Friedrichs, i.e. 1.

$$\frac{\mu_x \Delta t}{\Delta_x} + \frac{\mu_y \Delta t}{\Delta_y} \leq C \qquad (1)$$

These conditions must be taken into consideration when choosing a particular grid size, because the calculations and number of iterations rely in the conditions defined above. In other words, the smaller the grid used in the digital terrain model, as well as other inputs needed, the lower associated time step is necessary to fulfill the Courant–Friedrichs–Lewy condition.

This is the main reason to choose a 20 x 20 meters grid size to model both *Barcarena* and *Lage* catchments. Therefore, a commitment to achieve the best detail possible is made, for a reasonable processing time.

The Green-Ampt equation is built-on in MOHID for calculate the infiltration when using 2D modeling.

$$F(t) = Kt + \psi\Delta\theta \ln\left[1 + \frac{F(t)}{\psi\Delta\theta}\right] \qquad (2)$$

Where F is the total volume already infiltrated t is a time step, K is the hydraulic conductivity of a particular soil type, θ is the quantity of water contained in a particular soil type and ψ is the wetting front suction head (Mays 2005), at the moment al the parameters are used as default values, but the necessary information is being acquired.

At the present time, some tests were already made. The basin was delimitated and a digital terrain model was created. The drainage network was shaped and the different cross-sections are already sized according to Strahler hierarchy. The parameters needed for modeling floods in different types of land use were already introduced in the model, as Manning's Roughness Coefficient or impermeable parameterization. The Urban Atlas from European Environment Agency was the data source that provided the different land uses identification.

Although the model is under calibration and validation, some tests are already possible. In Figure 6 is shown one of those tests, resulting from hourly precipitation values occurred on 2/18/2008.

Figure 6. Maximum water depth result for precipitation occurred in 18/2/2008. At white the delimitation of flood areas occurred in 1983. Source: own production

4.3.2 *Production of flood risk maps*

Floods are responsible for one third of economic losses as a result of natural disasters in Europe, being one of the natural events that most often occurs (e.g. EEA, WHO et al. 2008; De Moel, Van Alphen et al. 2009).

In several European countries, the production of flood risk mapping is usually done using depth-damage curves for different elements at risk. These curves represent the relationship between one flood characteristic (depth, water speed, or duration) and the percentage of potential damage done to a structure or element exposed to that flood (EXCIMAP 2007).

This methodology depends on specific information that can be achieved through historical flood damage events, surveys to affected populations, information compiled by specific entities (e.g. insurance), or through experiences in civil engineering laboratories (Dutta, Herath et al. 2003).

Whereas information is not available or properly systematized, its used an alternative, the evaluation of vulnerabilities, weighting the different elements exposed and producing a qualitative risk map (see e.g. EXCIMAP 2007 pp.125-130). The weight of each variable is obtained using the specific methodologies, such as semi-structured surveys, being the Delphi survey an example (see e.g. Schmidt-Thomé, Kallio et al. 2006 pp.68-76).

Taking into account the exploratory studies performed during the definition of the EU Directive 2007/60/EC on the assessment and management of flood risks, depth-damage curves will be used for the risk evaluation (EXCIMAP 2007; FLOODsite 2009; Meyer, Scheuer et al. 2009; World Bank 2012).

A set of depth-damage curves were selected from reference European studies e.g. MERK-study (Meyer and Messner 2005), according to their suitability to the study area. These curves will be complemented with others, estimated using flood data (e.g., water height) obtained by hydrological modeling of historical flooding episodes and the respective material losses recorded by insurers during the last 11 years. The data available for this study was provided by an inquiry done to Portuguese insurance companies, corresponding to a universe of 57% of the total national floods related to insurances. In total, seven depth-damage curves for different categories from other studies will be considered. The estimated curves will be evaluated in terms of uncertainty using the Monte Carlo method to define the confidence intervals for each curve.

The damage categories analyzed correspond to tangible, direct, primary damage (e.g. walls, contents, and inventory) and the estimated curves refer to walls, home and commercial/services contents.

The pairwise comparison method for multiple decision makers (Malczewski 1999) will be applied to cross the different categories of damage used in the final flood risk map. The weights given by this method and the correspondent matrix will be obtained by the method of Delphi surveys.

The risk analysis will cover different return periods and is complemented by a functional assessment of buildings exposed to flooding.

It remains to note that this approach is pioneering work in Portugal as it adopts depth-damage curves as methodology to create risk mapping. The same methodology will be used to assess flood risk in present days and in different climate change scenarios and the results compared to understand the possible future alterative system regimes.

4.4 *Resilience evaluation in Urban Planning*

Developed under the project “sustainable land use policies for resilient cities” an urban planning based evaluation of resilience was created. These approaches were called Policies, Programs, Plans and Project Evaluation Methodology.

The proposed evaluation methodology consists in a traditional matrix format to make it as simple as possible (P. Pinho (coord), Martins et al. 2010). This approach was created aiming the analysis planning policies to different case studies and doesn’t take into account climate change evaluation. In this first approach the same methodology is used, although with small changes.

The matrix here applied comprises five main columns corresponding to: i) the main attributes of resilience; ii) the dimensions of resilience; iii) the components of resilience; iv) the indicators; and finally v) the main findings of the evaluation (P. Pinho (coord), Martins et al. 2010).

The attribute must reflect a positive quality, such as complexity, connectivity and adaptability (the more the better) but not in the case of vulnerability (the more the worse); they should reflect a dynamic perspective, so that we can easily identify gains and losses (e.g. capital formation, recovery). The attribute should be able to equally cross the four dimensions – economic, social, environmental and governance - and be defined so that overlaps are avoided as much as possible (P. Pinho (coord), Martins et al. 2010).

5 FIRST FINDINGS IN THE EVALUATION OF RESILIENCE IN CACÉM'S POLIS PROGRAM

The recent development of *Cacém* in the context of Metropolitan Area had its genesis in the 60’s of the last century. This reflects the diversification of accessibilities to that area with the creation of IC19 highway. Together with the presence of the railway, linking the territory directly to the city center of Lisbon, *Cacém* grows densely and becomes a dormitory town. In 1998, the *Sintra* municipality states that this process is "characterized by a change in the types of occupation, not supported by urban instruments, resulting in disqualification (…)" of that territory. So

Cacém was characterized by the predominance of high-density housing, where the road structure is dominated by the standoff situations, because the streets were only executed in response to urbanization and immediate interests. This lack of regulation has had consequences for the areas adjoining the *Jardas* stream, occupied improperly and serving only for building rears.

Only in 1999, the Municipal Master Plan of *Sintra* was approved, existing since 1998 a Detailed Plan for downtown *Cacém*. This Detailed Plan evolved to be worked and implemented under the Polis Program in 2003, and reviewed again at the end of this process in 2008 (Portas, Guedes et al. 2011).

The Polis Program is based on a specific management structure (Polis Cacém S.A.) and political-legal simplification, in which the funds needed to implement the objectives of the Plan, were provided by the Community Support Framework III (MAOT 2000).

The main policies/measures listed in the Strategic Plan of the program of urban renewal and enhancement of cities - Polis Program, and evaluated in the context of resilience consist in i) urban redevelopment, ii) restructuring of the road network infrastructure, iii) Mix land uses aiming the integration of tertiary activities and establishing a new metropolitan polarity iv) environmental requalification. The evaluation of the adopted strategies in the environmental requalification is under research in the context of floods and climate change.

The Polis Program as urban policy does not specify actions related to flood control, but the document that supports the intervention in *Cacém*, includes some measures for this purpose (The intervention strategy states: i) “maximizing the infiltration rate”, ii) “riverine system as a linear structuring and element of the new Downtown of *Cacém* - The *Jardas* stream integrating banks and areas adjacent to the stream”) (MAOT 2000).

The *Cacém* case study indicators are mostly obtained from the analysis of the different examined plans, as well as from the evaluation reports performed during the intervention. There are also taken into account, some indicators obtain by quantifying areas in planimetric maps (before the intervention) and in the Implementation of the Detailed Plan Map, assuming for these indicators the cartographic error in the 1:1000 scale. In the future and with the hydrologic modulation of floods under climate change scenario these documents will be reanalyzed for a more comprehensive approach of urban resilience.

The main goals of the intervention aimed the creation of a new centrality in Lisbon’s Metropolitan Area, and the improvement of the urban environment (MAOT 2000).

Underneath the resilience concept two policies/measures, transverse to both documents, were analyzed. i) The first one focuses in urban restructuring, acknowledged as a solving factor of many constrains, and mostly created by the rapid urbanization process, through the improvement of the urban image and public space. ii) The second policy/measure to be analyzed is connected to environmental requalification since it will bring improvements to the welfare of the *Cacém* population and users, as well as promote the mitigation of hazardous situations such as floods and also increase the *Jardas* stream biodiversity (Dias 2010).

i) The first group of indicators is based on the policy/measure of urban renewal, evaluating the flexibility accomplished by the intervention in its environmental dimension, and more specifically in the component of the built environment.

In the formulation of the plan were accounted the surfaces of buildings to demolish and those to maintain. In the implementation phase also accounted

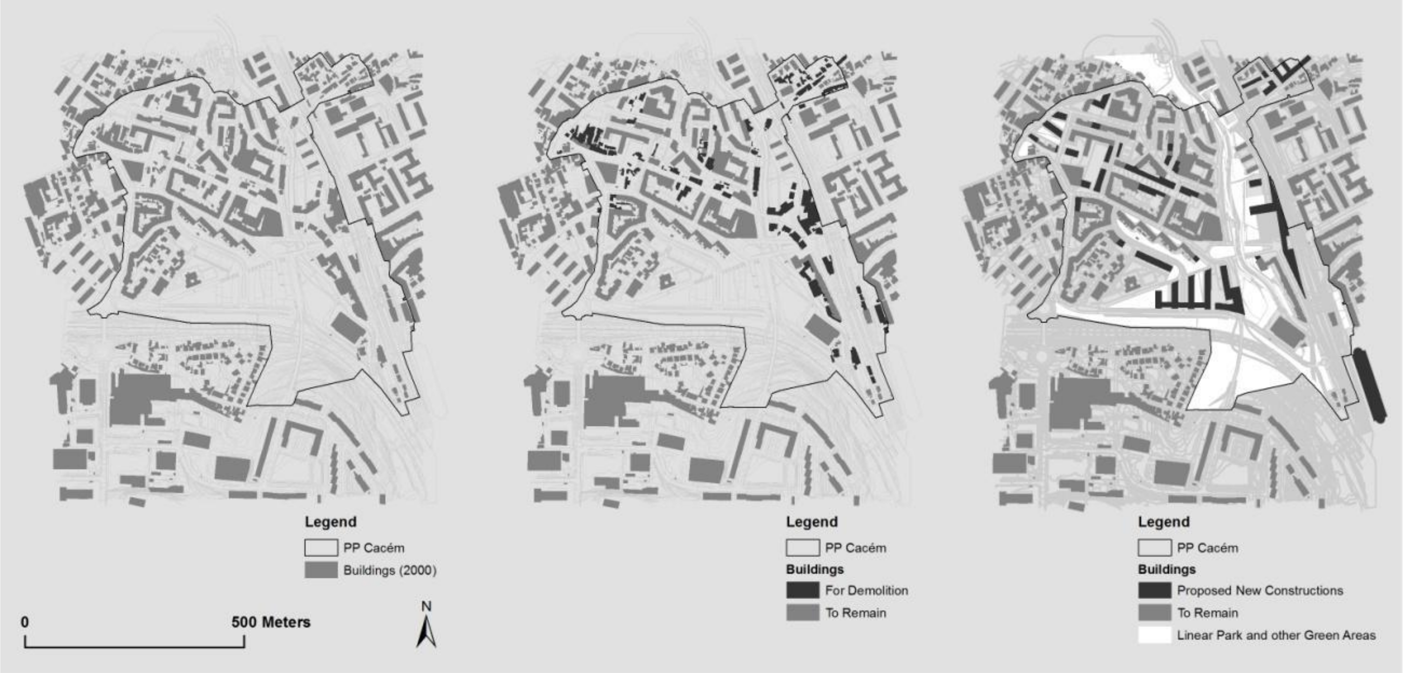

Figure 7. Existing and proposed building and green areas. Source: own production with information from *Cacém’s* Detailed Plan (PP).

were the actual demolitions in accordance with the plan. The choice of these indicators considered the need for substantial changes in the built environment in order to solve constraints created by the rapid urbanization process. Also, in this first group recreational areas along the *Jardas* steam are included, as well as extensions of existing and proposed bike paths in the formulation of the plan, comparing them with the results obtained after the implementation. Again, the objective of the analysis lies in the qualification and availability of public space and areas of water retentions as opposed to the constraints resulting from the rapid urbanization process (see Figure 7).

ii) The second group of indicators based on the policy/measure environmental restoration, assessing the flexibility of the environmental intervention, but in this case, unlike the second group of indicators, this specifically evaluates the natural component.

One of the main objectives of the Strategic Plan and consequently, the Detailed Plan for *Cacém* is the restoration of the *Jardas* stream and surroundings areas, which includes the regularization of the stream and the creation of an adjacent linear park. This group of indicators aims to evaluate the availability of green areas and their importance to *Cacém*, while contributing to mitigate flood situations in the *Jardas* stream, due to heavy rain.

To set proper situations resulting from the rapid urbanization process, it was necessary to demolish nearly 30% (24.2100 m2) of the built surface area contemplated in the plan. At the end of the term of the *Cacém* Detailed Plan and under the Polis Program, almost 83% (20,079 m2) of these demolitions where completed. These modifications were necessary to rectify the alignment of buildings and streets and to eliminate any “bottlenecks” in the local road network, which were recurrent conditions in downtown *Cacém* before the intervention. These changes contributed significantly to the improvement of public space, urban image and architectural image, reflected unequivocally in the local population survey as a contribution of the intervention for this purpose (Dias 2010).

The demolished areas have a significant importance in the overall image changes of the area, e.g. the requalification of the *Jardas* stream. This water line crosses the central area of *Cacém* lying at the rear of buildings before the intervention. The redevelopment of the area provided a large qualified area of public space and riverside areas of contemplation (9.943 m^2). It also introduced the first cycling path within the plan area, with a length of 3000 meters, allowing the creation of a linear park with considerable green spaces areas. It should be noted that before the plan, there was no qualified spaces along the river and all the assumptions developed in this regard in the planning phase were performed entirely, respecting the duration of the Detailed Plan under the Polis Program. Taken together, these interventions led to the improvement of living conditions and contributed to the mitigation of flood situations, by clearing the surrounding river area as well the regularization of a water-course (Dias 2010).

The Polis Program intervention follows the experience and knowledge gained in the interventions needed to achieve the 1998 Expo. The intervention under analysis was possible only through the celerity and simplification of procedures adopted under Polis Program, easing the planning process (Folke, Colding et al. 2002). Therefore it was carried out in *Cacém* area a process of environmental and urban requalification that led to the restructuring and resolution of many of the constraints, which resulted from the rapid urbanization process, observed in this area(Dias 2010).

6 MAIN FINDINGS

Portugal, especially the suburban areas, had a growth form that can be defined as land use management (ESPON 2007). This kind of approach had consequences at different levels of urban planning that reflected in the increase of flood situations. The case of *Cacém* is a good example of urban resilience improvement, with the recent modifications as a result of the implementation of a Detailed Plan. However, in the present state of the investigation, is not possible to conclude if the area is more resilient to flood in climate change scenarios.

It was also noted that the integration of existing methodologies for the study of floods can be assimilated into the methodology discussed here in relation to urban resilience. The integrated approach to flood and climate change represent an added value to obtain the alternative regimes system under analysis.

ACKNOWLEDGMENTS

The author would like to thank the *Fundação para a Ciência e Tecnologia (FCT)*, Portugal, for the PhD grant (SFRH/BD/70435/2010).

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