Guidelines for Climate Change Adaptation in Brazilian Cities Through Urban Green Infrastructure

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Abstract. One of the significant challenges for managers and urban planners today is adapting cities to climate change. Studies published in the Assessment Reports (AR) of the Intergovernmental Panel on Climate Change (IPCC) indicated several evidences of climate change and also showed possible impacts on urban infrastructure, service availability and natural resources. Thus, adaptation actions emerge as a necessary coping strategy and search for urban resilience. Green infrastructure refers to a set of interventions aimed to preserve natural ecosystems and to support for urban systems. This research aims to identify what are the main impacts projected for the Brazilians cities, due to climate change, and also provide guidelines to the green infrastructure adoption as an adaptation strategy. The methodology was based on the evaluation of the general panorama of climate change on the national context indicated by the Brazilian Panel on Climate Change (PBMC). In addition, a review of articles related to green infrastructure was made aiming for the selection of possible solutions focused on its applicability. As a result, guidelines for urban planning were settled as a contribution to reducing the vulnerability of Brazilians cities.

1. Introduction

Nowadays, climate change is one of the main discussion topics in the world, being highlighted in meetings and debates in all government levels (federal, state and city). The importance of this subject comes from consistent scientific evidence concerning the human influence on the planet’s climate. If years ago climate change was interpreted with uncertainty, current in situ observations and ice core records endorse the changes verified [1].

Considering the negative impacts foreseen by climate change, lots of international negotiations have been happening to settle a global agreement to face this problem. Those conventions, therefore, have been seen as a key component for the orientation of future decisions about the reduction of GHG emission and global warming [2]. It has been created in 1988, as a result of the international effort, the Intergovernmental Panel on Climate Change (IPCC) by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) having as goal, providing to the scientific community, government leaders and civil society, in a transparent and open way, regular climate changes scientific-based evaluations and its possible impacts, future risks and mitigation and adaptation options [3].
Concerning the challenges to the development and implications on the geophysics, biological and human systems projected by IPCC reports, Brazilian specialists got together in 2011 to elaborate the Primeiro Relatório de Avaliação Nacional (RAN1, the first national assessment report) from the Painel Brasileiro de Mudanças Climáticas (PBMC, Brazilian Panel on Climate Change). Since it characterizes the vulnerabilities of each region in the national territory and indicating possible ways to face this phenomenon, this report is a reference in the climate change comprehension.

Out of all the orientations mentioned in the RAN1, the suggestion to elaborate studies and programs that involve adaptation aspects to the urban impacts projected for the Brazilian territory can be found. These studies are very important, either in the strategy settlement and the actuating guidelines or in the public resources targeting made by the government leaders [4].

In Brazil, some efforts are being made in the elaboration of public politics on the adaptation theme, however, most of these initiatives are under development phase or improvement [5]. In this context we can highlight the National Policy on Climate Change (PNMC), that makes official the Brazilian commitment on climate change combat and sets goals, strategies, guidelines and acting instruments; the Brazil’s National Adaptation Plan (NAP), which aims to promote the national vulnerability reduction and risk management contribution related to this phenomenon; and the National Plan for Low Carbon Emission in Agriculture (ABC Plan), which has as the objective planning and organizing mitigation and adaptation actions in the farming sector.

It is important to mention that an effective adaptation means the implementation of actions that assess as an integrated way, the management of current and future risks, as the national development strategies which can contribute to the reduction of climate change vulnerability [6]. Consequently, the rising demand for adaptation solutions to climate impacts provides new opportunities for the development of more efficient and sustainable technology, which can use the non-explored potentialities.

Cities have an important highlight in the climate change theme, initially, due to the fact that most of the population living in urban areas and also because of the socioenvironmental problems related to the development standards and land use transformation which tend to be potentialized by climate change [6]. Therefore, it gets clear the need for politics to improve the city’s resilience and to enable the reduction of possible social, economic and environmental impacts.

Based on what has been exposed, this research aims to identify what are the main impacts projected for the Brazilians cities, due to climate change, and also provide guidelines to the green infrastructure adoption as an adaptation strategy.

2. Methods
The literature review studies for the elaboration of adaptation strategies for climate change show a difference between the types of proposals. The classification considers some criteria, such as the government level in which the action is being applied; the kind of intervention that is being implemented; the expected answers; and the purpose of the studies - either seeing in its hands-on applicability or aiming to provide new knowledge on the phenomenon [7].

This research aims to explore the new approaches directed to the cities’ adaptation on the climate changes, either in the present or in the future, through an analysis of potential applicability of a multifunctional and ecosystem net called green infrastructure. Some questions guide the research development, such as: What are the expected impacts on the Brazilian cities?; How can the creation of urban system support contribute to the negative effects of climate change?

In order to get the expected results, this study was made in the following steps: (1) Systematic review elaboration; (2) Document selection and identification of risks; (3) Document selection and evaluation of the green infrastructure applicability in the urban context; (4) The connections between risks and green infrastructure.
2.1. Systematic review elaboration
At first was selected studies around the identification of the risks projected to the Brazilian cities, arising from climate change, as well as researches and practices implemented on the green infrastructure. Due to the huge amount of material obtained in the initial research, it was necessary to set some criteria on the delimitation of the content used for the research.

Therefore, for the identification of the risks, it has been adopted RAN1 as a reference, considering that the report is a compilation of high trustworthy studies, selected by specialists and presented in a multidisciplinary and systematic way [4]. About the green infrastructure, research on the database was made, having some strategic keywords to the selection of the content to be used for this research.

2.2. Document selection and identification of risks
RAN1 was published in 2015 and had the participation of more than 360 specialists from many institutions and work fields. The long literature review made for the report elaboration generates the production of three volumes, name as the following way: Volume 1 - Scientific base on climate change; Volume 2 - Impacts, vulnerabilities and adaptation; and Volume 3 - Climate change mitigation [4]. After selecting the document, it was verified its adequacy to the research theme. Seeing the content present in each volume, it was decided that only the second volume of the report would be used, because the content of the others wasn’t directly about the foreseen identification of risks to the urban context and adaptation actions.

Initially, the document shows a general overview of climate change and national context. After, some potential impacts, vulnerabilities and strategic adaptation actions are shown in different systems and sectors. At last, the expected impacts for each region in the Brazilian territory are characterized, such as their regional sustainability implications in Brazil.

Although we recognize that risks related to climate change shouldn’t be assessed separated from the local context, for this research, it was decided to keep a general approach. This choice comes from the premise that all the available action possibilities should be analyzed aiming to develop practices that can promote human resilience and being applied in different urban contexts. For this reason, it is important to mention that the adaptation strategies introduced in the following must be evaluated à posteriori, considering the specificities and vulnerabilities of each location.

The selection of risks considered only the impacts directly related to the urban infrastructure, thus the risks of “indirect effects” were discarded, such for example, the increase of infectious disease caused by climate change. It is understood that the vulnerability has its origin on the local population exposure, on the weaknesses of the human settlements, and the socio-environmental issues arising from the urbanization process. Therefore, the adoption of more efficient and sustainable technical solutions, replacing conventional practices, contributes to the urban resilience to the phenomenon of climate change. [8-9].

2.3. Document selection and evaluation of the applicability of green infrastructure in the urban context
Considering the reliability of the data used for this study, to the green infrastructure literature review, it was made a research on the database Science Direct using keywords. The search strategy used the keywords: “Climate Change”; “Adaptation” and “Green Infrastructure”. In order to select the most relevant articles achieving the purpose of this work, a careful selection was made with the criteria of selecting only the articles published between 2009 and 2019 and not using the literature review papers.

Lastly, a total of forty publications about cases and simulations on software were found using the green infrastructure for risk mitigation related to the thermal discomfort and hydrological problems.

2.4. The connection between risks and green infrastructure
To facilitate the collected data, the risks identified during the methodological procedure described in item 2.2, were listed and organized according to the similarity. The grouping criteria took into account the system or sector in which each risk is in, as the kind of impacts responsible for their emergence.
Posteriorly, the relation between the aforementioned data and the green infrastructure system technique solutions, obtained during the methodological procedures described in item 2.3 was evaluated. The evaluation result is explained below.

3. Results and Discussion

Green infrastructure corresponds to an interconnected system composed of natural and artificial resources implemented in open spaces and landscape, aiming to provide multifunctional benefits of ecosystem services. The system based on Nature-Based Solutions (NBS) enables the structural and social resilience, through the areas recovery, loss mitigation, among others [10-11].

Generally, the studies on the green infrastructure adoption to climate adaptation are related to the management of risks originated from anthropic activities [12]. In this regard, some works tried to identify measures to minimize the floods in urban areas [10][13-14]. The same way, [15-17] developed some studies aiming at the attenuation of the urban heat island phenomenon and outdoor thermal comfort improvement.

However, the efficiency of adaptation strategies based on green infrastructure requires a wider approach [18]. According to [12], this system implementation must be analyzed in three aspects: (1) Risk management, through the mitigation of socio-environmental problems and adverse climate conditions. (2) The political aspect, seeking alternatives to the traditional growth models; and (3) Urban planning, through action integration in many government levels.

Thus, the adaptation strategies delimited by the research were grouped considering their fit to the three aforementioned aspects.

3.1. Identifications of risks related to climate change

For Brazil, the trends detected by the global models about the precipitation regime show changes in the volume, frequency and distribution of the rainfall in the territory. In turn, studies related to air temperature indicate the increase of the global average and the hot night’s occurrence [4]. It is important to highlight that the reliability of the future climate scenario varies according to the research quantity and observation data made, especially on a regional scale.

Even though only a few in situ studies have been performed, global scale projection predicts sea level rise on the Brazilian coast. This phenomenon in the south-southeast coast has been reported by the national scientific community since the end of the ‘80s and early ‘90s. Such climatic variations are extremely important due to their direct effects on urban areas [4]. Although there are some divergences in the climate scenario projected by global and regional models, it’s appropriate to analyze the distinct conditions projected to improve city planning and management.

Concerning the urban areas in general, the main direct risks related to the hydrological system are: floods and inundations; high energy flow floods; high dragging potential runoff; overflow; slope mass movement; issues on the drinking water availability; problems in the food and energy production. About the water resources, the sea level rise can cause inundation risks, slope erosion and problems with the land and port transport services [4].

Similarly, the higher temperature condition may cause risks of increased thermal stress, intensification of urban heat islands, increased concentration of atmospheric pollutants; inundations related to storms occurring; and water shortage due to the evaporation and evapotranspiration [4].

3.2. Adaptation strategies based on risk management

Once climate change causes increased frequency and intensity of storms, cities must adopt actions integrating the land use and watersheds management strategies to mitigate inundation and flood risks. For this reason, a previous assessment of stormwater infiltration and retention capacity is recommended before establishing the urban area [10]. This measure is essential to the temporary storage of the water volume generated by extreme events.

In this sense, it is emphasized that assessments should be based on Geographic Information System (GIS) to identify spaces destined to conservation, intervention and green infrastructure
implementation. Besides, actions to the conversion of the impermeable surfaces into multifunctional systems with better infiltration and retention capacity are necessary [10][19].

Given the water shortage projections, another important adaptive measure consists of the use of urban design structures as buildings, parking lots and squares for the capture and stormwater reuse [10]. When planned, areas destined to the watershed management can be situated as a way to preserve the existent biomes and hinder the urban sprawl [19]. On the other hand, the vegetation implementation allows the improvement of microclimate in cities and is a relevant measure for mitigating thermal stress and urban heat islands [20].

3.3. Policy approaches for the urban green infrastructure implementation

The adaptive measures based on green infrastructure will require local regulations that can guide the urban intervention and set the political limits to new proposals implementations [10]. It is important to emphasize that climate change affects more severely the poorer population, whose settlements are generally located in peripheral and environmentally fragile areas. The urgency for new solutions represent opportunities to review the ethical and social justice matters related to the development mode implemented [21]. Thus, the politics must act to combat the socio-environmental inequalities observed in the territory, through the elaboration of plans and programs that aim to promote climate justice [22].

3.4. Urban green infrastructure planning and climate adaptation

As observed in previous studies, some characteristics of the current model of urban planning hinder the diffusion of technologies related to the green infrastructure in cities [12]. Mostly, adaptation actions consider multiple aspects of urban management and, for this reason, need to be developed in an integrated way in the three government levels. Besides, adaptive measures must consider methods for assessing progress made after the system implementation.

4. Conclusion

The natural climate variation already causes challenges to urban planning and management. Considering that climate change is inevitable, it is necessary to develop strategies to adapt cities to this phenomenon [21]. It was observed in the research that most of the risk scenarios associated with climate change are related to old issues about the urbanization process of cities. Historically, it is known that this process contributed to the vegetation suppression, soil sealing, urban heat island formation, among other aspects [4]. Thus, adaptation actions should promote urban resilience, mainly through combat against socio-environmental issues, which will be aggravated by climate change.

Knowing the national capacity on the technological potential and biodiversity, the present study sought and explored analyzes of the possible benefits obtained from the implementation of the green infrastructure to climate adaptation in Brazilian cities. Although the green infrastructure solutions obtained in the review are focused on flood problems, other types are highlighted. It is therefore necessary to choose appropriate solutions to the problems of each locality.

Although it is recognized that this research has some limits on the scale of analyze, it is expected that the results obtained can guide future research on the green infrastructure applicability on a regional and/or local scale.

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