NEW FEATURES OF THE RIVERSHORE: CLIMATE CHANGE AND NEW RELATIONS BETWEEN TOWN AND WATER

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Abstract – The study of Climate Change, applied to the Mediterranean urban scale, stresses several questions about how to adapt 'old towns' to the 'new climate'. On another hand, Climate Change is also forecasted to affect the sea-level, which rise is menacing important urban areas (such as New York or the Flamish Delta region) and, even though at a lower level of risk, Mediterranean important urban heritages like the cities of Venice or Istanbul.

Although the difficulties of downscaling, climate scenarios show that Mediterranean areas will be affected on the one hand by thermal waves and, on another, by torrential patterns of rain, concentrating the total amount in a short time, that can cause difficulties in urban life, especially in coastal areas, mainly due to the draining systems. This asks for Sustainable Urban Drainage Systems and for a more efficient management of the water cycle, also rethinking the role of urban spaces. Portugal is considered Mediterranean, at least under the climate point of view, despite its coasts are almost Atlantic and, consequently, more exposed to the sea-level rise.

Lisbon is not exactly along a sea shoreline, but on the estuary of Tagus river, which would be probably affected by Climate Change effects because of run-off and, mainly, due to the forecasted rising sea-level. Rethinking and redesigning its relationship with water, trying to make this urban area more resilient, becomes crucial: it asks to study run-off and sea-level rise forecasted for 2100 and for intermediate steps, and to adapt the urban life and its spaces to the occurring scenarios. This work deals with the *Frente Ribeirinha* in South-West Lisbon, setting the objectives for its adaptation to flooding risks: 'from above' (rainfalls and consequent run-off) and 'from below' (sea-level rise), proposing a set of actions which can be combined according to different strategies.

The developed strategy proposals illustrate three different scenarios of how the whole area could be adapted, depending on the choices related to heritage protection, traffic management, run-off calming. These scenarios propose to transform the South-Western Lisbon waterfront working differently: one more with nature-based solutions, and the other two changing more radically the coast line, designing islands or bays (one could be consequent to the other) that establish priorities, 'securing' some urban nodal areas and 'sacrificing' some others. The first scenario is more related to planning choices regarding land-use, while the others are more related to design and infrastructural choices.

FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Alessandra Casu, Jlenia Zaccagna, *New Features of the rivershore: climate change and new relations between town and water*, pp. 174-182, DOI 10.36253/978-88-5518-147-1.18

Introduction

Climate change is not only a global phenomenon, but it also has local effects, cause of catastrophic and extreme events, resulting in numerous negative consequences within urban areas. Extreme events, becoming more and more frequent nowadays, are a significant issue for the protection, security, adaptation and defense of towns and of human kind: thus, we are required more information given by scientific research, about future forecasts, regarding temperatures and precipitations, possible worst-case scenarios, should these changes accelerate due to climate mutations.

Scientific research establishes a framework of alteration in ecosystems and the increase of extreme weather phenomena, with effects especially in urban areas [2], and with economic, social and environmental contexts suffering dramatic consequences, generated by the increase of global warming [3].

The areas that undergo multiple transformations —such as the urban ones— risk to be the most critical of all, as the different natural matrices can no longer withstand this kind of stress. In order to avoid serious consequences, in addition to face the consequences of global warming [6], new adaptation strategies are becoming increasingly urgent [10]. A response to climate change can also be the conclusion of environmental, economic and social sustainability policies, able to set mitigation and adaptation targets for towns.

Urban areas then need to cope with a different approach, specifically regarding adaptation, strategies and interventions, which purpose is to provide safety and environmental comfort, making cities as protective and resilient as possible to weather events. One important problems is waterproofing the soil, which leads to some of the major and determining impacts, such as the change related to the outflow of water, the urban heat islands, the instability of the ground and the absence of environmental comfort [8].

In the Mediterranean climatic area, an extreme study case is represented by the territory in which the city of Lisbon is located, interposed between two large water bodies: the Atlantic Ocean to the west and the Tejo river estuary to the south and east. Because of these two large water bodies and the whole impact of the effects of climate change [5], Lisbon *Frente Ribeirinha* is classified in many studies as a vulnerable area, and it becomes necessary to develop a model of adaptation to the changing relationship between the city and the surrounding waters.

Environmental problems caused by climate change are anticipitated, such as flooding caused by tidal changes, the increase in urban runoff, the mass of storms and heat waves, which will negatively affect the *Frente Ribeirinha*, by exposing the whole area at high risk. The whole area at risk interacts with the watercourse of the Tejo River: within the city there are several tributaries that can increase vulnerability in well-defined areas and are subject to floods, in case of water bombs. It is expected that the groundwater will increase, exposing plenty of buildings and roads at risk of destabilization, and soils to erosion.

The goal is to succeed in making this area more resilient to the effects of climate change, on the one hand to the rise of the average sea level and, on the other hand, to extreme weather events.

Flood management practices have to overcome sectoral paradigms to respond to climate change, through multidisciplinary and interdisciplinary approaches.

Materials and Methods

Regarding future scenarios the traditional, sectorial approach is quite misleading, because "estimated projections are indicative rather than definite, yet they are reliable" [4]. Urban planning should consider estimated projections as a deterrent to change, and the design of urban spaces should be crucial to adapt whole settlements to the expected changes. Some spaces are actually among the most vulnerable, especially to floods and, for these reasons, we propose three design scenarios, working with the uncertainty of future forecasts related to climate change, and paying attention to the transformation of coastal areas.

The model proposed within this article takes into consideration the research-by-design approach, as described by Nijhuis et al., [9]. Research by design allows to interpret the urban landscape as an interdisciplinary and multiscale research object, to acquire theoretical knowledge, flexibly useful for working in situations of unpredictability. Working with the uncertainty of future forecasts related to the effects of climate change and coastal city transformations, having an ecological approach that takes into consideration the different environmental dynamics with a holistic vision, constructing and evaluating future adaptation scenarios make research-by-design an appropriate working tool to cope with the issues that climate change requires to tackle in urban planning.

Resilience has become a key objective in urban and non-urban transformation operations, subjected to extreme catastrophic events [11]. The system's resilience, in this process of risk management, is interpreted as the ability to anticipate, prepare and respond to threats imposed by alteration with the minimum damage that involves the social, economic and environmental profile; this concept within the process implies the objectives, strategies, hypotheses and the drafting of adaptation plans.

Through the study of the impacts, and future forecasts of the effects induced by climate change, two main starting adaptation strategies are here designed, aiming to face the problem of water during events of urban flooding "from below"[1] and "from above"[2]. These two aspects should contribute to increasing the strength of the entire urban area.

The first step consists in the basic knowledge given by the scientific literature, that shows the observations of future forecasts at a global scale [7], as opposed to the local scale of the city of Lisbon [5], in which the downscaling of forecasts is defined: the worst effects of climate change will result into an increase of the average sea level affecting not only coastal areas but also transition environments such as estuaries and, in this case, the Tejo River, also influenced by rainfall dynamics.

The Town Council, together with a research center at the University of Lisbon, developped scenarios over a time frame which looks into 2100, the date on which the worst effects are expected to occur. Temporal analysis, 2025-2070 and 2100 [5], has allowed to analyze scrupulously the data relative to the amount of volume of water expected for the superficial outflows in the inside part and the data in order to characterize the amount of volume of flood water caused from the raising of the average sea level.

The action of adaptation to these phenomena coming "from below" faces a reality that can see no other device than the redesign of the whole river bank in the southwestern area, in order to reduce vulnerability.

[1] Expected sea level rising for 2100, referring to areas that develop from the bank of the river up to 5÷10 m of altitude (*efeito do mar*).
[2] Runoff through the whole catchment sub-basins.

The area behind the river bank is characterized by urban valleys and by an excessive waterproofing of soils, that will make it be affected by further aggravating phenomena. Because of the valleys and of the runoff it becomes necessary to identify surface outflows through the Curve Number [8] method per each sub-basin, which confirms the danger and instability of the soil at the onset of extreme weather events, such as heavy rainfall and flooding. Starting from the catchment area scale is crucial to obtain a detailed framework on how to deal with the problem without neglecting some critical situation being exposed to change.

Results and Discussion

Through the identification of the criticalities of the river bank and the area behind, due to the possible raising of the level of Tejo river and to the increase in heavy rainfalls, through the definition of objectives and the priority areas of intervention it has been possible to design three scenarios for 2100, in which the focus is on coping with the two problems related to water, "from above" and "from below".

For what refers to water “from below”, Lisbon's sea level expected by 2100 increase by + 5.69 m a.s.l. [1], exposing the entire river bank to high risk of flooding (Figure 1).

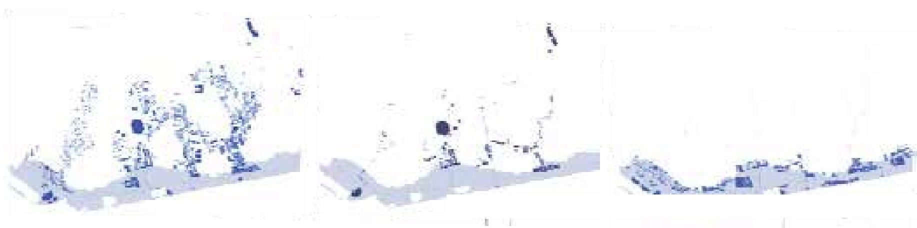

Figure 1 - Map of the elements exposed to risk for the expected sea-level rise (1 buildings at risk of instability: location on slopes starting from water channels up to 100 m away; 2 buildings at risk of submergence: placement within river channels - depressed areas; 3 flood risk buildings: location in the first 5 m of the *frente* starting from the river).

While the sea level of reference is fixed, for water “from above” the runoff depends on land use in proposed scenarios. Through the above-mentioned Curve Number method [9], simulations of different runoff and the consequent flooding risks are provided.

The different scenarios, each one through the implementation of measures to secure elements at risk (population, historical monuments, museums, hospital) in coherence with the current urban context, give a new design to the shore.

The first one (Figure 2), the safest among the three, proposes a re-naturalization of the river banks and the valleys, in order to “absorb” different qualities and quantities of water, “from below” and “from above”, in a more resilient and flexible configuration that allows different tidal intervals, either in relation with runoff or not. The first one, the safest among the three, proposes a re-naturalization of the river banks and the valleys, in order to “absorb” different qualities and quantities of water, “from below” and “from above”, in a more resilient and flexible configuration that allows different tidal intervals, either in relation with runoff or not. The behaviour of the whole urban ecosystem, in this case, is similar to the one of the Venetian "barena" (lagunar saltmarsh) in which —depending on tidal oscillations— some lands emerge or are submerged.

Figure 2 - Scenarios of re-naturalization of river banks and valleys.

The other two scenarios don't work so much with nature-based solutions, but select some public buildings that should be taken out of risk (hospital, museums, monuments, etc.), "sacrificing" other areas along the river banks to provide "room for water", especially for volume rising "from below".

In the second scenario (Figure 3), some "bays" are obtained by excavating the river banks, also in order to close the life-cycle "from-cradle-to-grave" by re-using —at least partially— the demolition wastes to build "dikes" that would protect the public buildings from flooding risk, obtaining a sort of "promontory" per each public building that keeps its accessibility but could be also be reached by boat, re-activating existing stations.

In the last proposed scenario (Figure 4), "bays" become so huger that the "promontories" per each public building become islands. Accessibility changes, losing almost all shoreline roads by excavating the river banks until the limit represented by the railway (that, instead of as a "dike", works as a gravel draining filter). This scenario has a peculiarity: it can be alternative to the others and, at the same time, it can represent an "incremental" evolution of the second one, in case the reality of climate effects on the estuary along the time would be worse than expected scenarios.

Figure 3 - Scenario of “bays” excavated in the river banks and “promontories” to host public buildings made safer from flooding risks.

Figure 4 - Scenario of “islands” instead of “promontories” to host public buildings.

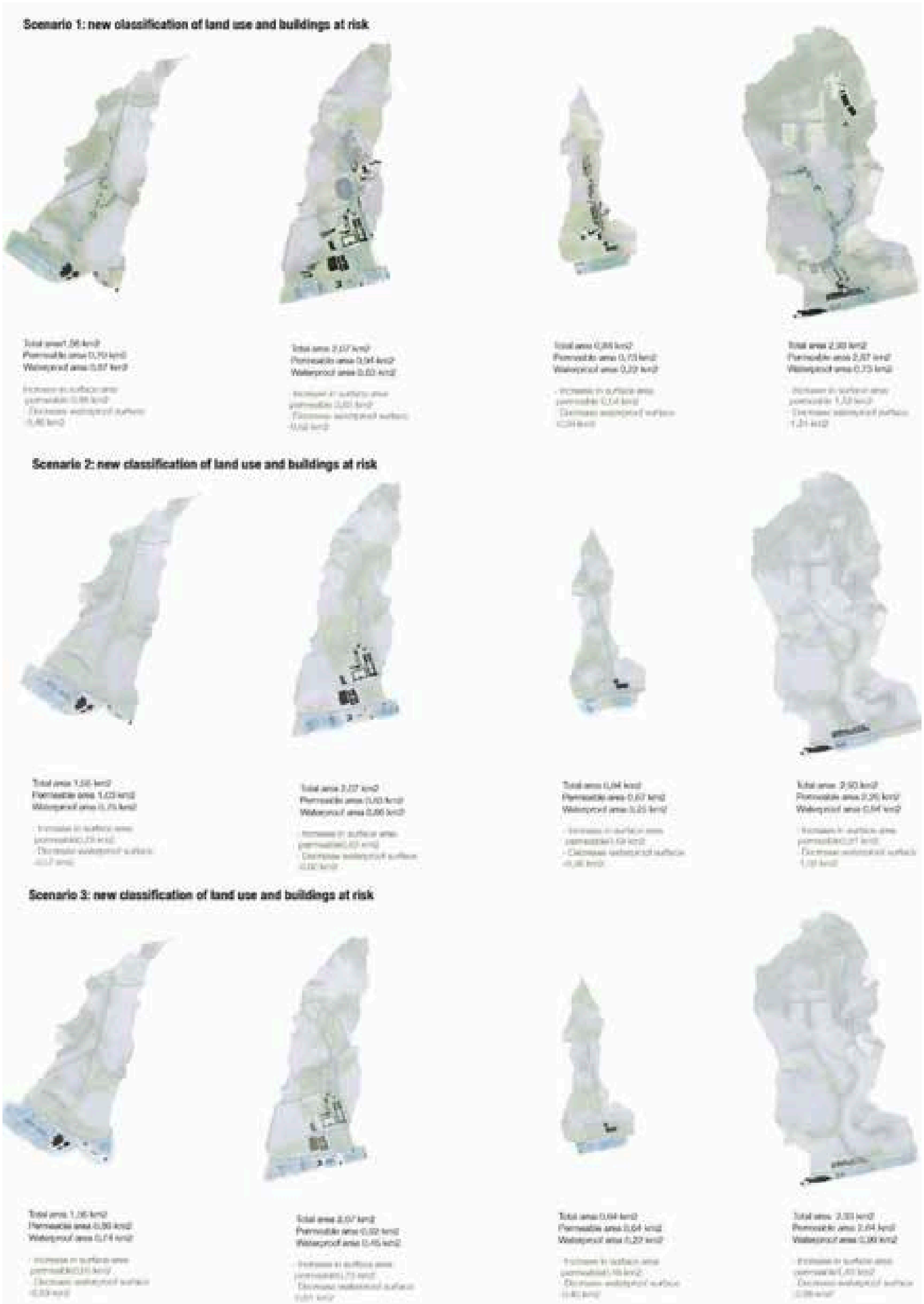

Figure 5 - Comparison between the consequences of each proposed scenario.

Conclusion

The results obtained offer a technical support in the decision for urban adaptation to the effects of climate change.

The three scenarios proposed in this work outline a series of long-term measures to support the river bank, becoming an effective tool to adapt the urban area of the south-west part of the catchment area, classified after multiple studies as a vulnerable area, through proposals to redesign the river bank. To furthermore support the decision, per each scenario some data are provided: land use measures, buildings to demolish or re-locate, interventions on accessibility, mobility and transport infrastructures.

As can easily be seen in Figure 5, the most preferable and flexible scenario, the first, requiring nature-based interventions implies harder policies of re-localisation and demolition that compromises the feasibility and the political and financial sustainability of the proposal. The other two scenario, as above mentioned, can even be one consequent to the other, implying an equally flexible and evolutive response to the flooding risk. Nevertheless, the last one is more extreme and requires stronger interventions on the mobility system, that suggest to choose the other alternative and change orientation only depending on real level of sea rise and environmental change, that could justify this choice as a sort of second chance.

The interventions chosen for the scenarios can not only define different responses to the trend of climate effects, but also verify the adequateness of forecasts and any changes in the long term.

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