Proposal for the use of riparian areas to mitigate the impact of urbanization in landscape fragmentation

Proposition d'utilisation des zones riveraines pour atténuer l'impact de l'urbanisation sur la fragmentation du paysage

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RÉSUMÉ

La fragmentation du paysage est l'un des principaux facteurs qui affaiblissent encore les vestiges de végétation dans les zones d'expansion urbaine. L'application du concept de trame verte et bleue, qui comprend, entre autres, la création de couloirs verts dans les zones riveraines, est une stratégie qui peut atténuer ces impacts. Cet article a pour objectif de caractériser ce phénomène en analysant l'évolution de l'occupation urbaine dans deux bassins versants situés dans la région métropolitaine de Belo Horizonte, au Brésil, et en utilisant de métriques de paysage pour sa quantification. Vu que la fragmentation a augmentée entre 1985 et 2017, nous avons commencé par proposer des stratégies de gestion du paysage, en développant des scénarios d'occupation permettant d'accroître la connectivité de zones vertes, par le biais de la récupération de zones riveraines. Les résultats montrent qu'un scénario réaliste, qui considère la récupération des zones riveraines non urbanisées de manière dense, peut améliorer la connectivité des zones vertes à un niveau supérieur à celui de 1985.

ABSTRACT

The landscape fragmentation is one of the main factors that weaken the remnants of vegetation in areas of urban expansion. A strategy that may mitigate these impacts is the application of the green and blue infrastructure concept, which includes the creation of green corridors in the riparian areas. This paper aims to characterize this phenomenon by analysing the evolution of urban occupation in two hydrographic catchments located in the Metropolitan Region of Belo Horizonte, Brazil, and the use of landscape metrics for its quantification. When the fragmentation increased in the period between 1985 and 2017, we started with the proposal of strategies for the management of the landscape, with the development of occupation scenarios that allow the connectivity increase, by means of the recovery of marginal areas to the watercourses. Results show that a realistic scenario, which consider the recovery of riparian areas not densely urbanized, can improve green areas connectivity to levels better than 1985's.

KEYWORDS

Connectivity, green and blue infrastructure, landscape fragmentation, riparian areas, urban planning.

1. INTRODUCTION

Landscape fragmentation is one of the principal impacts of urbanization (Rogan & Lacher, 2018). Reduction and isolation of green areas in patches separated by a matrix of anthropogenic soil use seriously affect the structure and functions of these remnants, leading to biodiversity loss (Haddad et al., 2015). Reduction and fragmentation of natural areas in the urban environment are also related to several socio-environmental impacts such as reduced human access to green areas, increased surface runoff and consequent increase in flood occurrence, deterioration of air quality, increased surface temperature and further (Di Giulio et al., 2009).

In this context, a strategy for urban space planning and management that seeks to mitigate the impacts of fragmentation is needed (Forman et al., 1997). The application of the green and blue infrastructure concept, which includes the creation of green corridors in the riparian areas, can bring, in addition to ecological benefits, hydrological, sanitary, social, environmental and economic gains (Nascimento et al., 2016). The green and blue infrastructure was recently considered in the territorial planning of the metropolitan region of Belo Horizonte, Brazil, involving participatory processes in the construction of ecological corridors proposals in environmentally strategic areas (Oliveira & Costa, 2018).

Thus, the objective of this study is to evaluate the impact of urban expansion on the fragmentation of the landscape and to propose alternative scenarios for the urbanization evolution, considering the need to mitigate the impacts of fragmentation, respecting the characteristics of the urban occupation, as well as the vocation of the studied areas. These scenarios will be constructed in order to extend the connectivity, according to the principles of green and blue infrastructure, through the creation of urban green corridors (Pellegrino et al., 2006). The proposed study is part of the MoMa-SE research project entitled "Modelling strategic metropolitan water sources as an input for water and land management in the face of climate change" and developed in partnership with the Federal University of Minas Gerais, University of Brasília, University of São Paulo and LEESU, a laboratory of the École de Ponts ParisTech, in France. This project proposes, as a main hypothesis, that it is possible to increase the resilience of strategic water sources to anthropic pressures and climatic changes, through measures of land use regulation, adoption of soil and water conservation techniques based in concepts of green and blue infrastructure. In Minas Gerais, three reservoirs with different uses and catchments with different levels of urbanization are under study: the reservoirs of Serra Azul, Vargem das Flores, and Pampulha. This paper focuses on the last two catchments.

2. METHOD

The characterization of land use and occupation evolution in the study area was made based on the comparison of satellite image classification for the years 1985 and 2017. This classification was obtained from the database Collection 3 of MapBiomas Project, which was based on images of Landsat satellite, with spatial resolution of 30 meters (Mapbiomas Project, 2018).

According to the Brazilian Forestry Code, the riparian areas are stated as permanent protection areas (APP), and extents to a minimum of 30 meters of the watercourses. APP, in addition to the primary protection functions for the watercourse itself and the riparian forest, may alleviate the effects of fragmentation by connecting isolated green patches (Metzger et al., 2010). For this reason, they were used strategically in the construction of recovery scenarios in the present research. Two modeling scenarios were evaluated: scenario 2017Par, the same landscape of 2017, with recovery of APP that are not developed urban occupation; and the scenario 2017Tot, with recovery of all APPs. The fragmentation degree of each scenario was evaluated by applying the landscape metrics that measure the fragmentation, through the software Fragstats 4.2.1 (McGarigal et al., 2018). The metrics used were: percentage of landscape (PLAND), number of patches (NP), largest patch index (LPI), effective mesh size (MESH) and mean of Euclidean distance of nearest neighbor (ENN_MN).

3. RESULTS

The land use classification of both catchments, which as neighbor catchments, in 1985 and 2017 is shown in Figures 1 and 2. The results of scenario construction with partial and total recovery of APP, maintaining the same soil occupation of 2017 in the areas outside the APP, are presented in Figures 3 and 4 respectively.

In 32 years, there was a remarkable increase of the urbanization and reduction of the vegetated areas in both catchments. In Pampulha catchment, an increase of 23.2% in the urban area is observed, while the green areas (forest and savanna) decreased by 21.4%. In Vargem das Flores catchment, the urban

area grew by 114.5%, while green areas decreased by 6.3% in respect to it in 1985. Therefore, an increase in anthropic impact in the remaining natural environments of the study areas is observed, which suffer from real estate market pressure and the demand for new areas for urban expansion.
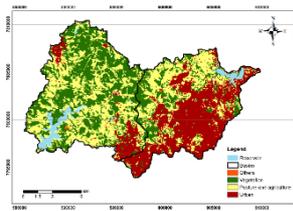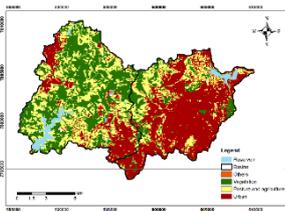

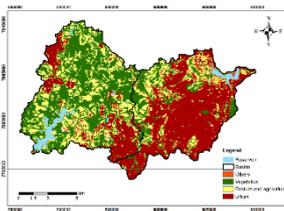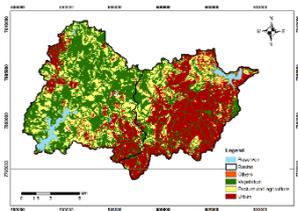| Figure 1. Land Use Map - 1985 | Figure 2. Land Use Map - 2017 | Figure 3. Land Use in Scenario 2017Par | Figure 4. Land Use in Scenario 2017Tot |

In 2017, in Pampulha catchment, 22.5% of APP were covered by vegetation. With the recovery of APP classified as pasture and agriculture, in Scenario 2017Par, 45.8% of APP would be vegetated. In Vargem das Flores catchment, in 2017, 44.9% of the APP were vegetated and, in Scenario 2017Par, 77.1% of APP would be covered by vegetation. In Scenario 2017Tot, in both catchments, 100% of the APPs would be recovered and reforested. It should be noted that Scenario 2017Tot represents the ideal of occupation according to the Brazilian Forest Code, which would involve the removal of buildings and roads installed in APPs. In this way, it can be considered that this would be a scenario that is not feasible and very difficult to be achieved. On the other hand, Scenario 2017Par would be closer to a possible real occupation in the catchments, with recovery of APP that have not yet been occupied with urban infrastructure and are therefore more prone to recovery. Even so, the connectivity gain obtained with partial recovery of APP is remarkable, as shown in Table 1.

Table 1. Results of landscape metrics by scenario

Metrics		Pampulha Basin				Vargem das Flores Basin			
		1985	2017	2017Par	2017Tot	1985	2017	2017Par	2017Tot
NP	Number of patches	353	216	330	89	286	232	202	83
LPI	Largest Patch Index	3.8	1.7	7.6	22.6	31.4	30.4	44.2	51.1
MESH	Effective mesh size	22.2	9.8	60.9	505.0	1188.9	1143.7	2360.1	3110.8
PLAND	Percentage of landscape	17.2	13.4	16.8	23.7	47.5	44.6	49.8	52.0
ENN_MN	Euclidean Nearest Neighbor	114.5	167.0	116.0	103.3	86.6	106.9	92.2	84.0

Between 1985 and 2017, there was a reduction of the NP, LPI and MESH, and an increase of the metric ENN_MN in both catchments. This result indicates the increase in the fragments isolation (ENN_MN), a reduction of their areas (MESH) and the disappearance of smaller fragments (NP). Stands out the difference in the magnitude order in metrics LPI and MESH between the two catchments. Although the PLAND in Vargem das Flores is approximately three times greater than in Pampulha, the largest patch of the first remained almost ten times greater than the last. The difference between the weighted mean area of the patches is even more remarkable. While MESH in Vargem das Flores catchment remains greater than 1,100 hectares in 2017, in Pampulha catchment it did not exceed 22.2 hectares in 1985. Thus, the fragmentation between 1985 and 2017 increased.

With partial and total recovery of APP, a growth of 3.4 and 10.3 is obtained for PLAND in the Pampulha catchment, and a growth of 4.2 and 7.4 in PLAND for the Vargem das Flores catchment, respectively. That is, the recovery of degraded APP, even in the most optimistic scenario, reached a maximum percentage of 10%. The improvement in the degree of connectivity reached much more representative levels. The metrics LPI and MESH increased in the two catchments, both in relation to 2017 and 1985. That is, even the partial recovery of the APPs generated a reduction in fragmentation, including in relation to the 1985 scenario, with notable increase in the area occupied by the largest patch and the weighted mean area of the patches. On the other hand, the mean distance between patches decreased from 2017 to scenario 2017Par, that reached levels very close to that of 1985. Scenario 2017Tot, in turn, implied an even larger reduction of the ENN_MN, to lower values than that of 1985. The results of the evaluation of landscape fragmentation in the scenarios with partial and total recovery of the riparian areas show the potential of these areas for the promotion of connectivity. Highlight can be given to the ability of the more realistic scenario, with recovery only of non-consolidated occupation areas, to improve connectivity to even better levels than 32 years earlier.

In reference of stormwater management, an additional analysis can be done, considering that the riparian areas are usually the most impacted by floods. In this way, for the municipality of Belo Horizonte, the most urbanized one, in Pampulha catchment, the data from flood prone areas was crossed with the

scenarios with recovery and protection of the riparian areas. The results of this crossing analysis are presented in Figure 5.
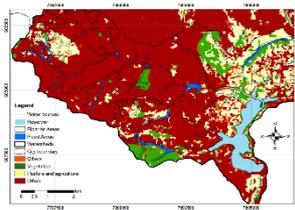

Figure 5. Flood Prone Areas, Riparian Areas and Land Use Map – 2017

Figure 6. Plate with flood warning in the Pampulha Catchment

Figure 7. Actual scenario of Flor d'água Stream (Nascimento *et al*, 2016)

Figure 8. Hypothetical scenario, with the stream restoration (Nascimento *et al*, 2016)

It can be observed that 57.4% of flood prone areas are inserted in the riparian areas, the other 42.6% are, naturally, contiguous to these ones. In the actual urban land use law, there are restrictions to new occupations in flood prone areas, however few recommendations are available for flood management in consolidated occupation in these areas. Nevertheless, the existence of these flood prone areas, identified in the ambit of the Belo Horizonte urban water management plan, demands actions more effective than signaling (Figure 6) and the creation of escape routes. In this way, a different paradigm could be explored, with the restoration of riparian areas, particularly these ones prone to flood. This proposal had already been discussed previously in other studies, as illustrated by figures 7 and 8.

4.   CONCLUSION

The proposed riparian area recovery, based on Brazilian environmental legislation, consisted of two possible paths: a complete recovery of permanent preservation areas marginal to watercourses, and a partial recovery, excluding areas with consolidated urban occupation. As expected, the scenario with full recovery would promote greater connectivity. However, the scenario with partial recovery of APP, which is more likely to be implemented, proved to promote considerable fragmentation reduction, and therefore is the recommended. In this sense, more attention should be given to flood prone areas, with the possible implementation of multifunctional linear parks, that could serve as green corridors and social interaction places with access restriction in rainy season. The implementation of this scenario, however, will require the efforts of public authorities, in order to encourage landowners to recover stretches of land that contain degraded riparian areas. The proposed scenario is aligned directly with the guidelines proposed by the Integrated Development Master Plan for the Metropolitan Region of Belo Horizonte, with the application of Green and Blue Network concepts, and has an intersection with other public policies in force and in operation in the State, such as the Payment for Environment Services.

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