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Sustainable constructions: applications for the city of Uberaba – MG

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Abstract

Objective: Indicate possible adaptations for sustainable buildings in the city of Uberaba/MG, assisting in the choice of alternatives for a better environmental quality of the urban environment. The percolation, delay and infiltration of rainwater and green roofs were listed.

Methodology/Approach: Both metropolises and cities in the interior of Brazil are facing several environmental problems, demonstrating the need to rethink the urban configuration, posing as a challenge to the public and private authorities the need to guarantee a sustainable city in environmental, social and economical aspects. Due to this imbalance in the sustainability tripod, public and private institutions sought to create plans and actions aimed at the macro and microenvironment in which society is inserted, such as, the Sustainable Agendas. In addition, they rely on the help of sustainable systems and devices to reduce the consumption of natural resources and environmental impacts.

Originality/Relevance: Through literature reviews, we searched for indicators as a suggestion for sustainability that may fit Uberaba's necessities, resulting in some local analyzes in contrast with studies on sustainability.

Results: It was observed the presence of actions that help in sustainability and show themselves as sustainable alternatives both for the government and the community itself, for example on roads and sidewalks: the increase in permeable areas and infiltration to reduce the percolation in periods of rain.

Theoretical/Methodological Contributions: The results of this study identify how through small local changes in homes and the urban collective area can help to minimize the damage caused by urban disasters, which arise through human intervention without proper study of the environment, suggesting contributions to these new actions for an increase in the city's environmental quality.

Conclusion: The use of interlocked concrete block pavement was chosen as a sustainability suggestion. Although in the economic analysis it is not entirely viable because of the higher cost of the concrete pavement for the ride, taking into account the performance criterion for the rainwater percolation, its choice is the most assertive. On the issue of sustainability, it takes several selection criteria for each specific action.

Keywords: Construction criteria. Urbanization. Sustainability. Environmental impact. Surface runoff.

Construções sustentáveis: aplicações para a cidade de Uberaba - MG

Resumo

Objetivo do Estudo: Indicar possíveis adequações para construções sustentáveis na cidade de Uberaba/MG, auxiliando em escolhas de alternativas para uma melhor qualidade ambiental do meio urbano. Foram elencados a percolação, o retardo e infiltração de águas pluviais e telhados com cobertura verde.

Metodologia/Abordagem: Tanto as metrópoles quanto as cidades do interior do nosso País estão enfrentando vários problemas ambientais, demonstrando a necessidade de se repensar sua configuração urbana, colocando como desafio ao conjunto do poder público e privado a necessidade de garantir uma cidade sustentável nos aspectos ambiental, social e econômico. Devido a esse desequilíbrio no tripé da sustentabilidade, as instituições públicas e privadas buscaram a criação de planos e ações voltadas ao macro e micro ambiente em que a sociedade está inserida, como, por exemplo, as Agendas Sustentáveis. Além disso, contam com o auxílio de sistemas e dispositivos sustentáveis na redução do consumo de recursos naturais e diminuição dos impactos ambientais.

Originalidade/Relevância: Por meio de revisões de literaturas buscamos indicadores como sugestão para a sustentabilidade que possam se enquadrar para a malha urbana de Uberaba, obtendo como resultado algumas análises locais e contrastando com os estudos sobre sustentabilidade.

Resultados: Foi observada a presença de ações que auxiliam na sustentabilidade e se mostram como alternativas sustentáveis tanto para o governo quanto para a própria comunidade, como, por exemplo, nas de vias e calçadas: o aumento das áreas permeáveis e da infiltração para diminuição da percolação em período de chuvas.

Contribuições teórico-metodológicas: Os resultados deste estudo identificam como pequenas mudanças locais nas residências e na área coletiva urbana podem auxiliar para a minimização de danos causados por catástrofes urbanas, que surgem por meio de uma intervenção humana sem estudo adequado do meio, sugerindo contribuições para o aumento da qualidade ambiental da cidade.

Conclusão: O uso do pavimento de blocos de concreto intertravados foi o indicador escolhido para sugestão de sustentabilidade. Apesar da análise econômica não ser totalmente viável, devido ao elevado custo do pavimento de concreto para o passeio, levando-se em conta o critério de desempenho para auxílio da percolação de água pluvial, sua escolha é a mais assertiva. No quesito sustentabilidade, são necessários vários critérios de escolha para cada ação específica.

Palavras-chave: Critérios de construção. Urbanização. Sustentabilidade. Impacto Ambiental. Escoamento Superficial.

Construcciones sostenibles: aplicaciones para la ciudad de Uberaba – MG

Resumen

Objetivo del estudio: Indicar posibles adaptaciones para edificaciones sustentables en la ciudad de Uberaba / MG, asistiendo en la elección de alternativas para una mejor calidad ambiental del entorno urbano. Se enumeraron la percolación, el retraso y la infiltración de agua de lluvia y techos verdes.

Metodología/Enfoque: Tanto las metrópolis como las ciudades del interior de nuestro país enfrentan diversos problemas ambientales, demostrando la necesidad de repensar su configuración urbana, planteando como un desafío al conjunto de autoridades públicas y privadas la necesidad de asegurar una ciudad sostenible en aspectos ambiental, social y económico. Debido a este desequilibrio en el trípode de la sustentabilidad, las instituciones públicas y privadas buscaron generar planes y acciones dirigidas al macro y microambiente en el que se inserta la sociedad, como por ejemplo las Agendas Sustentables. Además, cuentan con la ayuda de sistemas y dispositivos sostenibles para reducir el consumo de recursos naturales y reducir los impactos ambientales.

Originalidad/Relevancia: A través de revisiones bibliográficas buscamos indicadores como sugerencia de sostenibilidad que encajen en el tejido urbano de Uberaba, obteniendo como resultado algunos análisis locales y contrastando con estudios sobre sostenibilidad.

Resultados: Se observó la presencia de acciones que ayuden en la sostenibilidad y se muestren como alternativas sostenibles tanto para el gobierno como para la propia comunidad, como por ejemplo, en caminos y aceras: el aumento de áreas permeables y la infiltración para reducir la percolación en temporada de lluvias.

Aportes teóricos y metodológicos: Los resultados de este estudio identifican cómo pequeños cambios locales en las residencias y en el área colectiva urbana pueden ayudar a minimizar los daños ocasionados por las catástrofes urbanas, que surgen por la intervención humana sin un adecuado estudio del entorno, sugiriendo contribuciones para aumentar la calidad ambiental de la ciudad.

Conclusión: El uso de pavimento de bloques de concreto entrelazados fue el indicador elegido para la sugerencia de sostenibilidad. Si bien el análisis económico no es del todo factible, debido al alto costo del pavimento de concreto para la acera, teniendo en cuenta los criterios de desempeño para ayudar a la percolación del agua de lluvia, su elección es la más asertiva. En términos de sostenibilidad, se requieren varios criterios de selección para cada acción específica.

Palabras clave: Criterios constructivos. Urbanización. Sustentabilidad. Impacto ambiental. Escorrentía superficial.

Introduction

Humanity, since modernity, has been studied from the notion of feeling of belonging. If in prehistory the choice for the place to live was made based on basic needs of natural resources (water and food) and security, with technological development, the human being starts to “control” nature through agriculture and livestock , initiating the first social organizations (villages and later civilizations), reducing the need for constant changes in environments. This evolution of knowledge about the environment and nature itself has provided, over the centuries, the creations of civilizations in the first cities.

According to the United Nations Department of Economic and Social Affairs (DESA), 4.2 billion people, that is; 55% of the world population lived in urban centers in 2018. By 2050, an additional 2.5 billion citizens will have chosen a city to take up residence and about 6.7 billion people will be living in cities, making the world almost 70% urban (https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020).

In this context, cities began to face problems related to the lack of planning and management in their conception and experience, due to the population growth and intense urbanization experienced in the last 100 years, suffering catastrophes of all forms: floods, extreme droughts, landslides, earthquakes and others, demonstrating how weak the environment is (Carvalho, 2001).

In Brazil, in a study directed at the Statute of the city, the author Sonia Carvalho (2001) explains that the right to the city is for everyone, as well as the right to a sustainable city. This statute regulates articles 182 and 183 of the 1988 Federal Constitution, referring to urban policy at the federal level. In the City Statute, the right to sustainable cities is considered as “the right to urban land, housing, environmental sanitation, urban infrastructure, transport and public services, work and leisure, for present and future generations ”(Federal Constitution Brazil, 1988).

For this reason, the vision of sustainability gains more and more strength and converges to the study of the cities of the future, seeking to minimize the environmental impacts generated by the construction and implantation of the urban system. Faced with these new challenges, the term sustainable city and / or smart city has been gaining influence in the master plans for the execution and management of urban projects, through the reframing of urban space.

> [...] sustainable city is the human settlement constituted by a society aware of its role as a transforming agent of spaces and whose relationship is not due to the nature-object reason, but to a synergistic action between ecological prudence, energy efficiency and socio-spatial equity. (Romero, 2007, p.51)

The coordination of several urban agendas such as the use of land, water, energy, waste, education, health, cultural vitality, mobility, economic development and social inclusion, help the city to perform well. Considering the city a spatial entity, it presents itself in two situations: habitable and sustainable, when it occupies its space in harmony with environmental processes and respecting human needs. If the city disregards the landscape in which it is inserted, it is inefficient and destroys the environment on which it depends (Andrade, 2014).

The natural and essential resource for life is water, but being a scarce and finite resource in both individual and collective aspects, it brings the need for current and future generations to develop efficient and effective methods for its conservation. Thus, for the maintenance of water resources it is extremely necessary to understand the social process of construction and management of the natural / urban space where they are located, incorporating their social, political and environmental dimensions (https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020).

The fact that water is not accessible to everyone and, in urban areas, is becoming less and less available due to geographical, social and economic factors, has worsened with the growth of population density in large cities, increasing the demand for water and food, and boosting its use in various industrial and agricultural activities. In addition, the production of sewage and garbage has also increased, generating an increasing degradation of water resources, by discharging pollution into rivers (Moraes; Jordão, 2002).

In this context, it is understood that it is possible to check the suitability for sustainable buildings, making it possible that through better planning and environmental management, buildings arising from accelerated demographic and urban growth, which cities today have as a real problem, become sustainable alternatives.

Given the above, the objective of the study is to indicate criteria for sustainable buildings in the city of Uberaba-MG.

Theoretical reference

Agenda 2030 – United Nations Organization

The United Nations met at its headquarters in September 2015 with world leaders from 193 member countries and decided on an action plan to eradicate poverty, protect the planet and ensure that people achieve peace and prosperity. The plan entitled Agenda 2030 for Sustainable Development has a set of 17 Sustainable Development Goals (SDGs) for the coming years.

Figure 1 - Agenda 2030 Sustainable Development Goals (SDGs)

Source: https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020.

In the case of Brazil, given the importance of this process, the National SDG Commission (CNODS) incorporated, in its 2017-2019 Action Plan, the tasks of adapting the global goals to the Brazilian reality and defining indicators to monitor their compliance.

With this vision, the Municipality of Uberaba created the document entitled “U + 20 - The Uberaba Vision 2037” to assist in the viability of building a sustainable city over the years.

With this worldwide movement, there are several authors and bodies focused on building theories that help urban sustainability. For example, the increase in the area occupied by vegetation, especially arboreal, has benefits in reducing the impacts of climate change such as reducing carbon dioxide and mitigating the heat island, consequently

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increasing the comfort of citizens. This arboreal increase has positive consequences in terms of biodiversity, hydrological behavior in the urban space and social, cultural and economic aspects (Alcoforado, 2009).

The same author lists mitigation measures to reduce environmental impacts and climate change, bringing other social and economic benefits:

> Increase the area occupied by vegetation (especially arboreal); reduce car traffic; increase permeable surfaces; create water storage systems; renaturalize rivers to improve water retention and prevent flooding; adapt land use and infrastructure to extreme hydrological phenomena; adjust urban geometry to the needs of cooling and ventilation; increase and improve open public spaces; increase the albedo of urban surfaces (using lighter colors); use low conductivity construction materials. (Alcoforado, 2019, p. 60).

According to the 2009 United Nations Global Report on Human Settlements, entitled "Planning Sustainable Cities" (Un-Habitat, 2009), environmentally sustainable urbanization requires:

> Reduction of greenhouse gas emissions; implementation of actions to mitigate and adapt to climate change; minimizing peripheral urban growth; development of more compact cities and served by public transport; rational use and conservation of renewable and non-renewable resources; reduction of energy consumed and waste produced; waste recycling; reducing the ecological footprint of cities; (Un-Habitat, 2009, p. 2).

UN-HABITAT - United Nations Program for Human Settlements proposes two ways to reduce the impacts of socio-environmental disasters resulting from climate change. The first of these is prevention, with the adoption of an alert system and planning of land use and more appropriate building codes. The second is "build back better" - rebuilding better, avoiding the mistakes of the past (Un-Habitat, 2006).

IPTU VERDE – Salvador/BA

An initiative of the Municipal Government of Salvador, in 2017 the sustainable certification program for buildings in the municipality, called IPTU Verde, was developed through Decree No. 29,100/2017. The certification was created with the objective of encouraging enterprises to contemplate sustainable actions and practices aimed at reducing the consumption of natural resources and reducing environmental impacts. In the process, there is the option of project feasibility both for new ventures and for constructions that have the interest to carry out the renovation and adaptation in the desirable areas. The certification does not exempt the full compliance with the environmental, urban planning, building, tax and other applicable legal norms.

Methodological procedures

The cities had a great urban population growth in the last century, going through several economic, political, social and environmental transformations, verifying the increase in the consumption of natural resources for the growing industrial production and as a result of this whole process, it caused the imbalance of the environment urban environment.

In the urban environmental issue, sustainability arises in the search for changes in attitudes and values for the creation of a democratic and quality space for all its citizens. This study sought through an exploratory bibliographic review, indications of small sustainable actions in homes and in the public environment that contribute to the improvement of the environmental quality of the city of Uberaba. Emphasizing the natural water resource, it is possible to verify sustainable alternatives that aim to increase the permeable areas with a consequent increase in the infiltration of rainwater to reduce the runoff during rainy periods.

From this research, Sustainable Urban Agendas were listed, elucidating the objectives that correlate with the objective of sustainability in the urban environment.

Bearing in mind that the IPTU Verde project in Salvador presents innovation in the public sector, encouraging the private sector to improve civil construction, counting on tax discounts such as gratification for actions taken. This study considers three aspects contained in the sustainable project in the booklet of sustainable actions and practices - IPTU Verde de Salvador (Law No. 29,100, of November 6, 2017); presented in Table 1.

Table 1 - Framework of Sustainable Systems and Devices selected for verification of suitability and sustainable viability in the city of Uberaba - MG

Sustainable systems and devices	Description
Percolation	Use of permeable paving in at least 60% of the sidewalk area, meeting the criteria set out in Law 8140/11. The permeable floor to be used must have a minimum permeability percentage of 80%, as evidenced by the technical specification of the floor used.
Rainwater delay and infiltration	Construction of reservoirs and / or infiltration ditches that allow rainwater runoff to be delayed. A specific project must be submitted with the ART / RRT in the protocol.
Green roofs	Implementation of a green roof in at least 25% of the roof area of the building. The area for the green roof should be continuous, excluding the roof area, the stairway boxes, reservoirs, helipads, and equipment allocation area.

Source: Law no. 29,100, of November 6, 2017.

Of the selected sustainable systems and devices, the item Percolation - use of permeable pavements in the sidewalk areas stands out. According to Costa (2006), the parameters that make the installation of permeable pavements feasible are the type of soil, water level and groundwater, acceptance by residents, topography and costs involved.

Thus, an economic analysis will be carried out with the objective of comparing the cost of building the coating layer of two paving systems - reinforced concrete sidewalks and interlocking concrete block sidewalks.

If for this comparison, own labor is used, the items indicated in the TCPO for each paving system will be considered. Otherwise, the items referring to the hourly cost of labor and use of equipment would be replaced by the cost of the contract. If TCPO data were to be used, the data in Table 2 would be considered for paving with interlocking concrete blocks and Table 3 for reinforced concrete paving.

Table 2 - Interlocking paving of concrete blocks on a sand cushion - unit: m².

Components	Unit	Consumption
Paver	h	0,23
Servant	h	0,46
Fine washed sand	m³	0,005
Medium washed sand	m³	0,05
Concrete block for interlocking paving 16 faces (length: 110 mm / thickness 80 mm / width: 220 mm)	unit	39
Vibrating plate compactor, diesel, power 10 HP (7.5 kW)	h prod.	0,03

Source: TCPO (2013, p. 97).

Table 3 - Concrete walkway, fck = 13.5 Mpa, including box preparation, and = 7 cm - m² unit.

Components	Unit	Consumption
Bricklayer	h	1,20
Servant	h	1,20
Clapboard (width 10 mm / height 70 mm / peroba wood type)	m	2,00
Structural concrete turned on site, consistency for vibration, gravel 1, fck 13.5 Mpa	m³	0,07
Detailed composition including the production of inputs		
Bricklaver	h	1,20
Servant	h	1,62
Medium washed sand	m³	0,065
Crushed stone 1	m³	0,015
Crushed stone 2	m³	0,045
Portland cement CPII-E-32 (39 Mpa resistance)	kg	19,67
Clapboard (width 10 mm / height 70 mm / peroba wood type)	m	2,00
Electric concrete mixer, power 2 HP (1.5 kW), capacity 400 l	h prod.	0,021

Source: TCPO (2013, p. 97).

In order to obtain the aforementioned costs, price surveys were carried out with suppliers of material, labor and equipment in the city of Uberaba, thus enabling the calculation of a local average.

The calculation of the salary floors were those available on the SINTRACON-MG website presented in Table 4 and charges will be calculated at 1.54% of the salary floor.

Table 4 - Salary floor for construction workers / MG - UNION COMPANIES

Function	Minimim wage (month) - R$	
Servant	R$	1.088,88
Bricklaver	R$	1.510,31

Source: Sindcomerciários – MG.

Roofs with green roofs are also highlighted for the selected sustainable systems and devices. In Brazil, Santos et. al. (2013) simulated the water dynamics on two green roofs with different vegetation for different intensities of precipitation in the region of Pernambuco and found a reduction in runoff between 15% and 30% of the total precipitate. Understanding that this reduction brings environmental benefits, we used the values of reduction in runoff presented by Santos et al (2013) and simulated four scenarios of flow reduction in the downtown area of the city of Uberaba, Figure 2.

The simulation scenarios were: Current Scenario (conventional roof coverage); Scenario 1 (15% reduction in the total precipitate); Scenario 2 (20% reduction in the total precipitate); Scenario 3 (25% reduction in the total precipitate); Scenario 4 (30% reduction in total precipitate).

For this, the project flow was considered as the catchment area, which are the roofs of the buildings, sources of precipitation in the region. The amount of liters of rainwater that can be captured and the volume of its storage must be calculated according to NBR 10844/89 using the flow equation:

$Q = I.A/60$

Which one: Q = flow (liters/min);

I = rainfall intensity (mm/h);

A = contribution area (m^2);

Figure 2 - Bairro Centro, Uberaba / MG

Source: Satellite image of September 9, 2018 made available by Google Earth browser, adapted Author 1, 2019.

To calculate the roof area in the delimitation of the Uberaba city center, Google Earth was used with the measurement methodology of each block, with the verification by the satellite image, it was observed that for this location we could consider the decrease around 20% of the area considered as non-roof / roof area.

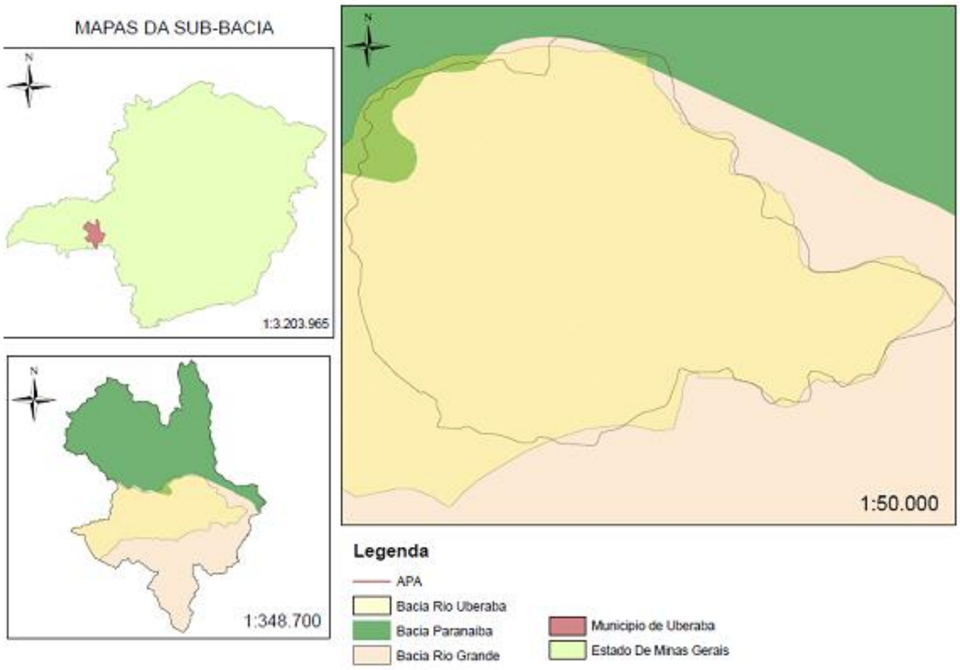
Characterization of the study area

The city of Uberaba is located in the Triângulo Mineiro microregion in the state of Minas Gerais, with south latitude 19°45'27" and west longitude at 47°55'36", in the Southeast region of the country. It has an area of 4,529.70 km², with 256 km² occupied by the urban perimeter (5.7% of the total area).

According to IBGE (2019) by the last census of 2010 the population was 295,988 inhabitants and in 2019 the estimated population is 333,783 inhabitants, making it the 8th most populous municipality in the state.

The municipality is located in the area corresponding to two Federal Hydrographic Basins: the Paranaíba River Basin and the Rio Grande River Basin, see Figure 3.

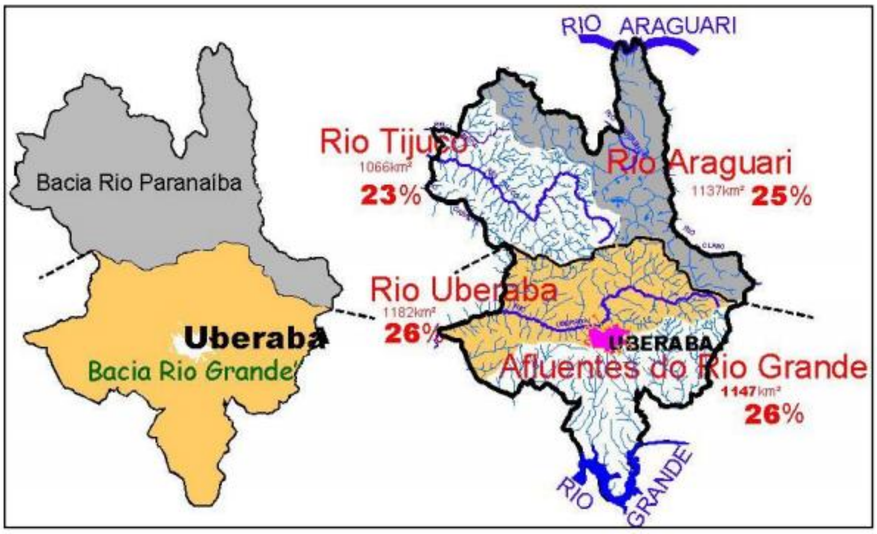
Figure 3 – Location of the municipality of Uberaba in the hydrographic basins



Source: http://www.uberaba.mg.gov.br/portal/acervo//links/Arquivos/anuario_U20.pdf, recovered on September 9, 2020.

The Uberaba River is located in the hydrographic basin of Rio Grande, Figure 4, with an extension of about 150 km and approximately 2,346 km² of its basin. In its location in the municipality of Uberaba, there is the Environmental Protection Area - APA of the Rio Uberaba Hydrographic Basin, integrating the Uberaba River basin with approximately 535 km² of surface area, including 8% of the urban area. It stands out for its importance in terms of water resources and economic aspects related to agricultural activities and supplying the city of Uberaba.

Figure 4 - Hydrographic network of the municipality of Uberaba.



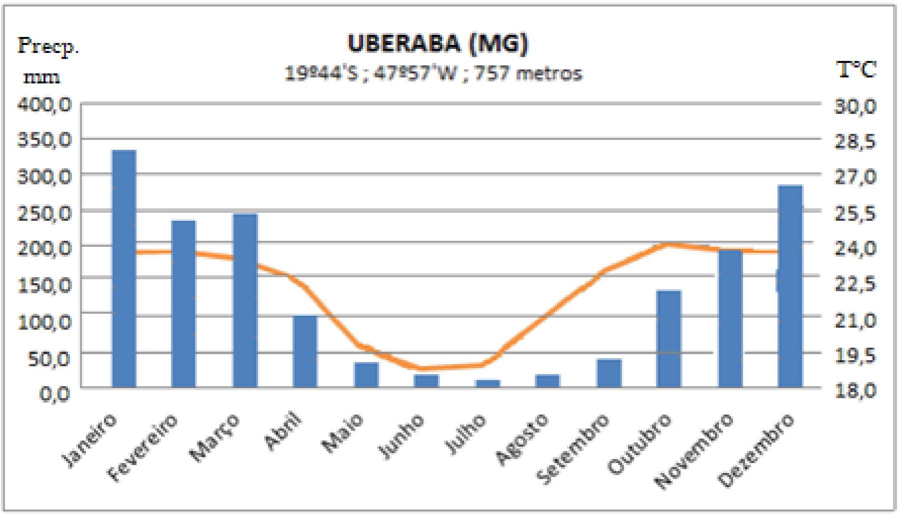
Source: http://www.uberaba.mg.gov.br/portal/acervo//links/Arquivos/anuario_U20.pdf, recovered on September 9, 2020.

According to data from the Environmental Assessment Report, the region originally had cerrado cover interspersed with forest spots, but systematic deforestation reduced the natural floristic coverage to a few areas. The cerrado is the dominant vegetation, and the vegetation consists of tortuous trees, with thick and cortical barks. The relief varies from flat to slightly undulating in the majority of the area of the municipality, to strongly undulating in small patches of podzolic soils. The Serra de Ponte Alta has the highest altitude of 1,031 meters, the minimum is with the border of the state of São Paulo, 522 meters and the headquarters of the city has an average of 764 meters. (Data taken and adapted from the site:http://www.uberaba.mg.gov.br/portal/acervo/agua_viva/arquivos/impacto_social/Relatorio%20de%20Avaliacao%20Social.pdf, recovered on September 9, 2020).

According to Oliveira (2005) with the exception of the extensive flat avenues that were built with the channeling of tributaries of the Uberaba River, the city of Uberaba is on the hillsides, having an irregular urban topography.

Using data from the stations of the National Meteorological Institute, INMET between the years 1990 to 2015, Novais (2016) created the climate chart below.

Figure 5 – Climogram (average monthly rainfall and average monthly temperature) in Uberaba between 1990 and 2015



Source: Novais, 2016.

Uberaba (MG) was 22.2ºC. The month with the highest average temperature was October with 24.0ºC, with a maximum above 31ºC. The one with the lowest average temperature was June, with 18.9ºC, and minimums below 13ºC. In terms of rainfall, the annual average (1990-2015) was around 1636 mm. The month with the highest rainfall was January with 327.0 mm; and the least amount was in July with 11.9 mm. It is concluded that the rainy season happens from November to March and the dry season from May to August (Novais, 2016).

Results and discussions

Sustainable Urban Agendas

As Sustainable Urban Agendas, Agenda 2030 and U + 20 - The Uberaba Vision 2037 were selected.

Agenda 2030 - SDG Sustainable Development Goals

According to ONUBR, the 2030 Agenda constitutes an action plan targeting people, the planet and prosperity. Search through the collaborative partnership between countries and all interested parties for its effective implementation (https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020).

In analysis, the objectives that correlate with the work were elucidated, taken from the 17 Sustainable Development Goals presented in the agenda; which are directly and indirectly related to planning for sustainable buildings:

> Objective 6. Ensure the availability and sustainable management of water and sanitation for all; Objective 7. Ensure reliable, sustainable, modern and affordable energy access for all; Objective 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; Objective 11. Make cities and human settlements inclusive, safe, resilient and sustainable; Objective 12. Ensure sustainable production and consumption patterns; Objective 13. Take urgent measures to combat climate change and its impacts; Objective 15. Protect, recover and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, stop and reverse land degradation and stop biodiversity loss; (https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020).

U + 20 – The Uberaba Vision 2037

According to the Municipality of Uberaba, the document entitled “U + 20 - The Uberaba Vision 2037” aims to show what the city might look like in 20 years. It seeks to guide the actions to be planned and carried out by all institutions in the city, whether public or private, with annual review. Available on the city hall website, guidelines and proposals are mentioned that will guide the municipal government, companies and the community for government planning and strategy, supported by society during these 20 years (PMU, 2017). The proposed guidelines are: “accessible city, citizen city, educated city, smart city, productive city, healthy city, safe city.” (https://nacoesunidas.org/pos2015/agenda2030/, recovered on September 9, 2020).

Sustainable Project – constructive characteristics for sustainability

Rainwater percolation

The actions of the human being, arising from the progress of the urban environment, interfere in the natural balance of the hydrological cycle in quantitative and qualitative factors, altering its natural balance with the formation of impermeable surfaces, increasing the runoff, which together with other factors, such as the incorrect disposal of garbage, generate significant losses for the whole society, causing urban floods. A resource for minimizing urban impacts is sustainable control actions that promote the infiltration of rainwater into the soil (Reis, 2005).

In the regional news it is possible to notice that Uberaba does not differ from the situation illustrated by the author above. Most of the streets, sidewalks, backyards and open spaces in the city are paved or cemented and in times of precipitation, rainwater quickly flows into drains, mouths of wolves and in a short time they are in rivers. After the rains stop, we will find the streets and sidewalks in the highest dry places and the flooded lowlands, cases verified by the population, such as, for example, Avenida Leopoldino de Oliveira, which mostly stays with flooded spots, even after small rains and short duration.

To assist in these flooding problems and economic losses due to flooding with loss of assets, it is possible to opt for the installation of permeable pavements, thus avoiding the total waterproofing of public roads and public and private sidewalks. This strategy can be accomplished through the implementation of concregramas and interlocked. Figures 6 and 7 show strips of lawns or gardens, seeking adequate afforestation on the pavement so that there is also accessibility for all citizens and the enhancement of aesthetically landscaping in the city (Costa, 2006).

Figure 6 - Interlocking permeable sidewalks

Source: Author 1, 2019.

Figure 7 - Permeable pavement in the form of interlocked concrete used in a closed condominium

Source: Author 1, 2019.

The following parameters that allow the installation of this type of equipment must be considered: type of soil, water level and water table, depth of the impermeable layer of the soil, acceptance by the residents, free area of the lots, topography and costs involved (COSTA, 2006).

For an economic analysis of the comparison between the installation of the sidewalk with interlocking pavement and conventional concrete, it was considered the execution costs with the hiring of own labor, as suggested by TCPO 2013. The cost for the execution of the base to receive the pavements it was not considered because it is the same executive method and the average material costs were obtained through market research in local companies in the industry. The BDI (Indirect Benefits and Expenses) considered is equal to zero, since, as it is public works, it does not aim at profit and there is no way to estimate indirect expenses for city hall, Tables 5 and 6.

Table 5 - Cost composition for interlocking pavement (own labor) in the city of Uberaba - MG

Components	Unit	Consumption	Price	Social Charges	Total Cost
Paver	h	0,23	R$ 8,58	154%	R$ 3,04
Servant	h	0,46	R$ 6,19	154%	R$ 4,38
Fine washed sand	m³	0,005	R$ 50,00	-	R$ 0,25
Medium washed sand	m³	0,05	R$ 50,00	-	R$ 2,50
Concrete block for interlocking paving 16 faces (length: 110 mm / thickness 80 mm / width: 220 mm)	unit	39	R$ 1,25	-	R$ 48,75
Vibrating plate compactor, diesel, power 10 HP (7.5 kW)	h prod.	0,03	R$ 155,00	-	R$ 4,65
	Execution price of 1 m² (own labor)				**R$ 63,57**

Source: Author 1, 2019.

Table 6 - Composition of costs for the concrete walkway (own labor) in the city of Uberaba - MG

Componentes	Unit	Consumption	Price		Social Charges	Total Cost	
Bricklayer	h	1,20	R$	8,58	154%	R$	15,86
Servant	h	1,20	R$	6,19	154%	R$	11,43
Clapboard (width 10 mm / height 70 mm / peroba wood type)	m	2,00	R$	4,50	-	R$	9,00
Structural concrete turned on site, consistency for vibration, gravel 1, fck 13.5 Mpa	m³	0,07	R$	255,00	-	R$	17,85
Detailed composition including the production of inputs							
Bricklaver	h	1,20	R$	8,58	154%	R$	15,86
Servant	h	1,62	R$	6,19	154%	R$	15,43
Medium washed sand	m³	0,065	R$	50,00	-	R$	3,25
Crushed stone 1	m³	0,015	R$	20,00	-	R$	0,30
Crushed stone 2	m³	0,045	R$	25,00	-	R$	1,13
Portland cement CPII-E-32 (39 Mpa resistance)	kg	19,67	R$	0,39	-	R$	7,67
Clapboard (width 10 mm / height 70 mm / peroba wood type)	m	2,00	R$	4,50	-	R$	9,00
Electric concrete mixer, power 2 HP (1.5 kW), capacity 400 l	h prod.	0,021	R$	65,00	-	R$	1,37
		Execution price of 1 m² (own labor)				**R$**	**54,00**

Source: Author 1, 2019.

It can be noted that the values of m² to be invested for execution between the two floors have a reasonable difference in large areas, since the interlocking floor has a higher cost of approximately 17.7% - R $ 63.57 - in relation to the concrete floor - R $ 54.00. These numbers prove the relatively high cost of paving interlocking concrete blocks when compared to concrete pavement, a reason that can be considered relevant when choosing a paving system.

The above figures are only used to compare the costs of implementing the coating layers of the two chosen paving systems. Due to the fact that Uberaba has a recent history of using the interlocking pavement, it was not possible to estimate the scale of maintenance required in this system, which would allow conclusions to be reached regarding long-term costs.

For structural solutions in the city of Uberaba, a study related to hydraulic engineering works is needed, which would help to minimize the impacts caused by floods, through measures that act directly in the basin. These measures could be direct physical measures, aiming at reducing the runoff coefficient and decreasing the effects of erosion and, as a consequence, reducing flood risks, issues that will not be addressed in this work.

Rainwater retention

Silveira (Silveira, 2002 as quoted in Poleto, 2011) informs that as an effect of urbanization, there was an intensification of soil waterproofing, reducing the infiltration of rainwater, thus generating a sharp increase in the runoff of rainwater and consequently greater volume of water to be drained.

Urban Sustainable Drainage Systems (SUDS), according to Poleto (2011), appeared to control runoff, increase soil infiltration, improve the balance of the hydrological cycle and encourage the sustainable use of water. For the purpose of rainwater retention, the system must allow runoff, but in a controlled manner, to reduce the risk of flooding. Solutions, for example, for homes or public areas, are the use of a retention box and a retention pond that initially allows the reserve of water from the rains and later the flow to the urban drainage system. This system does not take advantage of the collected water, it is limited to collecting the water and promoting its temporary storage, Figure 8.

Figure 8 - Example of a rainwater retention zone.

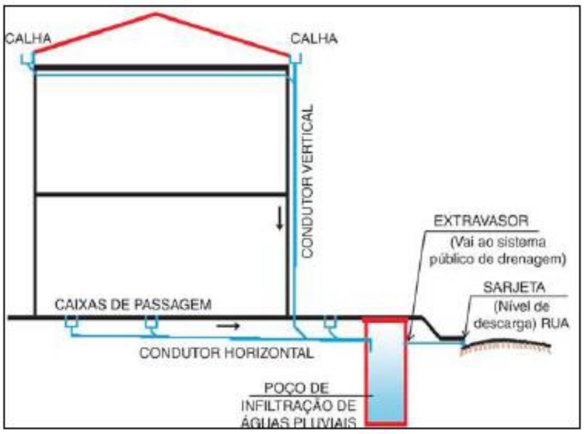
Source: FEAM - State Environment Foundation, 2006.

Infiltration of rainwater

In a document prepared by Caixa Econômica Federal, the authors John and Prado (2010) coordinate the Selo Casa Azul project, which indicates the use of reservoirs that allow water to infiltrate the soil (Figure 9). The purpose of this action is to prevent the risk of flooding, mitigate the request from public drainage networks and provide recharge of the water table. The rainwater infiltration system does not use the collected water, it only directs it to the soil.

For the feasibility of installing this action, as a sustainable construction strategy, several studies are needed that consider parameters such as the water table level, local soil profile as to the permeability and infiltration rate, the potential for collapsibility of the soil, rainfall indexes of the region, the emptying time and the contribution area of the system which, due to the complexity, may make the use of this technique unfeasible.

Figure 9 - Schematic detail of the rainwater infiltration system model



Source: John; Prado, 2010.

Use of rainwater

Water scarcity will affect two-thirds of the world's population in 2050 according to the UN (2019). This means that work and dedication will be needed to ensure safe drinking water and food security for everyone. One of the main measures to alleviate the issue of individual water consumption is conscious and responsible consumption.

According to Decree nº 24.643, July 10, 1934, the rainwater belongs to the owner of the building where it precipitates, and can be used at will, and it is not allowed to waste these waters to the detriment of others (BRASIL, 1934).

NBR 12217 informs that rainwater reservoirs are elements whose main function is to store the rainwater collected through the roofs of buildings, which contribute to the redistribution of flows, thus reducing the incidence of flooding downstream (ABNT, 1994).

Thus, the proposal to use a cistern (Figure 10) in Uberaba for the use of rainwater is presented as an alternative for saving water resources, and also financially, in terms of reducing the water bill, the private network and the reduction of flooding in the streets and avenues during the rainy season.

Figure 10 – Exemplification of cistern

Source: www.sempresustentavel.com.br, recovered on September 9, 2020.

Green roofs

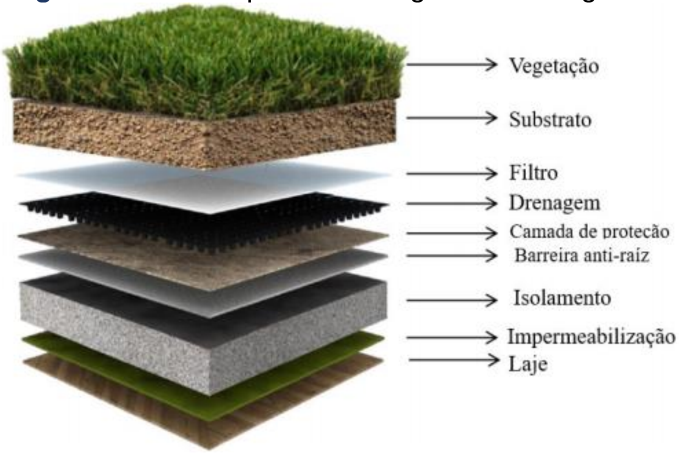
Green roofs are known for converting the surface of a conventional roof into a multifunctional space, using vegetation for this. This practice has been used extensively in Germany for more than 30 years. In 2002, more than 12% of the flat roofs in that country had some type of vegetation (Harzmann, 2002 as mentioned in Carter and Butler, 2008).

In general, green roofs (Figure 11) have seven constituent layers, which are:

Vegetation layer that corresponds to the vegetation cover, which is verified according to the climate of the region where the green roof is built. The vegetation of this layer reduces the speed of runoff of rainwater and there are two subsequent processes, that of evapotranspiration into the atmosphere and that of water retention in the substrate;
The substrate is the soil layer that has the function of fixing the vegetation, provides water and nutrients, it is in this layer that there is the temporary storage of water during the rains;
After the substrate, there is the filter layer, which is the filter layer that does not allow mixing of the substrate layer with the draining layer;
The drainage layer acts by retaining part of the rainwater, functioning as a stock for the vegetation during periods of drought;
Protective layer is intended to retain moisture and nutrients above the roof structure, providing physical protection for the waterproofing membrane against the growth of vegetation roots;
The waterproofing layer, which can be associated with an insulation layer, prevents the roof structure from having contact with water and is carried out with the use of water repellents;
Roof structure (slab) has the function of supporting the entire load of the green roof. (Carter and Butler, 2008).

For green roofs to be a sustainable solution and also able to meet the expectations of its users, efficient material selection is vitally important (Vijayaraghavan, 2016).

Figure 11 – Exemplification of green coverage



Source: Vijayaraghavan (2016).

Among the advantages of implementing the green roof, there is a reduction in the speed of rainwater runoff on the roof, increased retention of rainwater in the urban drainage part, contribution to reduce pollution, decrease in the temperature of the micro and macro environment external in consequent thermal comfort, and contribution to the greater durability of buildings, as it reduces the thermal amplitude (Castro; Goldenfum, 2010).

In Brazil, Santos et. al. (2013) simulated the water dynamics on two green roofs with different vegetation for different intensities of precipitation in the region of Pernambuco and found a reduction in runoff between 15% and 30% of the total precipitate. The roof area of the Uberaba city center, obtained by Google Earth, was 399,100 m² of coverage area, which collects rainwater. Using data from the National Institute of Meteorology (INMET) for the calendar year 1990, the maximum daily height (mm) was 56.8 mm / h, we will consider this rainfall intensity for the composition of the four study scenarios and considering that 50% of existing buildings in the city center implement this new alternative.

Table 7 presents the values of reduction in runoff in the simulation scenarios.

Table 7 - Values of reduction in runoff in the simulation scenarios in the Centro de Uberaba neighborhood - MG

	Current Scenario	Scenario 1 (15% reduction)	Scenario 2 (20% reduction)	Scenario 3 (25% reduction)	Scenario 3 (30% reduction)
Q liters/min	377814,7	349478,6	340033,2	330587,8	321142,5

Source: Author 1, 2019.

From the analysis of Table 6; comparing Scenario 1 with the Current; there is a 7.5% reduction in flow when transforming 50% of the roofs from conventional roof to green roof. This reduction increases to 10% from the Current Scenario to Scenario 2; 12.5% for

Scenario 3 and 15% for Scenario 4. The calculations made in this study proved that the use of green roofs can promote a decrease in the runoff of rainwater when compared to the conventional roof, as it reduces the volume of rainwater directed to drainage networks.

Final considerations

The characterization of the study area allowed to verify that the region is extremely favored by natural resources and needs to use them in a sustainable way for their preservation, in order to reconcile with the activities of the urban city.

In this sense, the 2030 Agenda with 7 objectives that correlate with work and U + 20 - The Uberaba Vision 2037, which highlighted the local government's concern in seeking joint actions in the public and private sectors, for a better outcome, becomes evident as Sustainable Urban Agendas. planning and management of the urban agenda.

In verifying the use of systems for sidewalks that allow greater permeability of the area, through the economic analysis carried out in the study, the cost of using interlocking concrete blocks was approximately 18% higher than that of conventional concrete pavement - system with greater adhesion to the ride. This difference in cost may be the reason for choosing when the criterion is only economic, but in the sustainable issue one of the criteria considered to be relevant is the efficiency of the system to aid, in this case, the percolation of rainwater.

Regarding sustainable systems and devices for the retention, infiltration and use of rainwater, the studies become more complex, for this reason they were not expanded in this article.

It is concluded that the use of green roofs, implanted in 50% of the residences would bring a reduction of up to 15% in the runoff flow to the downtown area of the city of Uberaba. However, this analysis of the study does not verify the technical vision necessary for the waterproofing. In this case, quality is extremely important, in addition to not considering the future regular preventive maintenance that this sustainable alternative requires for the conservation of vegetation and aesthetic expectations, which may not allow its long-term use.

It is considered that there is a need for a larger number of studies for the region on what fits as possible for local sustainability, allying with a better approach that helps to build the awareness of the whole society about its role vital for changing the urban scene.

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