Implementation of Green Blue Infrastructure in Built-up Urban Areas Guided by Social Participation

La mise en œuvre des infrastructures vertes et bleues dans les zones urbaines guidée par la participation citoyenne

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RÉSUMÉ

Au Brésil, l'occupation des espaces urbains fréquemment ignore le cycle de l'eau et la couverture végétale naturelle des sites. Cette démarche favorise la formation d'îlots de chaleur et de changements sur le cycle hydrologique urbain et sur la qualité de l'eau. Le concept d'infrastructures vertes et bleues (IVB) peut contribuer à réduire les impacts environnementaux de l'urbanisation. Cette étude s'est centrée sur les enjeux de la planification et de l'implémentation d'IVB dans un bassin versant de la ville de Belo Horizonte, au Brésil. L'étude met en évidence, d'un côté, l'identification des critères physiques et urbains capables de guider le choix des meilleures pratiques de gestion, et l'évaluation de ces choix par la population intéressée ou touchée par cette initiative, d'autre part. La méthodologie développée a été appliquée à une étude de cas, le bassin versant du ruisseau Flor d'Água, via la réalisation d'entretiens semi-structurés et de groupes de discussion. Des scénarios comparatifs ont été construits et modélisés à l'aide des logiciels QGIS et SWMM, à savoir: (CSU) état d'urbanisation actuel, (PRIV) IVB dans des zones privées, (PUBL) IVB dans des zones publiques. Les résultats ont mis en évidence d'importants défis, tels que des contraintes d'espace dans les espaces construits, la nécessité de services, qui n'existent pas encore, dans le secteur public et le manque de connaissances sur l'approche IVB. Cependant, la mise en œuvre de l'IVB par le biais de solutions structurelles et non structurelles peut apporter des avantages à l'environnement urbain dans les deux scénarios, auxquels elles sont implémentées.

ABSTRACT

The urban occupation in Brazil frequently disregards the natural hydrological processes and the presence of green areas, resulting in heat island issues and changes in quantity and quality of the hydrological cycle. The concept of green and blue infrastructure (GBI) can contribute to reduce the environmental impacts of urbanization. This study focused on issues of planning and implementation of GBI in built spaces, highlighting, on one hand, the detection of physical and urban criteria able to guide the choice of best practices, and on the other, the assessment of these choices by the concerned population, mainly in public and private spaces. The methodology was developed and applied in a case study, the Flor d'Água stream catchment, by working with stakeholders through semi-structured interviews and focal groups. Comparative scenarios were constructed and modeled with assistance of QGIS and SWMM software: (CSU) Current state of urbanization, (PRIV) GBI in private areas, (PUBL) GBI in public areas. The results exposed important challenges such as space limitations in built environments, requirement for services not yet existing in the public sector and lack of knowledge. Nevertheless, the GBI implementation through structural and non-structural solutions can bring benefits to the urban environment in either scenario.

KEYWORDS

Green blue infrastructure, hydrologic modeling, LID solutions, social participation

1 INTRODUCTION

Urban stormwater management should have multiple purposes according to the characteristics and functions of previous natural systems. Therefore, the conditions and necessities at each site should be the guiding principles of the project objectives, which may be related to peak flow reduction, improvement of water quality, recreation, recharge of aquifers and economic valuation (ASCE, 1992).

The green blue infrastructure (GBI) aims to achieve these goals by protecting the environment and promoting biodiversity through an interconnected network of green and blue spaces, both natural and artificial, within and between urban areas. The use of this type of infrastructure stands out in metropolitan areas, where several types of land uses coexist, being relevant for the protection of water resources and for the mitigation of impacts of urban activities (Nascimento *et al*., 2016).

However, the change from conventional water management towards GBI concepts can lead to environmental conflicts between different actors involved, creating barriers to this transition. Therefore, the social point of view is of particular relevance to accomplish a more sustainable urban water management. In this context, this paper presents a methodology for evaluating stakeholders' perception regarding the implementation of GBI, based on the evaluation of its hydrological benefits, which advantages also reach environmental and socioeconomic benefits.

2 MATERIAL AND METHODS

2.1 Case study

The methodology was applied in a case study, the Flor d'Água creek catchment, affluent of the Pampulha Lake, which is of relevant historical and urban importance to the city of Belo Horizonte. However, its water quality is threatened due to the high amounts of silting and pollution. Thus, the study of the hydrological behavior of the Flor d'Água stream catchment contributes to the Pampulha Lake catchment recovery and preservation understanding.

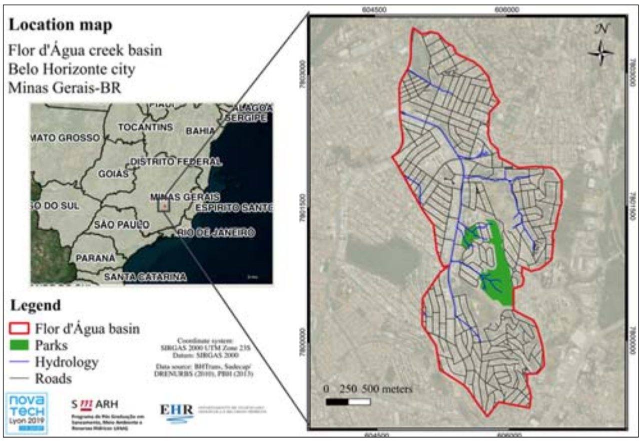

Figure 1: Case study area: Flor d'Água creek catchment in Belo Horizonte, MG.

2.2 Comparative scenarios defined by stakeholders participation

The assessment of the green and blue infrastructure in the Flor d'Água creek catchment was held by the comparison of scenarios, defined according to physical and urban analysis of the territory and guidance of identified stakeholders. The contact with the stakeholders occurred through semi-structured individual interviews or focal groups, according to the number of participants.

Two types of interviews were conducted with different perspectives: one focused on the implantation of GBI in private areas, and the other in public areas. The interviews were constructed based in literature review (Kati and Jari, 2015; O'Donnell *et al*., 2017; Raymond *et al*., 2016). The questions intended to analyze obstacles and barriers to the GBI implementation in the study area, and also to discuss solutions to overcome them. The results of the interviews also helped to define the comparative hydrological scenarios.

Table 1 (columns 3 and 4) details the interviews and focal groups held for each scenario and the GBI infrastructures considered in the hydrologic modeling.

Table 1: Summary of the interviews and focal groups and the green blue infrastructures chosen for each scenario.

Scenario	Description	Method	N of Participants	Green blue infrastructures
CSU	Current state of urbanization	-	-	No GBI infrastructures
PRIV	GBI in private and residential areas	Interviews Focal group #01 Focal group #02	6 3 6	Rain barrel Green roof Rain garden
PUBL	GBI in public areas	Interviews	SUDECAP* (1) PROPAM* (1) COPASA* (1)	Bio-retention cell Roadside trees

*SUDECAP: Municipal Infrastructure Implementation and Maintenance Company; PROPAM: Program For The Environmental Protection of The Pampulha Stream Catchment and Lake; COPASA: Water Utility Management Company.

2.3 GBI simulation through LID solutions

The land use and physical parameters were processed with the QGIS software for the construction of typologies of homogeneous areas by overlapping layers containing information related to the land use, road system, lot size, slope, and public/private lots. These layers were combined in order to obtain a single layer, which carries information for the environmental and urban assessment of the study area. In order to accomplish the hydrological comparison, the scenarios were distinguished by variations in land use features and associations of GBI techniques, according to the criteria recommended by Nascimento *et al*. (2016). Table 1 (column 5) shows the techniques chosen for each scenario.

The simulation of the LID techniques in SWMM (EPA-USA) considered the insertion of GBI acting in parallel. For the roadside trees, its hydrological contribution was considered through the CN parameter of target areas. The design hyetographs of the precipitation events were defined from the rainfall time distribution to the RMBH proposed by Pinheiro and Naghettini (1998) for events of 10, 20, 50 and 100 years of recurrence time. In order to quantify the benefits of GBI implementation, the scenarios were compared in terms of runoff.

3 RESULTS AND DISCUSSION

The Flor d'Água creek sub-catchment was characterized according to environmental and urban aspects by mapping the current land use and soil occupation (Figure 2, left). The Figure 2 (center) shows the sub-catchments defined in SWMM for the hydrological simulation. Figure 2 (right) shows the homogeneous typologies used to apply the different LID solutions considered in each scenario.

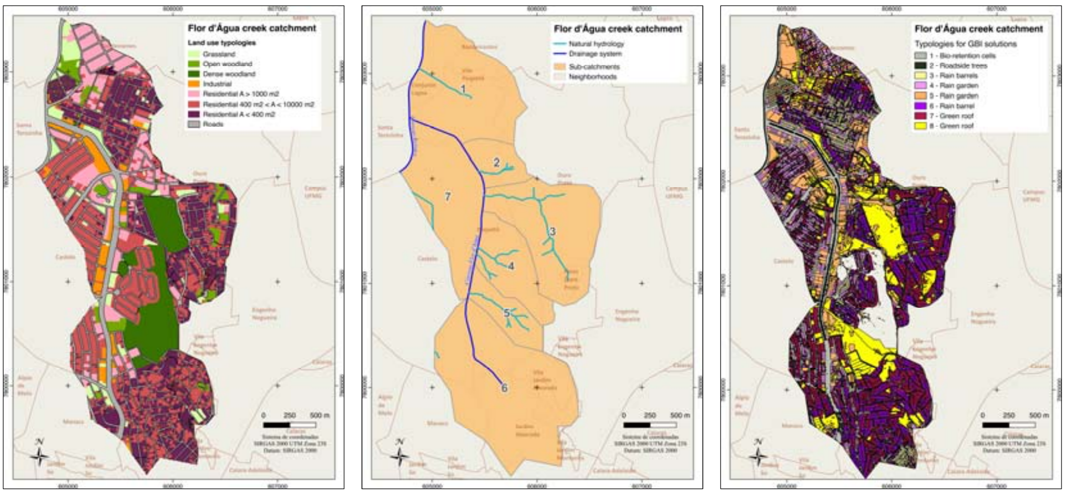

Figure 2 – Current land use and soil occupation of Flor d'Água catchment (left); sub-catchments used in the hydrological modeling (center); homogeneous typologies used to define GBI solutions (right).

3.1 Public and private areas interviews and focal groups

The interviews of the public sector representatives have shown that they recognize the importance of an integrated and participatory management to accomplish goals such as GBI. However, they believe that the involvement of the population faces obstacles, especially in low-income neighborhoods, which have concerns about basic sanitation, education and public health. The public sector also recognizes that GBI implementation barriers, such as financial resources, cultural barriers and political interests, still hinder the implementation of more concrete measures. Regarding GBI expectations, the public sector converge saying that the decision makers, as city councilors, tend to be more traditional and, consequently, less open to solutions such as those presented by the implementation of GBI.

Regarding the interviews of citizens, a high acceptability of GBI solutions was identified among all groups of interviewees. Dwellers often recognize the benefits of GBI techniques as a potential for flood reduction, as well as other improvements such as on the quality of life. However, they recognize that the solutions presented have to be integrated throughout the urban environment and hardly will be effective without mutual contribution of the residents and the public sector.

3.2 Hydrologic modeling of comparative scenarios

The results of GBI techniques simulation for the scenarios were quantified according to the runoff reduction registered in the model outlet in relation to scenario CSU, current state of urbanization. For the simulation of the Flor d'Água stream catchment, the 10, 20, 50 and 100-year return period rainfall design events with 15-minute duration were evaluated. Figure 3 shows the outflow in the catchment outlet for all scenarios and for all return periods. Table 2 presents the comparative results of peak flows and also the respective damping observed in each simulation, relative to the CSU scenario.

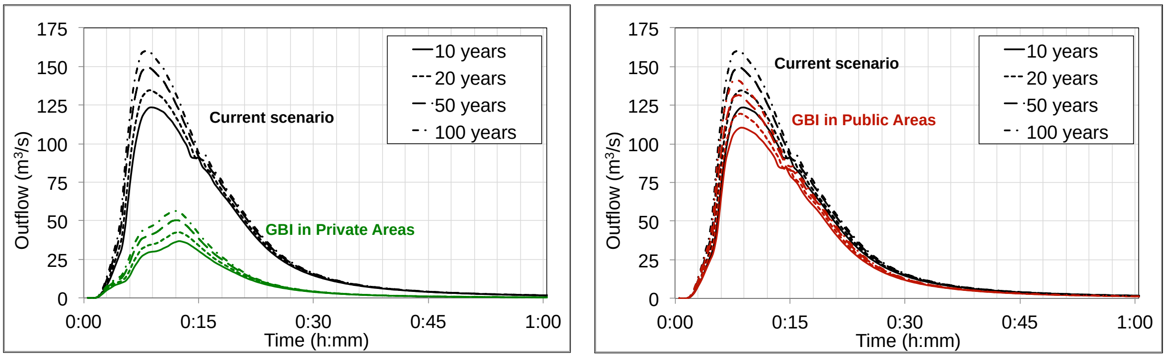

Figure 3: Outflow over time for precipitation events of 15 min and different recurrences at Flor d'Água catchment.

Table 2: Comparative results of the Flor d'Água catchment simulations for all scenarios.

	Peak flow (m^3/s)				Percentage of peak flow reduction			
Time of recurrence (yrs)	TR 10	TR 20	TR 50	TR 100	TR 10	TR 20	TR 50	TR 100
CSU	123,47	134,52	149,34	160,05	-	-	-	-
PRIV	36,78	42,57	50,27	56,35	70%	68%	66%	65%
PUBL	110,28	119,47	131,29	141,11	11%	11%	12%	12%

From the results, it can be noticed that the implantation of GBI techniques in private areas is responsible for a greater reduction of the precipitated volumes, considering the occupational characteristics of the studied catchment, which is mostly residential. Nevertheless, in all the established GBI configurations, significant benefits were observed in the reduction of surface runoff in a consolidated urban area, even considering limitations for its implementation.

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