Climate change and Master Plan: flood mitigation in Belo Horizonte

Mudanças climáticas e Plano Diretor: mitigação de inundações em Belo Horizonte

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Abstract
The UN's New Urban Agenda has penetrated urban planning at the same time as extreme events caused by climate change. In view of the scenario of increased flooding in Belo Horizonte, state of Minas Gerais, the Master Plan approved instruments to mitigate the impacts through discounts on the fees charged for additional building rights for new buildings that use "green and blue infrastructure." The applicability of this incentive is analyzed across the territory based on a comparison between the discounts and the costs of new sustainable techniques. It is concluded that the instruments tend to be adopted where land value is higher, being insufficient for a large part of the city, mainly areas with greater climate vulnerability, which demand more direct interventions from the government.

Keywords: master plan; real estate market; urban planning; climate change; urban economics.

Resumo
A Nova Agenda Urbana da ONU penetra o planejamento urbano ao mesmo tempo que eventos extremos causados pelas mudanças climáticas. Diante do cenário de intensificação de inundações em Belo Horizonte – MG, o Plano Diretor aprovou instrumentos para mitigar tais impactos. por meio de descontos na Outorga Onerosa do Direto de Construir para novas edificações que utilizem "infraestruturas verdes e azuis". Analisa-se a aplicabilidade desse incentivo pelo território, com base na comparação entre esses descontos e os custos das novas técnicas sustentáveis. Conclui-se que os instrumentos tendem a ser adotados onde o solo é mais valorizado, sendo insuficientes para grande parte da cidade, em especial as áreas de maior vulnerabilidade climática, que demandam intervenções mais diretas do poder público.

Palavras-chave: *plano diretor; mercado imobiliário; planejamento urbano; mudanças climáticas; economia urbana.*

Introduction

Cities have a privileged role for socio-political experiments, since they are spaces in which there is a greater concentration of human, financial and political resources. These conditions enable metropolises to serve either as "mirrors" or as disseminators of innovative policies in urban planning, whether for other large urban centers or for small and mid-sized cities (Teixeira and Pessoa, 2021).

Among the reasons for needing new urban policies is climate change, along with the expected impacts on extreme hydrological events, and the occurrences and intensities of floods and droughts. Urban floods, and events caused by flooding through overflow from the main watercourse channels and urban macro drainage structures, thereby affecting occupied urban areas, have intensified due to the progressive impermeability of soils, as well as by changes in the precipitation regime (intensity, duration and frequency of rainfall events), which may be associated with climate change. Accelerated flood events, considered from the perspective of the frequency of occurrence, intensity and impacts, when compared to other extreme events related to water, are the most commonly observed among natural disasters, when considering current and projected scenarios. This clearly reveals the need to plan and invest in measures to mitigate the impacts of floods (Banco Mundial, 2012).

Belo Horizonte (BH), the planned state capital of Minas Gerais, inaugurated in 1897, was constituted from the Curral del Rey settlement, located in the basin of the Arrudas River, an area with a history of frequent flooding on its marshlands. As detailed in the literature review, the problem of urban flooding has accompanied BH throughout its entire history and is associated with the formation of the urban-industrial metropolis (Villaça, 1998; Borsagli, 2016; Almeida, Monte-Mór and Amaral, 2017), the exclusionary functioning of the real estate market (Nabuco, 2019), the occupation of the valley floors and canalization projects (Borsagli, 2016; Calazans, 2021) and a generalized lack of various types of infrastructure (Pinheiro, 2019; Nascimento, Bertrand-Krajewski and Brito, 2013; Rosa et al., 2020; Rosa et al., 2022a).

Given the limitations of urban planning, inadequate infrastructure and socioeconomic inequalities, climate change and its impacts are set to aggravate the current urban situation, thereby causing adaptation measures to become increasingly necessary, crucial, and difficult (Martins and Ferreira, 2011). In view of this, the contemporary world demands the inclusion of watercourses in the urban landscape, which, in turn, demands the integral, integrated sanitation of urban watersheds. Processes such as this had already been indicated by Lefebvre (1970), when he characterized the "urban revolution" as a set of transformations that contemporary society experiences in order to pass from the period in which issues of growth and industrialization predominate through to the period in which the urban problem decisively prevails and in which the search for solutions and modalities proper to urban society will come to the fore. Thus, after Fordist industrialization, in its peripheral form (the Global South), had led to the formation of an extensive, degraded and degrading urban-industrial process, currently, an extended re-naturalization is sought, and the question of survival returns to the fore (Monte- Mór, 2018 and 2022).

Because of this need, economic incentives were introduced for adopting sustainable infrastructures in new buildings, through the Master Plan of Belo Horizonte, which came into force with the approval of Municipal Law n. 11,181/2019. Part of these incentives dialogues with the concepts of the Green and Blue Network (GBN) and the Green and Blue Infrastructure (GBI), with the aim, among others, of mitigating environmental impacts, in addition to promoting multifunctional spaces.

In Belo Horizonte, in accordance with the 2019 Master Plan, buildings that adopt GBI in their designs are able to receive a discount on the payment of the Onerous Grant for Building Rights (OODC). Since the new zoning of BH has adopted a Basic Coefficient of Utilization (BCU) equal to one (1) throughout the municipality, the promotion of urban benefits arising from the so-called "urban kindnesses" has become an attraction for future buildings as a way of exceeding the coefficient, while respecting the other urban parameters, with a reduction in the overall value of the grant (Belo Horizonte, 2018b). In the case of rainwater drainage, the objective is to mitigate the effects of soil sealing on the hydrological regime, in order to recover the conditions of natural flow (Belo Horizonte, 2020a).

These proposals adopted by the city of Belo Horizonte in its new Master Plan (MP) have introduced objectives proposed by the UN through the New Urban Agenda approved in 2016, during the United Nations Conference on Housing and Sustainable Urban Development, in Quito (United Nations, 2019a).

Thus, this study proposes an analysis of the economic incentives policy for adopting "green and blue" (GBI) techniques in new buildings, with a focus on flood mitigation. These incentives will be applied to new constructions through OODC discounts.[1] The study seeks to assess the capacity of this economic incentive policy to influence decisions for adopting such infrastructures and, thus, contribute to a reduction in runoff and to the mitigation of floods. For this purpose, comparison scenarios have been built between the costs of implementing GBI techniques in relation to the OODC values, considering a typical residential building project and varying the urban parameters given by the new zoning. To simulate the calculation of the OODC value, tax data on the values of vacant lots have been used, based on the Real Estate Transaction Tax (ITBI). Interacting the data of a building project with the urban parameters and with the ITBI fees of the lots, estimates of the OODC values were obtained. If these values are higher than the cost of adopting GBI techniques in new buildings, there is a de facto economic incentive for construction companies to adopt these techniques, so that they obtain discounts on the OODC value. In other words, low OODC values tend to discourage the adoption of sustainable GBI-type techniques in the case of this policy. As the results have indicated, this is the case for a large section of the municipal territory, where the value of land is low and, therefore, the OODC is also low, which, in these areas, induces construction companies not to adopt the sustainable techniques discussed herein. Furthermore, several types of green infrastructures with different costs are also compared, in order to understand how more popular techniques may generate greater incentives for adopting these devices.

This article is organized as follows: the next section presents the theoretical and empirical context into which this work is placed, based on a literature review, which also recalls the history of the use and occupation of the study locus and its relationship with floods and the context of climate change, master plans and infrastructure investments for flood mitigation strategies. The following section details the methodology adopted and how it responds to the objectives proposed in this article. The results and discussion of the research are then presented, followed by the final considerations.

Literature review

The advancement of climate policies and adaptation initiatives requires greater flexibility from governments so as to be able to include this issue in local political agendas. Thus, an innovative approach may contribute to the creation of policies that increase efficiency in the use of resources, reduce contradictions between policy approaches and avoid competition between mitigation policies and other priority agendas (Di Giulio et al., 2019).

Impermeable surfaces, such as concrete or asphalt, retain heat and reduce evaporative cooling, expanding urban heat islands, which thereby contribute to increased rainfall. Therefore, there is a need for studies that consider different contexts in order to put forward solutions. The complexity of this lies in the process of considering urban morphologies, the building materials used and how human activities affect atmospheric circulation, thermal and light radiation, and energy and water balances (Bai et al., 2018).

It is also essential to carry out studies and climate surveys of the regions, as well as planning that takes into account the results obtained from such studies. Based on this, the Intergovernmental Panel on Climate Change (IPCC), has forecasted that integrated urban planning, in which transit-oriented development and more compact urban formats, with investments in interurban infrastructure, may reduce pollutant emissions and help construct more resilient urban spaces (Klug, Marengo e Luedemann, 2016).[2]

While there are metropolitan regions (MRs) that are more structured toward facing the likely impacts of climate change on a local scale (São Paulo, Belo Horizonte, Rio de Janeiro, Curitiba and Recife), there are nonetheless regions which are outstandingly negative in this respect (Brasília, Belém and Salvador). The main factors responsible for this disparity between the MRs are the economic demeanor and demographics of the regions; thus, on the one hand, São Paulo was the pioneer in initiatives against climate change, and, on the other, regions with a concentration of poverty demonstrated the greatest lack of local initiatives to deal with the topic (Sathler, Paiva and Baptista, 2019).

One example of these initiatives would be the proposed project for the Sarmiento Park, in a dense urban region of Buenos Aires, which presented good results with its environmental, social and economic improvement, even though it was difficult to change the standard approach in the treatment of rainwater for a more sustainable system. Another example is the implementation of the controversial restoration of the Cheonggyecheon Stream, formerly a covered river in Seoul, which was transformed into a public park with a nature theme. There are also other components that may be implemented in urban areas, such as green corridors, nature reserves, bioretention basins, floodable parks and even more traditional techniques, such as boulevards and central gardens and their more complex version, rain gardens. These methods are both less costly for the government and present the possibility of covering a greater territorial extension (Kang and Cervero, 2009; Cho, 2010; Kozak et al., 2020).

The positive externalities that this increase in green areas in large urban centers is able to bring about are considerable, since, in addition to ensuring greater water absorption, it also contributes to reducing heat islands – directly interfering with the increase in heavy rains, increased biodiversity, beautification and improvements in water treatment. In addition to these factors, the local residents of four cities in different countries have observed improvements in conditions such as: flood risk management, water quality, increased health and well-being, improved quality of air and the reusing of rainwater (Fernandes, 2018; O'Donnell et al., 2021).

Another externality that should also be considered is that this improvement in the urban space may bring a valorization in the real estate of the vicinity where these techniques have been implemented. By simply removing the obsolete port and part of the railway infrastructure in Rosario, in Argentina, which opened access to the Paraná River bank, property prices increased by up to 21% for the first ten blocks from the banks of the river. While in the city of Seoul, presented above, these values reached 33% (Kozak et al., 2020).

In the case of Belo Horizonte, a brief review of its occupation and history of land use is required in order to understand the current situation of flood risks, the policies proposed by the New Master plan and future trends based on climate change. This contextualization also clarifies the case study proposed in this article.

The planning of Belo Horizonte ignored the various streams that drain the region, which, during the early years of the city, resulted in problems of flooding and water pollution. The valley of the Arrudas Stream runs east to west, while the city, in the early years, following its planning, was formed in a north-south direction, with the planned area destined for the included to the south of the stream, and the first favelas forming in the north (Villaça, 1998; Borsagli, 2016; Almeida, Monte-Mór and Amaral, 2017). Another factor that contributed to the spread of the city beyond its planned urban zone were the high prices of urbanized land, associated with restrictive legislation on land use and occupation and the speculative processes of real estate capital (Nabuco, 2019).

The occupation of valley floors often occurred with a lack of sewage infrastructure, leading residents to discharge sewage directly into the water courses. Over time, there was an increase in the spread of diseases and pests due to an accumulation of impurities in the water and along the river banks, a situation further aggravated in periods of rain, when all the pollution was exposed to the occurrence of floods (Borsagli, 2016; Calazans, 2021).

The canalization process of streams did not only occur in areas of informal occupation. For many decades, the municipal administration adopted the concept of what was termed a "sanitary avenue" (a covered river or stream) in order to implement roadway infrastructures and basic sanitation. Sanitary avenues were aimed at expanding the road system and seeking to expand the allotted spaces for the real estate market. This process often led to the eviction and removal of populations from villages and favelas that, in many cases, occupied the valley floor. The increasing impermeability of the land associated with the canalization of watercourses led to significant changes in the flood regime, with a large increase in runoff volumes and maximum flows, as well as the frequency and intensity of floods. As the sanitary avenues attracted commerce and service activities, in some cases, small industrial workshops, housing and heavy traffic to high-risk flood areas, the impacts of these events progressively increased (Pinheiro, 2019; Nascimento et al., 2013; Rosa et al., 2020; Rosa et al., 2022a).

Flood risks, investments and climate change

In the process of climate change currently underway, cities have been placed in a prominent position, either because it is cities that will suffer the most from climate change, or because it is they that have contributed and continue to contribute the most to the intensification of this process. This fact may be observed with the increase in climate disasters in urban areas, which has almost quadrupled over the past thirty years (Espíndola and Ribeiro, 2020).

According to the definition of climate change established by the United Nations (UN) during Rio-92, changes in the Earth's climate are attributed directly or indirectly to human activity, and are responsible for altering the composition of the global atmosphere, and are added to natural factors observed over comparable periods. There are natural factors that contribute to climate change, such as volcanic events and the decomposition of organic matter, however, according to the Intergovernmental Panel on Climate Change (IPCC), human activity is primarily responsible for global warming, which since 1800 – period of the Industrial Revolution – has intensified.

Climate change occurs in different ways around the world, manifesting itself with different characteristics in each region of the globe, and it may be this which is mainly responsible for floods and droughts in different places during the same period of the year. What they have in common is the increased energy in the atmospheric system, which causes a climate complexification, given the interactions between the physical environment and human societies (Klug, Marengo and Luedemann, 2016).

Therefore, it is of fundamental importance to discover ways to encourage short-term investments, with options for maintaining these investments in the long term, considering the worst scenarios, since the nature of urban environmental problems are economic (due to the high values related to projects that aim to mitigate climate impacts), political (since it is only the State that is capable of concentrating the necessary efforts for tackling climate change), and ethical (since the impacts of these changes will intensify inequality, in a world where climate refugees already exist). This demands an effort from all sectors involved (World Bank, 2012; Serpa, 2008).

In addition, according to the United Nations, when we estimate something for the future of cities, it is important to consider – chiefly in underdeveloped countries, which have fewer resources to address such scenarios, thereby presenting high levels of social, economic, and environmental vulnerability and a lack of infrastructure – that the rapid growth of the urban population presents a challenge for meeting the Sustainable Development Goals (SDGs). This problem has been imposed onto these regions by climate change (Espíndola and Ribeiro, 2020; United Nations, 2019b). This is because cities are the spaces that contain the necessary forces to put transformative actions into motion, especially with regard to their ability to face the sectorial, demographic, spatial and ecological challenges that climate change and its eventual extreme risks may present (Chu, Hughes and Mason, 2018).

In Belo Horizonte, an example of this is the huge region demarcated as being vulnerable to the possibility of flooding and consists mostly of peripheral neighborhoods. Moreover, in 2020, data from the Municipal Secretariat for Urban Policy (SMPU) reported that in the city, there are 144 high-risk flood areas, where 44% of the municipal territory has become impermeable, and it is expected that with climate change there will be a 32% increase in problems associated with heavy rainfall in the city (Belo Horizonte, 2020a).

The same document also reported that, for the year 2030, the SMPU expects that the number of highly vulnerable neighborhoods for flooding will increase by 60%, thereby totaling 331 neighborhoods. The most susceptible regions will be: the Northeastern region – which has the highest number of vulnerable neighborhoods within the city –; the Eastern region; the Central-South region – which is more biophysically sensitive to landslides –; and the Northern region – with a greater tendency to suffer from an increase in temperature (Belo Horizonte, 2016 and 2020a). This condition therefore indicates the vulnerability of almost the entire territory of Belo Horizonte. Even with the different socioeconomic conditions in the city, this barrier will not restrict the environmental impacts, making actions of confrontation more complex and demanding the adherence of society as a whole.

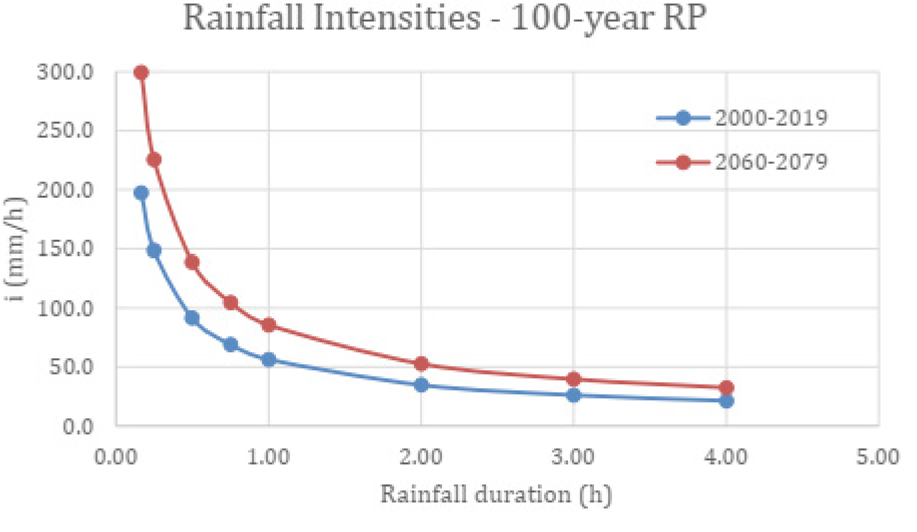
Due to these scenarios, in Belo Horizonte, over the last ten years, there has been an investment of R$2 billion on structuring interventions, such as the expansion and adaptation of canalizations, the creation of detention basins, in addition to interventions for the treatment of valley floors, with the aim of reducing flood risks. In projects, R$1.3 billion has been budgeted for the Municipal Works Plan, which aims to complement the works already carried out, seeking to improve the efficiency of the urban drainage system (Belo Horizonte, 2020b).

The areas most at risk of flooding are those where soil permeability is lower – between 20% and 40% –, and therefore unable to efficiently absorb rainwater. In addition, the city's poor populations have historically been pushed toward regions of greater geomorphological risk. There are greater flood risks affecting housing complexes, villas and favelas, representing a total of risk areas of almost 40% (Silva, Raposo and Meireles, 2021).

Thus, the greater social vulnerability of this population may be considered a determining factor in the predisposition to risk situations in any given territory. A community that is socially vulnerable has less access to resources that enable its capacity to adapt and cope with natural disasters. Within this context, the State becomes a necessary actor since it is capable of promoting the necessary adaptation measures across these vulnerable urban regions.

Nascimento et al. (2022) calculated long-term estimates of daily rainfall for the period 2000-2100, based on global circulation models and climate change scenarios, for the Metropolitan Region of Belo Horizonte. The precipitation data series from 2000 to 2019 is composed of monitored data. Based on the time series obtained, the authors developed equations for intensity, duration and frequency of precipitation that have, for example, estimated increases of around 38% in the maximum intensity of the precipitation event lasting 1h and a payback period of 10 years. For the 100-year payback period, the estimated increase is 52%. The payback period is the average time for an event of a given magnitude to be equaled or overcome (see Figure 1).

Figure 1 – Estimated rainfall intensity for a 100-year RP in Belo Horizonte



Source: Nascimento et al. (2022).

Urban drainage systems are no longer able to fully perform their functions, and thus become overloaded during rainy periods. The estimates presented above of the increase in rainfall intensity alert us to the gradual difficulty of dealing with the growing urban disasters resulting from climate change. Within this scenario, swift action by urban actors becomes crucial, aiming to mitigate the consequences that are already part of our reality.

Thus, the study corroborates the survey of disasters related to the SMPU estimates for the Belo Horizonte scenario, in which intensified flooding is expected. The climate analyzes have collaborated for the creation of and adherence to policies, plus regulations for land use and occupation in the municipality in order to deal with the climate context.

Challenges and proposals for tackling climate change

The need for a more serious urban approach to climate change came with the 1997 Kyoto Protocol, which established a growing movement of subnational governments – cities and states – to place the issue of climate change on the local political agenda. As a result, several cities around the world began to develop their own strategies so as to decentralize actions and thus deal with these challenges (Martins and Ferreira, 2011). From this movement, several city networks have emerged with common goals - the mitigation of and adaptation to climate change. Examples of these networks are the Cities for Climate Protection (CCP), the Climate Alliance, Energie-Cités and the C40 Cities, of which 3 Brazilian cities make part: Rio de Janeiro, Salvador and São Paulo.

The impacts of climate change will be/are more intense in urban centers. Therefore, it is from these places that measures should emerge that seek to mitigate such effects, through the formulation of policies to be elaborated, integrated and used as a way of controlling the use and occupation of the land. With this, planning (re)turns to the main question. This process must integrate both the public authorities and the private sector, because while one deals with the land, such as fiscal, legal and administrative issues – the city's social function –; the other treats it as a mere commodity – the real estate market (Braga, 2012). In addition to these actors, the participation of civil society should also be considered, whether by individuals and organizations with the power to pressure and influence governments and companies – which may be both social movements aimed at mobilizing the population on issues of collective interest, as well as more focused actions. in smaller social nuclei –; or whether by family, friends networks, school and academic environment, with the adoption of a more sustainable lifestyle.

The conditions for promoting the city's social functions are already ensured by the City Statute – Federal law No. 10,257 of July 2001 –, which establishes guidelines for implementing urban policies that guarantee the right to sustainable cities, via municipal planning instruments, tax, financial, legal and political institutes, which ensure that the social function of the city and urban property is fulfilled (Brazil, 2001).

The implementation of these instruments available on a national level contributes to reducing the vulnerabilities of cities. Belo Horizonte, as with other Brazilian cities, has integrated some of these concepts, instruments and parameters into its new Master Plan. Among other objectives, this movement aims to bring the city closer to global commitments for combating climate change (Klug, Marengo and Luedemann, 2016; Belo Horizonte, 2019).

The availability of instruments and resources for land control and use, aiming to implement climate change mitigation policies, even in the face of the social and financial impacts that such changes have brought to cities, has been insufficient for these policies to be implemented. In a survey carried out by Espíndola and Ribeiro (2020), for the 26 state capitals plus Brasília, a scenario was observed in which the municipal laws of just eight (Belo Horizonte, Brasília, Curitiba, Fortaleza, Manaus, Palmas, Rio de Janeiro and São Paulo) contain proposals that aim to mitigate/address climate impacts on their territory, while the other 19 state capitals have no considerations for climate change included in their policies.

This may partly be explained by the fact that Latin American cities, particularly Brazilian cities, have experienced a process of early urban transition and intense urbanization – today almost 85% of the Brazilian population lives in urban areas. Thus, urban areas have mostly been unable to conform to receiving this number of inhabitants. This has therefore, led to the accumulation of other problems, such as socio-economic, socio-environmental issues and delays/underfunding for the creation of urban infrastructure (Martins, 2009).

One of the approaches to deal with the need to re-naturalize watercourses in conjunction with land use is the so-called "Green and Blue Network" (GBN) and "Green and Blue Infrastructure" (GBI) techniques. The GBN approach came about within the context of an environmental recovery policy and promotion of biodiversity in France, designed for the Nord-Pas-de-Calais region – which, like Belo Horizonte, has also suffered from the environmental impacts caused by iron ore extraction. (Vilmal, Mathevet e Michel, 2012; Oliveira and Costa, 2018).

The GBN is based on a strategy that aims to protect and restore the natural systems of a city, the peri-urban and rural areas, seeking to mitigate the effects of climate change and the formation of heat islands, soil and water conservation, and atmospheric pollution control, creating connections between permanent preservation areas and promoting biodiversity (Allag-Dhuisme et al., 2010).

The GBI concept is more restricted to urban areas, incorporating GBN concepts, such as the objectives of protecting and restoring the natural environment changed by urbanization and the creation of connectivity between green areas. There is also a set of devices and techniques with "green" infrastructure functions, such as rain gardens, green roofs, retention and infiltration ditches, and "blue" infrastructure in the case of urban rivers and associated linear parks, lakes and urban reservoirs, with a wide range of physical (rainwater drainage, flood control, reduction of water and atmospheric pollution, combating the formation of heat islands) and socio-environmental (infrastructure for leisure and sports practices, enrichment of the urban landscape, creation of spaces for the coexistence and practice of solidarity economics, etc.) objectives.[3]

The introduction of the concept of GBN in the Minas Gerais scenario took place through the Master Plan for Integrated Development of the Metropolitan Region of Belo Horizonte (PDDI/RMBH) and the metropolitan macro-zoning studies, approved in 2011, as Bill No. 74 of 2017. This plan introduced a set of guidelines, policies and programs aimed at promoting the sustainable development of the Metropolitan Region of Belo Horizonte, reconciling economic growth, social equity and environmental sustainability, with emphasis on territorial reorganization capable of reducing socio-spatial inequalities (Tonucci Filho, 2012).

The constructive techniques of the GBI that may also integrate the GBN, within this context, serve as a tool for improving the quality of urban life and hydrological and climatic processes in urban areas. It is an alternative in long-term sustainable planning, and is classified within the scope of mitigation strategies, consisting of multifunctional networks of interconnected, permeable and vegetated fragments, that restructure the mosaic of the landscape, such as urban afforestation, vertical gardens, green sidewalks and the aforementioned green roofs and draining (or rain) gardens (Setta, 2017). These techniques have been adopted by several cities, especially in developed countries, such as Melbourne, Australia, Malmo, Sweden, Freiburg, Germany, Lyon and Bordeaux, France, and San Francisco and Boston, in the United States. Its use in developing countries is more recent, but growing, as in Cape Town, South Africa, Bogotá, Colombia, Santiago in Chile, several cities in China, in which the terminology "sponge cities" has been adopted and, in Brazil, in the cities of São Paulo, Porto Alegre, Niterói, Belo Horizonte, among others. Since Belo Horizonte has an estimated 144 high flood-risk areas, which may be aggravated by climate change, the adoption of climate policies and agendas focused on mitigation and adaptation becomes imperative (Belo Horizonte, 2018a; Belo Horizonte, 2019). In view of this scenario, in its new Master Plan, approved in 2019, the City Hall of Belo Horizonte has adopted a policy aimed at bringing about a trade-off with the payment of the OODC, in order to promote the implementation of sustainable architectural solutions in new developments. This policy was included in the logic of a broader policy of incentives for introducing a more sustainable, friendly urbanism, called "urban kindness". In the specific case of urban kindness, which this article addresses, the objective is to encourage real estate developers to mitigate the environmental impacts of their projects on a local basis through the adoption of green and blue infrastructure devices, in addition to what is required by law. The economic-based incentive enables enterprises to obtain greater construction potential if they employ such devices (Belo Horizonte, 2018b).

This policy is expected to achieve several objectives: to increase the visual permeability of the city, to improve the accessibility of urban environments, to achieve environmental objectives, such as mitigating the effects of climate change, and to reduce both the formation of heat islands and the risk of floods

(Belo Horizonte, 2020a). It is also expected that this policy will contribute to an increase in soil permeability, particularly in regions of the city with a high level of building density, a factor that contributes to increased flooding.

This policy may be divided into two proposals: (1) the choice of using design solutions to subtract the computed area – which is the built area considered in the calculation of the Utilization Coefficient (UC), which is the numerical ratio between the computed built area of a building and the total area of the lot –; or (2) urban amenities as a deduction of part of the OODC payment.

Within this scenario, enterprises are offered three options, free of charge (without payment of the OODC), to ensure an increase in the construction potential, in addition to the basic Utilization Coefficient (bUCs), namely:

1) a permeable area in the front spacing, on natural, vegetated and wooded land;

2) a permeable area on a portion of the land coinciding with the relevant vegetation area, regardless of its location on the plot;

3) an area for public use (Belo Horizonte, 2020a).

Hence, enterprises that adopt these measures in their projects will be eligible for financial benefits provided for by the policy. Since the new BH Master Plan imposes a bUCs equal to one throughout the municipality, thus limiting the construction potential granted free of charge, the adoption of urbanistic benefits is presented as an attraction for future enterprises to use as a way of exceeding the coefficient, without having to pay for the grant.

The introduction of green and blue infrastructure may help to reduce the impacts that urbanization has caused on the hydrological cycle and, from the perspective of generating flow, seek to return to the pre-urbanization conditions of the plots of land (Fernandes, 2018). In addition to other benefits, it is expected that the use of these devices will lead to a reduction in overflows and runoff volumes subsequently released into public urban drainage systems.

Currently, the city of Belo Horizonte has favored three devices: rainwater catchment tanks, which are mandatory under current legislation; green roofs, which will be the focus of this work; and drainage or rain gardens. Below is a brief description of each of these devices.

Rainwater catchment tanks

A catchment tank is required throughout the entire territory of Belo Horizonte, except in the zoning areas defined as special social interest zones (Zeis), and in the special social interest areas (Aeis). It aims to help with the surface runoff flows generated in the projects, thereby reducing the runoff loads on the public drainage network, and contribute to the improvement of its operation (Belo Horizonte, 2019).

Green roof

Green roofs are devices that may be used to help with the retention and evapotranspiration of rainwater, thus generating the abovementioned urban benefits. This technique is known for enabling the conversion of a conventional surface into a multifunctional space, using the appropriate vegetation. There are several concepts and models available regarding the type of intended use and the type of vegetation that should be used, as well as its final objective (Tassi et al., 2014).

Green roofs have the advantage of making it possible to achieve the goals of reducing the rainwater runoff produced by plots of land and their buildings, without occupying an area of land, i.e., they replace all or part of the conventional roofs of buildings. What, however, does not favor its use is its implementation cost, which can reach up to three times more than the cost of conventional roofing. The maintenance cost however, is low and can bring a positive return over time (Fernandes, 2018).

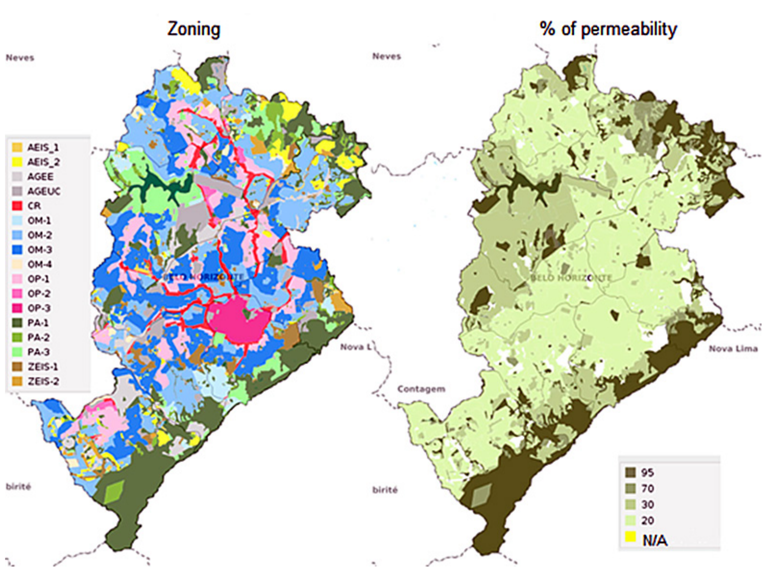
Drainage or rain gardens

Drainage garden refers to a vegetated depression, the purpose of which is to facilitate the infiltration of rainwater into the soil. It is made up of a combination of layers of organic sandy soil and substrate, to infiltrate and promote microbial activity. For the vegetation of the garden, native plants acclimatized to the region are indicated (Cortez et al., 2019).

Methodology

In order to analyze the urban kindness policy, a scenario was created to simulate a housing project. For this, the Goods and Real Estate Transfer Tax (known as ITBI) is used, provided by the Finance Department of the Municipality of BH, containing information for the period between Jan./2009 and Sep./2021. Moreover, from the current Master Plan, the zoning, permeability rate and utilization coefficient were used, as presented in Figure 2.

Figure 2 – Map with zoning and the permeability rate in BH



Source: Own elaboration using https://bhmap.pbh,gov.br. Viewed on: April 27, 2023.

For the simulation of a built-up area, a plot of land measuring 400 m² was selected, since this particular area was mostly represented in the data acquired from the Treasury Department, and the study adopted a permeability level of 20% of the area of the land, since this was the commonest level established by the Master Plan. In addition, the Preferential Occupation-3 (PO-3) zoning was chosen because it represents the central region of the city, with the most expensive square meter and where most of the disputes over land use have generally occured.

These data referring to the plot of land, such as area and permeability, are used in the Management Portal for Urban Policy Instruments (Sipu) to carry out the purchasing simulation of the Additional Construction Potential (ACP), thus obtaining the values relating to the purchase of OODC in the new enterprise.

The ITBI values are used as a means to estimate the commercialization prices of the plots of land. This is a way of estimating the value attributed to urban land by the real estate market and its spatial variation in the municipal territory.

Due to their amplitude, the ITBI values have been divided into 3 categories: values referring to 10% of the cheapest plots of land (10% lowest); median values (median); and values referring to 10% of the most expensive plots of land (10% highest). The aim of this division was to observe the degree of the policy's territorial coverage in relation to the different prices of urban land and, thus, determine whether there is a relationship between such prices and the incentives for adopting the urban kindness devices and, thus, attaining its benefits.

By inserting the data mentioned in the Sipu Portal, it was possible to arrive at some results regarding the possible values of the OODC, as well as the indicators that enable an assessment of whether the potential of the economic incentive influences the decision of the real estate entrepreneur in adopting urban kindnesses, thereby relieving them of the burden of the OODC payment. From these values issued by the Sipu Portal, the greater the savings generated by the installation of green and blue infrastructures in relation to the payment of the OODC, the greater the chances of it being adopted by real estate developers.

Urban land rent, which forms real estate prices (Amano and Almeida, 2021), is the ultimate source that informs the base values for calculating the ITBI. Land rent depends on several factors, many of them beyond the control of municipalities. Thus, one way of increasing the ability to carry out the aforementioned trade-off would be to lower the cost of deploying green and blue infrastructure devices. In the present study, it was decided to restrict the simulations to green roofs. The reasons for choosing this technique are based on the diversity of standardized models available on the market, as well as models that may be constructed in loco –; by the fact that it does not take up useful space, since it replaces part of the existing or planned roofs; and in being applicable to constructions regardless of their location, even though they are not among the devices with the lowest construction cost.

Thus, the values of green roofs for an area of 100m² were taken from the works of Savi (2012) and Santos (2018). The prices underwent corrections based on the inflation rate (INCC), referring to January 2022, and the labor and maintenance costs for 1 year were added, in order to standardize the implementation costs.

Results and discussions

As described in the methodology, the calculation of the estimated amount to be paid for the grant and the savings generated as a free grant was prepared with the aid of the calculation model available on the Sipu Portal of the Belo Horizonte City Hall. Charter 1 presents the data used for the scenario simulated herein, also as described in the methodology.

The results of the estimated grant values (OODC) through the Sipu Portal are presented in Table 2, which reproduces the image of the calculation summary page on the referred portal. These results correspond to properties with prices in the ITBI range of more than R$2,852.25 per m², which corresponds to the 10% most expensive in Belo Horizonte.

In this simulation, the 400m² plot of land will receive a building of 2000m² (in order to use all of its maximum Utilization Coefficient in the PO-3 zoning), with an ITBI value of R$2,852.25/m².

The Additional Construction Potential (ACP = 4.00) descriptively informs the additional built area referring to the size of the plot (400% of the total area of the plot, which represents 1,600m²). The Onerous ACP = 3.35 indicates the built area that may generate a grant (335% of the total area of the plot, which represents 1,340m²). The remaining 0.65 of the fraction represents the 100m² of free area acquired via urban amenities (free grant in Table 1) and the 160m² that correspond to the area of the transfer development rights (TDR), are divided into: 0.25 and 0.40, respectively.

Furthermore, the estimated amount payable for the onerous grant refers to the financial cost in order to achieve the maximum use of the land, reaching the maximum UC of this zoning (PO-3), for which the amount of R$1,911,007.50 is required. The savings

Charter 1 – UC and the selected zoning areas

Zoning	PO-3
Basic utilization coefficient	1
Maximum utilization coefficient	5
Area of the simulated plot of land	400 m²
Net built-up area (terrain x maxUC)	2.000 m²
Mean value of ITBI – R$/m²	2.852,25

generated with an onerous grant is the discount to be received, if any GBI technique is used in the enterprise (an area of 100m² was used as a green roof). Thus, there will be a deduction of R$142,612.00 from the onerous grant amount.

For the calculation used to arrive at the discount values the primary factor is the ITBI, a tax that enables the price of the plot of land to be estimated, i.e., the higher the price, the greater the discounts, considering that the other urban and design parameters remain unchanged. When analyzing the results for the ITBI range corresponding to the 10% cheapest and median plots, the results of the simulation scenarios differ significantly (Table 2).

Table 1 – Result of the OODC simulation with a discount for adopting GBI techniques

Summary of the Additional Construction Potential – ACP Utilization Coefficient - UC			
Additional Construction Potential		4.00	
Additional Construction Potential – Onerous		3.35	
Areas			
Additional total (ACP)	1,160,00 m²	Free grant	100.00 m²
Conversion	0.00 m²	Onerous grant	1,340.00 m²
TDR	160.00 m²	PBH	0.00 m²
Values referring to the grant			
Estimated amount payable for the onerous grant		R$1,911,007.50	
Savings generated by using GBI techniques		R$142,612.00	
Estimated amount payable for the suspended onerous grant by Art. 13 of Law n. 11.216/2020 and Art. 48 of Law n. 11,181/2019		R$0.00	

Source: own elaboration using Sipu/PBH Source: Own elaboration using Sipu/PBH.

Table 2 – Discount generated when GBI techniques are used

PO-3	10% smallest		Median		10% largest	
TDR*			160.00 m²			
Plot of land (R$/m²)	R$110.85		R$632.34		R$2,852.25	
GBI	No	Yes	No	Yes	No	Yes
Estimated OODC	79.812,00	74.269,50	455.284,80	423.667,80	2.053.620,00	1.911.007,50
Savings generated	R$5,542.50		R$31,617.00		R$142,612.50	

*Transfer Development Rights – minimum values required by §4 of Art. 45 of Law n. 11.181/2019.
Source: own elaboration.

Thus, when analyzing the cheapest plots of land in the city, which have an average ITBI value of R$110.85/m², the discount generated, in the case of an exchange between OODC payment for urban kindness funding, will only be R$5,542.50. While, for the median ITBI (R$632.34/m² of land), the discount will be higher, but still not enough to cover the costs of implementing green roofs, whose prices per 100m² range from R$29,400.00 to 49,907,00 (Charter 2) depending on the chosen model.

Since it is necessary to build some of the available techniques to access the discount they generate, their implementation cost may not be higher than the discount generated, so that the economic incentive makes sense. The "ITBI Breakeven" column displays this information simply, since it is possible to observe the necessary values of ITBI per m² so that financing the techniques is viable. The significant divergence in costs between green roof models is clear, thereby providing an opportunity for greater applicability if more popular green roof models are developed in the future. As the implementation costs of the techniques may not be higher than the OODC costs for the economic incentive to work, the more accessible they are, the greater their potential for adoption. In addition, the value of the OODC should not be too low, since this will not encourage the use of sustainable techniques, plus it will cause the city hall to lose potential revenue that could finance infrastructure works, housing and incentives for new centralities.

The results obtained with the simulations of the scenarios considered herein have indicated that only the plots located in regions with a higher market value will be motivated to adopt the incentives set by the MP. This scenario is repeated for all city zonings, unless the ITBI indicates high land prices, leading to an OODC discount which is sufficient to offset the cost of urban kindness.

Charter 2 – Prices of the models of green roofs

Roof model	**Total - 100m²** **(R$)**	**ITBI** Breakeven **(R$)**
Hexa Ecotelhado®	49,907.00	998.14
Cidade Jardim®	48,830.75	976.61
Vernacular	35,774.96	715.50
Modelo em BH	38,869.80	777.39
Alveolar Grelhado®	47,105.07	942.10
Alveolar Leve®	39,395.77	787.91
Moldado in loco	29,400.93	588.02

Source: Own elaboration using Santos (2018) and Savi 2012).

In addition to financial barriers, the green and blue devices may also contest architectural typologies that had already been socially established. This is the case of underground parking lots and garages; of swimming pools; sports courts and recreation areas; or even roof coverings. All of these, in their own way, may bring about difficulties for implementing the techniques, which, while projects are being created, ultimately contest the preferences. However, there is a wide variety of architectural design possibilities which may potentially meet different requirements. Experience gained from using these techniques will facilitate the development of alternatives.

Final considerations

It may be considered inevitable that cities need to adhere to the demands that climate change has been causing. According to the surveys presented, in the world (far) more than half of the population lives in urban areas, and, in Brazil, this figure is greater than 85%, with many of these areas already inserted in regions of climatic risk. The difficulty of addressing the problem becomes even greater when we consider that, for decades, these cities have suffered from high levels of social and economic vulnerability and a lack of basic infrastructure, factors that contribute to aggravating the impacts of climate change.

Studies such as those reported herein demonstrate that the increased number of natural disasters, particularly floods, leads to the need to devise alternatives to deal with these challenges. Thus, we may attribute, in part, to this need, the introduction of new urban agendas (such as the UN) and, specifically, urban policies that encourage the adoption of sustainable construction techniques in new buildings. It should be noted, however, that these proposals have been placed under a market-friendly prism, i.e., friendly to the market (real estate, in particular). Legislation could create instruments of the “command and control” type, to combat the same problems and have different results.

Belo Horizonte, given its history of disasters resulting from rain and the increase in this process caused, in part, by climate change, in its 2019 Master Plan, promoted measures that could be used to mitigate these impacts. Instruments were introduced to economically encourage the use of green and blue techniques (such as green roofs and drainage gardens), through OODC discounts associated with new buildings. This article has sought to analyze the potential use of these techniques throughout the municipality. Although the presented results focus on the PO-3 zoning, with the highest maximum coefficients, the results are essentially the same in other zonings that have not been presented due to the limits of this article, but which the authors may make available upon request. The results indicate that the adherence of the private sector to these technical strategies to mitigate the effects of soil sealing and climate change, from an economic perspective, will be compromised in regions that are less valorized by the real estate market.

As a result, the less favored regions for implementing these techniques – not necessarily needy regions, but those in which there is no need to purchase OODC, for example –, even though they are areas that constantly suffer from floods and other environmental urbanization impacts, do not will receive the techniques recommended by the urban kindness policy. This reveals that the policy studied is still far from guaranteeing a safer urban environment and that greater State participation will be necessary in the design and implementation of other financing models and incentives that do not only involve economic instruments. One possibility, still in the sphere of economic instruments, would be to directly finance the policy for implementing green and blue infrastructure, transferring the resources acquired through the sale of OODC in the municipality. Another important initiative, in the sphere of public administration, is the use of green and blue infrastructure in public spaces. These initiatives may also count on public funding.

Lastly, it should be noted that, on the day the final version of this article was completed, the Belo Horizonte City Council approved Bill No. 508/2023, which grants 50% discounts on the amount to be paid for OODC in the main centrality of the municipality, the one within the PO-3 zoning.[4] Therefore, the policy introduced in the new master plan already has the tendency to be stillborn, since, as the simulations carried out here indicate, low OODC values diminish the possibility of trade-off between the cost of introducing GBI techniques and obtaining discounts in the OODC.

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Notes

(1) The OODC is a mechanism that enables the possibility of purchasing the right to build above the limit allowed by law, upon payment of a sum of money to the municipality. These resources should finance policies for the formation of new centralities and low-income housing in the municipality and seek to recover part of the valorization of land generated by public action.

(2) With regard to compact cities and sustainability, see Fouchier (1997) and OECD (2012).

(3) See, for example, Farr (2008), Garcia-Cuerva et al. (2018) and Rosa et al. (2022b).

(4) See: Fontes (2023).

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