

## Urban Flood Mitigation as a Socioecological Function of The City: towards an integrated approach to Land and Water Governance

La réduction des inondations comme fonction socioécologique de la Ville : vers une approche intégrée de la gouvernance de l'eau et du sol urbain

Barbedo, José \*; Britto, Ana Lúcia \*\*, Miguez, Marcelo Gomes\*\*\*

\* Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia, Universidade Federal do Rio de Janeiro - COPPE/UFRJ

([zbarbedo@gmail.com](mailto:zbarbedo@gmail.com)); \*\* Programa de Pós Graduação em Urbanismo, Universidade Federal do Rio de Janeiro - PROURB/UFRJ

([anabrittoster@gmail.com](mailto:anabrittoster@gmail.com)); \*\*\* Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia, Universidade Federal do Rio de Janeiro - COPPE/UFRJ ([marcelomiguez@poli.ufrj.br](mailto:marcelomiguez@poli.ufrj.br))

### RÉSUMÉ

Les changements socio-écologiques et les enjeux de leur gouvernance, tels que ceux liés au développement urbain et la gestion des eaux pluviales, ne se déroulent pas dans l'isolement des luttes politiques. Au contraire, le changement de l'environnement urbain se déroule à partir d'une succession d'efforts délibérés de transformation et d'appropriation des ressources naturelles par les acteurs sociaux qui détiennent la partie plus importante du capital politique, économique et culturel. Dans une société où les différences sociales et économiques sont marquées, comme dans le cas des pays en développement, les conflits au niveau local reflètent et renforcent les rapports de pouvoir qui caractérisent les échelles plus larges, y compris le niveau national. Cette étude porte sur les relations entre le développement urbain et la vulnérabilité aux inondations urbaines, mettant en évidence la façon dont les processus de changement d'utilisation des terres interfèrent dans des conditions d'inondation. La «fonction sociale de la ville», telle que définie dans la Constitution brésilienne et dans le Statut de la Ville, la loi nationale en matière de planification urbaine, sont soulignées comme les guides normatifs centraux pour intégrer l'atténuation des inondations dans l'usage et l'occupation du sol. Afin d'évaluer les impacts des transformations dans l'usage et l'occupation des sols sur les inondations dans une étude de cas concret, celui de la ville de Parati, située dans le sud de l'Etat de Rio de Janeiro, un modèle mathématique a été développé pour estimer les coûts et les avantages hydrologiques des différents scénarios de développement urbain. Le problème des inondations urbaines est ainsi analysé sous de multiples dimensions, ouvrant ainsi une fenêtre sur une discussion plus large concernant les défis posés par la réduction des risques environnementaux et de la vulnérabilité sociale, ainsi que la promotion de villes plus inclusives et équitables.

### ABSTRACT

Socioecological changes and their governance, such as those related to urban development and storm water management, do not take place in isolation from political struggles. On the contrary, urban environmental change unfolds from a succession of deliberate efforts of transformation and appropriation of natural resources by the actors holding the bulk of political, economic, and cultural capital. In a society with marked social and economic differences, as in the case of developing countries, localized disputes reflect and reinforce national circumstances and the wider balance of power. This study focuses on the relationships between urban development and urban flood vulnerability, highlighting how land use change processes interfere in flooding conditions. The "Social Function of the City", as defined in the Brazilian Constitution and in the Statute of the City, national law concerning urban planning, is emphasized as a central normative guideline for embedding flood mitigation into land use decisions. In order to assess the impacts of land use change on flooding in a concrete case study, a mathematical model is developed for estimating hydrological costs and benefits of different scenarios of urban development in Paraty, city located in the Rio de Janeiro State. In this case, the problem of urban flooding is analysed at multiple dimensions, providing a window to the wider discussion of the challenges for reducing environmental risks and social vulnerability, as well as fostering more inclusive and equitable cities.

### KEYWORDS

Flood mitigation, land use change, social function of property, socioecological governance, Brazil

## 1 INTRODUCTION

The lack of articulation between the literature on stormwater management and the analysis of social conflicts concerning the access to urban land, often results in compartmented sectoral views, the duplication of policy agendas and a general failure to clearly materialize effective strategies for the mitigation of flood risks. This is particularly problematic in cities facing rapid expansion as it is commonly found in the Global South, where acute socio-spatial disparities are strictly connected with increasing environmental risks. Furthermore, there is little theory about the possible ways for mainstreaming flood mitigation in institutional settings where comprehensive stormwater management is yet to be developed. It remains unclear how to develop effective urban policies for the mitigation of flood risks into existing land use planning and management practices, especially in contexts marked by urban expansion. These shortcomings are particularly noticeable in Brazil, where housing deficits go hand in hand with increasing vulnerabilities to flooding. In pursue for answers to these challenges, we propose to theoretically explore the potentialities of combining hydrological modelling tools with the principle of the Social Function of the Land Property and of the City, as a promising pathway for curbing the current observable patterns of urban expansion into flood prone areas.

The principle of the Social Function of Property has been set forward in the political agenda of South American countries by social movements claiming the redistribution of underutilized farmland, originating a rich discussion on rural land reform (see Estevam, 2009). Since early 1980's, progressist demands for using the Social Function as a guiding principle for urban policy became increasingly vocal in Brazil. These demands have finally culminated in the Urban Reform Amendment (Emenda Popular da Reforma Urbana) inserted in article 182 of the 1988 Brazilian constitution, containing an explicit discussion of the Social Function of Property in the urban context. According to the Brazilian Constitution, the Social Function of Propriety has three main elements: i) economic (rational and adequate use of urban land); ii) environmental (adequate use of resources and preservation of the environment); and iii) social (compliance with the provisions that regulate urban land tenure and the guarantee of the right to affordable urban land). Accordingly, this principle incorporates both social and ecological concerns, making it particularly relevant for developing integrated policies designed for reducing socioecological vulnerabilities. The social function has also been described as an obligation to use property in ways that contribute to the collective or common good (Van Banning, 2001; Foster and Bonilla, 2011). It means that the right of private ownership includes an obligation to use land in ways that benefit society as a whole. Although this principle is not new, its recent internalization in legal instruments of urban policy, and the notion of the Social Function of the City as a policy guideline as developed in the City Statute is ground breaking in Latin America, and more generally, in the Global South. Conceptually, it constitutes a new paradigm to deal with property rights (see Alfonsim, 2003) by linking the exercise of urban property rights to economic, social, and environmental ends. Although the attempt to extend the social function principle to urban environments is not unprecedented, Brazil's efforts to create a legal framework that specifically outlines how this principle should be enforced in the urban context are rather exceptional (Ankersen and Ruppert, 2006).

Considering the social Function of the Property as a regulatory tool that potentially has the ability to change the logic of appropriation and use of urban land, this study aims to analyse on the relationships between land use and urban flood vulnerability, highlighting how land use change processes interfere in flooding conditions, examining the case of the city of Parati, in Rio de Janeiro State.

## 2 METHODOLOGY

This study combines quantitative information on urban flooding conditions (hydrological modelling) and empirical data on land use change dynamics obtained through secondary data analysis and direct observation during field work. Household income data for each neighbourhood of the study area has been collected from IBGE Census (IBGE 2010). Participation of the first author of this paper in a workgroup for discussing the Master Plan of Paraty, organized by the Municipality between February 2013 and July 2014, yielded an important inside perspective on related decision-making processes and highlighted the relevance of the various issues under analysis here. This also allowed to confirm direct observations on the field regarding land use change dynamics, which resulted in a high level of confidence in the findings.

The hydrological modelling exercise has been designed in order to quantify urban flood areas in our study territory, and to quantify the effects of hypothetical land use changes on urban flooding. In this experiment, the mathematical model MODCEL (Mascarenhas and Miguez, 2002, Miguez et al, 2011)

has been used for modelling where the study area is located. The study has considered the entire watersheds of the rivers Perequê-Açu and Mateus Nunes, within which the city of Paraty is located. The subdivision of watersheds in flow cells was carried out according to their topographical characteristics and urban typologies, comprising 378 cells representing lowland areas, 88 channel cells representing the rivers channels and 67 cells representing the hillside areas. After calibrating the model based on the correct representation of the current situation, an alternative scenario was simulated for a time recurrence (TR) of a high rainfall event with a predicted likelihood of one in five years (TR of five years) and a TR of 25 years.

### 3 FLOOD MODELLING

The simulation of the current conditions of the watershed of the rivers Pereque-Acu and Mateus Nunes resulted in flood maps which can be observed in Figure 1. On these maps it is possible to visualize the distributed impacts of land use change in the consolidated urban area. For hydrological events of low magnitude, the flooded areas in the current situation are already significant, especially in the area surrounding the Perequê Acu river on its urban area and in Jabaquara area. In this region, for events of 25 years flooding reached 79 cm. The river Mateus Nunes presents overflow at some points, especially on the right bank. It was observed in some neighborhoods water levels up to 26 cm for a TR of 25 years. After calibrating the model for the current situation, a future scenario following the current trend of urban expansion has been tested (business as usual scenario), represented on figure 2. By comparing the flood maps of the current situation (figure 1) and the business as usual scenario (figure 2), it is noticeable that flood levels have been aggravated as a consequence of the simulated land use changes. Finally, an alternative scenario of urban development has been simulated, directing urban growth to the remnants of available land located in downstream areas of BR101, bringing higher occupation rates in the Northern area of Jabaquara. This scenario proposes a mix of social housing together with larger plots for medium and high-income groups, concentrating urban growth in this area by increasing density rates. The region upstream of BR101 highway is preserved from further urban occupation, functioning as a buffer zone between the urban area and the upstream regions of the floodplain, transferring development rights of these properties to the area of Jabaquara. The implementation of the measures proposed in this scenario, would eliminate the flooding caused by the overflow of the Perequê-Açu in rainfall events of one in five years, as shown in Figure 3.

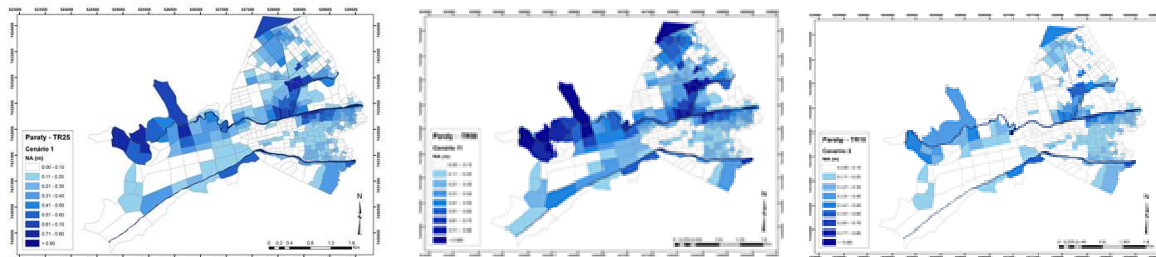


Fig. 1, 2 and 3: Flood maps of the current situation, business as usual, and alternative scenarios

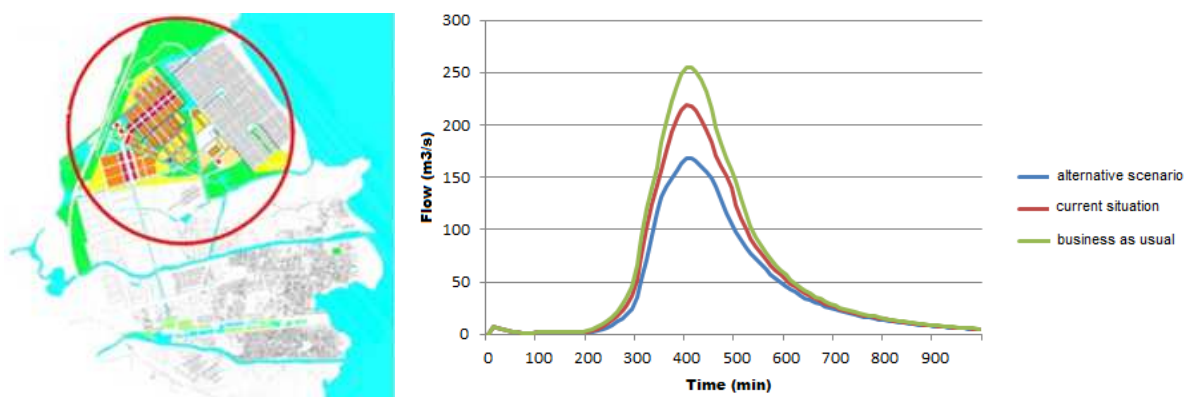


Fig. 4 and 5: Alternative scenario of urban development and comparative analysis of flows

The results of the modeling exercise show that the adoption of a more concentrated pattern of urban development together with the preservation of key resources in upstream areas of the floodplain may

reduce significantly urban flooding. The results of the modelling exercise shows that the adoption of higher density rates in lower regions of the basin can be effective in reducing the flooding impacts of urbanization. According to our experiment, while the densification of downstream areas would have a minimal impact on flood risk, the further occupation of the upstream areas along the floodplain will not only lead to the worsening of flood risks in the recently urbanized areas, but will also bring additional pressure to downstream areas, endangering the existing built heritage and implying future high costs of hard engineering infrastructure and maintenance services. The proposed alternative scenario presents lower water levels than the current situation in most flood prone areas, by restoring an element of flexibility to the Perequê-Açu and Mateus Nunes river basins, which in the present situation has been lost by the modification of river geometry and the progressive introduction of physical infrastructure. According to our model calculations, the restoration of connections between fragmented ecosystems can be effective in slowing down the runoff from heavy rains and reduce peak flows when flooding occurs, by sharing the water volume in both watersheds. This confirms that watershed planning designed to strategically restore wetlands has the potential to provide dramatic benefits by restoring ecosystem-level processes (functions) that maintain water resource integrity (White and Fennessy 2005). These findings show the importance of land use decisions at the local level, and how they influence human exposure to flood risks in the future.

## 4 DISCUSSION

The results of the modelling exercise, together with the analysis of land use change dynamics in the study area, suggest that the problems arising from the growing exposure of urban communities to flood risks, cannot be examined in isolation from ongoing political demands regarding the access to urban land. On the contrary, the increasing exposure to flood risks unfolds from the difficulty to interweave the interests of both extremes of the social spectrum, which in turn generates an ever-increasing consumption of land resources, and the consequent increase of flood risks.

Two distinct dynamics of land use change have been identified in the context of our study area, which apparently coexist in a symbiotic relationship: in one hand, there is a market-based logic of maximization of profit by private investors targeting high-income groups, on the other hand, there is a response emerging from the housing needs of the sectors of society which are excluded from this process of accumulation of wealth, which in turn creates new logics of appropriation of the urban space. These two logics of appropriation of the territory reflect a highly divided society which is manifested on the asymmetries regarding the exposure of people and assets to flooding. Within each dynamic of land use change, different actors influencing land use change dynamics have been identified in the study area: the dynamic of urban segregation is configured by the actors concentrated at the top of the social pyramid, holding the bulk of land resources. This group is configured by the corporative circuits of the real construction and the real estate business, linked to landowners and capital investors involved in land speculation markets. In turn, the dynamic of suburbanization in peripheral areas is configured by a wide range of social groups, resulting from the pressures and demands irradiating from the base of the society. Noteworthy, these social groups are composed not only by the landless or the migrant population, but also by an emerging middle-class with growing acquisitive power. The land use changes resulting from the activities promoted by these agents are predominantly manifested through the sprouting of informal housing in peripheral areas, characterized by ad-hoc processes of land subdivision and illegal constructions, which are radically transforming the physical and cultural landscape of previously rural and forest areas.

The symbiotic relations between segregation and suburbanization dynamics, although reflecting divergent interests at play, are not necessarily antagonistic, but rather seem to complement each other. Generally, these different logics of appropriation of the urban space are not properly articulated, generating an ever-extensive use of natural resources. The growing exposure to flood risks emerges therefore from the responses for the distributive conflict related to political asymmetries, expressed in the large deficits of affordable urban land for the majority of the population. In fact, the lack of strong and coherent housing policies are one of the major factors for the occupation of riverbanks and subsequent worsening of flood risks. In Brazil, as in many other countries with a colonial past, the poor never had access to land for housing in adequate locations (Baldez, 2003) being common to observe the simultaneous existence of land scarcity and land abundance in the same geographical space. The impressive concentration of land resources in Brazil, and the economic interests around ongoing land use change dynamics, contribute for the reproduction of vulnerabilities to flooding in the urban space. The continuity of reproduction of these inequalities are sustained by land use change dynamics of permanent urban expansion and socioecological fragmentation, allowing to accommodate inherent social conflicts to the process of urban growth (Ribeiro and Cardoso, 2003). The acknowledgement of

these characteristics suggests that it is not possible to adapt urban communities to flooding without thinking redistributive policies of urban land for housing needs, involving a deeper consideration of the socioeconomic conditions and housing demands of the groups living or working in the urban periphery, and their daily struggles for political recognition.

Herein lies the potential importance of embedding urban flood mitigation as an explicit socioecological function of periurban floodplains. The inclusion of flood mitigation as a socioecological dimension may be instrumental for operationalizing the Social Function of the City, both preventing property land owners from forcing negative externalities on society, as well as by assuring urban land for the most disadvantaged groups. Such an operationalization depends fundamentally from local governments, since the effective enforcement of the Social Function of the City is delegated to municipal master plans. According to Ondetti (2015) the lack of definition on the effective enforcement of this Constitutional principle makes the effective enforcement of the social function of property highly dependent on local conditions. This author observes that the fact that such tools are included in the master plans does not necessarily mean that authorities are actually utilizing them. Fernandes (2007) goes further on its criticism, sustaining that the ambivalence of the Brazilian law in this regard "makes this principle merely rhetorical". Such observations reflect the remarkable low level of embeddedness of the Social Function of Property in ordinary decision making - however, it does not mean this constitutional principle is inadequate or unnecessary in itself. On the contrary, the actual enforcement of this fundamental principle of urban policy requires the use of a larger set of instruments for informing land use decisions, by bringing quantifiable data such as the visualization of hydrological benefits (among others) associated with urban interventions that take into account social needs.

The use of MODCEL for modelling the study area has proven to be useful not only to estimate the effects of alternative scenarios of urban development in reducing urban flooding, but it can also be used in order to introduce principles of equity and social justice into land use decisions. The cell model establishes a causal link between changes in land use and the flooding externalities experienced by downstream parcels of land, and hence the people who live there. As is the case in many cities in developing countries, the urban areas in Paraty that are most prone to flooding are largely inhabited by poorer residents. The understanding of causal relations between different land uses allows us to identify who bears the cost of the conversion of urban land in terms of increased flood risks as a result of these actions. It also makes it possible to identify beneficiaries and providers of water-flow regulation sera direct connection between those who benefit from ecosystem services and those who can deliver them.

## 5 CONCLUSIONS

Conceptualizing flood mitigation as an eminently socioecological function, opens promising possibilities for effectively operationalize a principle solidly established in the Brazilian constitution, which has been largely ignored till now in practice. Adapting land uses according to a socioecological function such as flood mitigation, has an implicit sense of environmental justice, since social inequalities are at the root of the current trend of increasing exposure to flooding. As it has been argued in this paper, the Social Function of the City may prove to be a valid point of departure for embedding flood mitigation in planning and management practices, offering interesting potentialities that might be relevant to other regional contexts. However, such an operationalization can only be effectively pursued through a profound reorientation of public policy based on the acknowledgement of the interconnections between social and ecological concerns. Indeed, the increasingly inextricable interfusion between social and environmental problems require a more politicized basis of land and water governance, through which sectoral views need to be overcome.

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