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## NATURE-BASED SOLUTIONS APPLIED IN URBAN PLANNING IN JARDINS MANGUEIRAL, BRASÍLIA-DF

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### ABSTRACT

This article proposes Nature-based Solutions guidelines to the Jardins Mangueiral Housing Sector, in Brasília, Federal District, Brazil. The methodology consisted of reviewing literature on Nature-based Solutions and green infrastructure. The next step was the systematization and categorization of Nature-based Solutions, highlighting the benefits and possibilities of integrating mobility, and sanitation. Then, we conclude that the application of Nature-based Solutions in the area of study contributes to an integrated urban planning, from the adaptation's context to the challenges faced in Brazilian cities. Such implementation would improve the population's quality of life, offer attractive and functional spaces, encourage active mobility, improve urban drainage, increase environmental comfort, ecosystem recovery, and climate change alleviation.

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## INTRODUCTION

Since the Industrial Revolution, the process of urbanization and population growth have intensified pressure on the environment to meet the growing needs for raw materials, housing, and infrastructure (ROGERS & GUMUCHDJIAN, 2001). The urban development model adopted since then has resulted in biodiversity decrease, emissions of pollutants and Greenhouse Gases (GHG), depletion of natural resources, public space's deterioration, excessive use of cars, urban sprawling on rural areas, among other problems, which reduce urban population's life and health quality (ROGERS & GUMUCHDJIAN, 2001; SILVA & ROMERO, 2011a). Thus, cities need to promote sustainable development to provide mitigation and adaptation to climate change and reduce its effects on the population and the built environment (HERZOG and ROZADO, 2019).

In addition, the concept of sustainable development applied to cities foresees a balance between the environmental, social, and economic spheres, which results in the formulation of several related themes that aim to contribute to the reinsertion of green spaces in urban centers (ROGERS & GUMUCHDJIAN, 2001; CORMIER & PELLEGRINO, 2008). Nature-based Solutions (NbS) are alternatives for promoting sustainable urban development (HERZOG & ROZADO, 2019). When applied in cities, NbS have the potential to turn them resilient and sustainable, and increase the well-being of the population, social cohesion, and biodiversity by providing ecosystem services, green economy, and natural capital, besides integrating policies and actions at different scales and sectors (FRAGA, 2020; HERZOG & ROZADO, 2019). Despite the mentioned benefits, the topic is considered recent in the literature and, as it is of foreign origin, studies that contribute to its dissemination and adaptation to the Brazilian reality are necessary (FRAGA, 2020; HERZOG & ROZADO, 2019). In this context, the Jardins Mangueiral Housing Sector (SHJM) located in the Administrative Region of Jardim

Botânico, in Brasília, Federal District, was announced as a sustainable neighborhood, and considered as an area of environmental relevance (ANDRADE *et al.*, 2011; CARIZZI, 2015; MENEZES, 2015). Furthermore, the measures adopted in the design, construction, use and maintenance phases, as well as in environmental compensation, were not enough to guarantee the sustainability of the site (ANDRADE *et al.*, 2011; CARIZZI, 2015; MENEZES, 2015). Thus, the application of the NbS to the sector must contribute to the sustainable development of the region, through an integrated urban planning. The objective of this article proposes guidelines to the application of NbS to the Jardins Mangueiral Housing Sector, in Brasília-DF. For this, adaptation towards the local and regional context and integration between urban planning sectors should focus on housing, mobility, and sanitation, to ensure the construction of resilient and sustainable cities. The specific objectives are (i) the literature review, identifying concepts, context and relevant elements; (ii) the systematization of the NBS, identified in the literature review, and their respective benefits, in addition to their categorization according to their applicability in the housing, mobility and sanitation sectors; and (iii) the elaboration of guidelines for the application of the NbS in Jardins Mangueiral, in order to synthesize the results obtained, demonstrate the integration between the urban planning sectors and assist in the elaboration of future projects.

## METHODOLOGY

The first step consisted of reviewing the literature on three themes: Nature-based solutions, green infrastructure, and Jardins Mangueiral Housing Sector. In parallel, information related to social, environmental, economic, spatial, and legal constraints of the Jardins Mangueiral Housing Sector was compiled, for a better understanding of the study area. Then, in the second stage, based on the information collected on the NbS, we sought to systematize the typologies, listing their respective benefits, and categorize the solutions according to their applicability to the housing, mobility, and sanitation sectors, as well as demonstrating the integration possibilities. Finally, in the third stage, guidelines were set to the application of the NbS over the Jardins Mangueiral Housing Sector. To that, the local and flows defined in the thematic map were selected, to contribute to an integrated urban planning, compatible with the local context and needs, and to the construction of more resilient and sustainable neighborhoods.

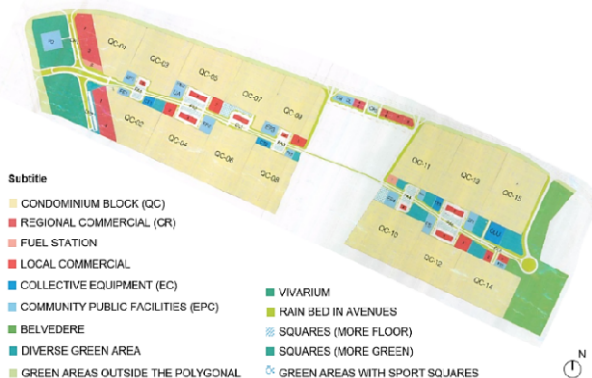
**Nature-Based solutions:** As stated, the Industrial Revolution, the growth of the population and the development of urban centers have been accompanied by the degradation of the environment (ROGERS & GUMUCHDJIAN, 2001). The growing demand to meet society's needs for housing, infrastructure and raw materials, added to automobiles in the city, resulted in pollution; scarcity of natural resources; unsanitary settlements; loss of biodiversity; climate changes; soil waterproofing; urban sprawl over rural areas; public space's degradation; separation between work, housing and leisure; and diminution of population's well-being and health (HERZOG & ROZADO, 2019; ROGERS & GUMUCHDJIAN, 2001; SILVA & ROMERO, 2011a; SILVA & ROMERO, 2011b). There is a need to promote cities' sustainable development, to ensure the demands of present and future generations through a balance between the social, environmental, and economic spheres (ROGERS & GUMUCHDJIAN, 2001). With this aim, several concepts have been created to contribute to sustainable development that, in common, defend the importance of urban centers' natural spaces (ROGERS and GUMUCHDJIAN, 2001). Among them, Nature-based Solutions stand out, presented by the World Bank, the International Union for Conservation of Nature (IUCN) and the European Union (EU), in the mid-2000s (FRAGA, 2020). According to Fraga (2020), as it is a recent topic, there are slight variations in the definition of NbS, "being understood as an umbrella concept that seeks to express all solutions that were somehow inspired, copied or based on in natural processes to generate some benefit to human societies" (FRAGA, 2020, p.16). Therefore, the NbS encompass concepts such as urban metabolism, urban ecology, green infrastructure, ecosystem services,

natural capital, and urban landscape, among others that recognize the importance of balance between the environmental, social, and economic spheres (FRAGA, 2020; HERZOG & ROZADO, 2019). Nature-based Solutions are recognized as providing multiple benefits, including adapting and mitigating climate change, generating green jobs, encouraging integrated and participatory planning, social cohesion, conservation and restoration of ecosystems and the promotion of sustainability and urban resilience (FRAGA, 2020; HERZOG and ROZADO, 2019). In addition, they contribute to global agendas, such as the New Urban Agenda and the Sustainable Development Goals (FRAGA, 2020; HERZOG & ROZADO, 2019). In Brazil, although not very widespread, NbS have been introduced among projects and initiatives by the Federal Government, universities, banks, private sector institutions and civil society (FRAGA, 2020). However, it is worth considering that, in countries with late industrialization and urbanization, such as Brazil (SILVA & ROMERO, 2011a), there is still a difficulty in considering such a holistic approach to urban planning (FRAGA, 2020), resulting in disconnected sectoral projects, such as housing, mobility, and sanitation, mainly due to the scarcity of financial and technical resources (FRAGA, 2020). According to Andrade *et al.* (2015), there are also challenges related to reconciling the Brown and Green Agendas, balancing development, industrialization, urbanization and late economic growth with the preservation, recovery, and reinsertion of natural ecosystems. Meanwhile, in developed countries, where the concept originated, the Brown Agenda is assured and efforts are being made to remedy the impacts through the Green Agenda (ANDRADE *et al.*, 2015). Examining the Brazilian context, Fraga (2020) and Herzog & Rozado (2019) reinforce the need to adapt NbS, as well as its benefits and applications, to local challenges, pointing out the importance of studies that contribute to a correct approach. In this sense, Fraga (2020) strives to understand and list the typologies of NbS that are most appropriate to Brazilian's cities context and challenges, considering sectoral public policies and case studies presented by Herzog & Rozado (2019), concluding that priority should be given to NbS capable of solving issues of sanitation and biodiversity preservation (FRAGA, 2020). The authors also point out the importance of involving, in the process, various sectors of society, including the public and private sectors, universities, social organizations, international organizations and local people, as well as the development of financing instruments for NbS (FRAGA, 2020; HERZOG & ROZADO, 2019).

The public sector has the role of regulating and promoting the adaptation and dissemination of NbS in the Brazilian context, through public policies, programs and government initiatives that ensure multiple benefits (FRAGA, 2020). In a complementary manner, the community must be involved in the process of creating, implementing, and maintaining the NbS (HERZOG & ROZADO, 2019), in order to ensure that the improvements are aligned with the real on the ground (FRAGA, 2020). As stated earlier, green infrastructure is under the umbrella of NbS concepts, being defined as "a network of green spaces that intentionally or strategically preserve, enhance or restore elements of a natural system [...]" (BROWDER *et al.*, 2019 apud FRAGA, 2020, p. 4). In addition, green infrastructure can be understood as a permeable network of multiple functions, even connecting public and private areas (HERZOG & ROSA, 2010). Thus, Cormier & Pellegrino (2008) argue that the insertion of green spaces with landscape treatment in cities represents not only aesthetic improvements, but also investments in infrastructure, which may be integrated into gray or traditional infrastructure. Those adopted measures must benefit the environmental comfort, biodiversity, rainwater management, alternatives for displacement, road integration, accessibility, among others (CORMIER & PELLEGRINO, 2008). When taken as infrastructure, NbS provide alternative transport modes, aimed at active mobility and encouraging sustainable sources, and make urban environments more attractive and comfortable for staying and moving (HERZOG & ROSA, 2010). In addition, Cormier & Pellegrino (2008) and Mascaró (2016) defend the combination of green infrastructures or green networks – such as the combination of rain gardens with swales or with permeable pavement –, enabling conduction, infiltration and

evaporation or evapotranspiration. Another aspect defended by the authors is the urban redesign with traffic calming strategies, such as what occurs through the narrowing of roads and the expansion of sidewalks, thus reducing vehicle speeding (CORMIER & PELLEGRINO, 2008; MASCARÓ, 2016). NbS can also be applied in buildings, in an integrated way, through permeable pavement combined with rain beds and/or swales close to external building areas (CORMIER & PELLEGRINO, 2008). Another option is the use of rainwater cisterns for human consumption or building maintenance (CORMIER & PELLEGRINO, 2008). In addition, it is possible to apply them at the building scale, in the form of fresh green surfaces as roofs, ceilings and walls, providing rainwater absorption, increasing energy efficiency, reducing heat islands, and increasing biodiversity (CORMIER & PELLEGRINO, 2008). In common, social and leisure spaces, NbS can be applied in the form of private gardens and community gardens, composting waste, providing local supply, environmental education, organic and native species cultivation, and social engagement (MASCARÓ, 2016). In addition, the implementation of a network of squares, urban and linear parks, along rivers and urban roads, provides an increase in biodiversity, the installation of adequate pedestrians and cyclists infrastructure for drainage improvement (FRANCO, 2021; MASCARÓ, 2016).

**Jardins Mangueiral Housing Sector:** Located in Administrative Region called Jardim Botânico, the Jardins Mangueiral Housing Sector (SHJM) is close to the Jardim Botânico Housing Sector 3, São Sebastião city and Papuda Penitentiary Complex, being delimited by two highways (DF-463 and DF-001) (DISTRITO FEDERAL, 2019a). Parallel to DF-463 we found Avenida Mangueiral, which covers the entire length of the SHJM and consists of the main connection and access road to housing blocks and other existing uses (DISTRITO FEDERAL, 2019a). In addition, we found Avenida Pau Brasil and other secondary roads perpendicular to Avenida Mangueiral, connecting it to DF-463, and a parallel road between Avenida Mangueiral and DF-463 (DISTRITO FEDERAL, 2019a). The SHJM was created as the result of the first Public-Private Housing Partnership held in Brazil (ANDRADE *et al.*, 2015; ARRUDA, 2013; MENEZES, 2015), with the objective of implementing a sustainable neighborhood, with adequate housing and infrastructure for families (ANDRADE *et al.*, 2015; ARRUDA, 2013; MENEZES, 2015). With 8 thousand houses, divided into 15 closed blocks, the development occupies an area of 200 hectares (MENEZES, 2015). The types of housing offered are two-story townhouses, with two or three bedrooms, and four-story buildings, with two-bedroom apartments (ARRUDA, 2013; CARIZZI, 2015; MENEZES, 2015). In addition, each block has common areas, such as sports courts, leisure area with barbecues and children's playground (CARIZZI, 2015). On the outside, the initial project (Figure 1) intended spaces for regional and local commercial uses, collective equipment (cults and club) and community public facilities (ambulatory, fire department, police station and schools), gas station, in addition to squares, flowerbeds, nursery and green areas close to the main and secondary roads (MENEZES, 2015).



Fonte: Source: authors, from the Associação dos Amigos do Jardins Mangueiral (2011). Available in: [https://aajm.org.br/wp-content/uploads/2018/10/mapa\\_bairro.jpeg](https://aajm.org.br/wp-content/uploads/2018/10/mapa_bairro.jpeg). Accessed in May 2022.

**Figure 1. Zoning Plan of Jardins Mangueiral Housing Sector**

More recently, the Federal District Land Use and Occupancy Law (LUOS) established the following uses (Figure 2): residential, which includes multifamily housing in apartment or house typologies combined or not with apartments (RE 3); commercial, service provision, institutional and industrial, concomitant or not (CSII 1, CSII 2 and CSII 3); institutional, exclusively, being able to be private or public (Inst); institutional with public equipment, exclusively for the development of activities inherent to sectorial policies, simultaneously or not with urban or community facilities (Inst EP); and that of fuel and lubricant retail establishments, with trade and services activities being optional (PAC 2) (DISTRITO FEDERAL, 2019a). In Figure 3, it is possible to observe some of the existing uses.



Source: authors, based on the Federal District Spatial Data Infrastructure – IDE/DF (2021) – Geoportal/DF. Available in: <https://www.geoportal.seduh.df.gov.br/geoportal/>. Accessed in May 2022.

**Figure 2. Land Use and Occupancy Law of the Jardins Mangueiral Housing Sector and the Botanical Garden 3**



Source: authors, from personal collection (2022).

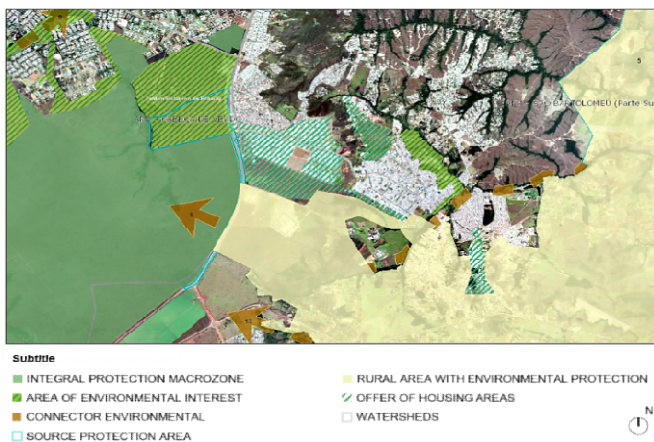
**Figure 3. Existing uses in Jardins Mangueiral Housing Sector**

According to the Federal District Master Plan for Territorial Planning (PDOT), the SHJM is in São Bartolomeu River Basin and is subject to other environmental factors, as shown in Figure 4 (CARIZZI, 2015; DISTRITO FEDERAL, 2009; DISTRITO FEDERAL, 2019b).

Thus, it is understood that the SHJM is located “in area of great environmental sensitivity” (CARIZZI, 2015, p.39), since the implementation of the enterprise causes the alteration and removal of soil and native savanna vegetation called Cerrado, as well as the waterproofing of the area, reducing the processes of flow, retention, and infiltration of rainwater, in addition to reducing the recharge of aquifers among other environmental problems (CARIZZI, 2015). In this context, Carizzi (2015) points out that although most of the envisaged environmental compensation measures were delivered, they



did not meet the demands of the residents, who should engage to put such demands into effect (CARIZZI, 2015). Additionally, Arruda (2013) identified that some of the measures adopted are not perceived by residents, despite affecting their well-being and daily life, which demonstrates the potential of environmental education actions. In turn, Menezes (2015), considering the concept of sustainability, understands that the environmental, economic and social spheres were not balanced in this case, since some environmental actions were not implemented. Andrade *et al.* (2015), applying an "Assessment of Sustainability and Quality of Urban Form" (ANDRADE *et al.*, 2015, p. 4), concluded that the SHJM enterprise is considered unsustainable, despite the propaganda and the proposed measures. The SHJM has been the subject of debate between the residents and the Government of the Federal District (GDF) who have different understandings regarding the destination of the area located between the sector and the Papuda Penitentiary Complex, called "polygonal of expansion" (MARRA, 2021; PARQUE, 2021). For the local community, the area should be converted into an Ecological Park (MARRA, 2021). Conversely, the GDF aims to build new housing units on the site, with a greater number of floors per building, which would disrupt the security of the penitentiary (MARRA, 2021).



Source: authors, based on the Federal District Spatial Data Infrastructure – IDE/DF (2021) – Geoportail/DF. Available in: <https://www.geoportail.df.gov.br/geoportail/>. Accessed in May 2022.

Figure 4. Federal District Master Plan for Territorial Planning

## RESULTS AND DISCUSSION

The Nature-based Solutions, presented in Table 1, consider the authors discussed above, regarding Fraga's method as the most appropriate to the Brazilian context and problems, as well as those listed by Herzog and Rozado (2019). Considering that green infrastructure is included in the NbS concept, the typologies mentioned by Cormier and Pellegrino (2008), Franco (2010), Herzog and Rosa (2010) and Mascaró (2016).

Table 1. Systematization of Nature-based Solutions

Nature-Based Solutions (NbS)	
Raingarden	Linear part
Rainbed	Urban park
Rain basin or rain pond	Ecological corridor
Swale	Afforestation
Filter Garden or wetlands	Private garden
Permeable flooring	Pocket forest
Green Roof or Green Wall	Urban agriculture
Rainwater cistern	Community vegetable garden and orchard
Recovery of urban springs	Coastal ecosystems restoration
Riverbanks restoration	Biological waste water treatment
Urban watersheds Restoration	Wastewater treatment with bioreactors and wetlands
Phytoremediation for water depollution	Recovery of degraded areas through reforestation

Source: Authors, based on Cormier and Pellegrino (2008), Fraga (2020), Franco (2010), Herzog and Rosa (2010), Herzog and Rozado (2019) and Mascaró (2016).

Similarly, the systematized NbS contribute to (i) the improvement of the population's health and well-being; (ii) air, water, and soil's depollution and recovery; (iii) green jobs' generation; (iv) strengthening the green economy centered on natural capital, among others. In addition, each typology of NbS has specific benefits, but they can also be applied in a network, expanding achieved gains. For example, linear parks provide public spaces for physical exercise, recreation, and contemplation, while encourage active mobility by offering infrastructure for pedestrians and cyclists. In sequence, the SBNs were categorized, considering the housing, mobility, and sanitation sectors, to guide the selection of appropriate typologies according to the context, the challenges, and the intended benefits. In addition, it is also possible to understand the integration between the SBNs for the formulation of sectoral public policies and strategic actions, promoting integrated urban planning. For example, rainwater beds can be applied to a house or a road, allowing (i) beautification of the site, (ii) filtration and infiltration of rainwater, which corresponds to sanitation, and (iii) implementation of traffic calming strategies along roads, which refers to mobility. Based on the information gathered, a thematic map (Figure 5) of the SHJM is proposed, consisting of six internal spots, namely: Spot 1, educational use, for environmental education; Spot 2, commercial use, and regional services; Spot 3, residential use, with common areas in each block; Spot 4, institutional, commercial, and local service use; Spot 5, recreational use; and Spot 6, commercial use, and services.

Table 2. Guidelines for Nature-Based Solutions application in Jardins Mangueiral Housing Sector

Guidelines for NbS application by Category	
Housing	Promoting the conservation and expansion of green and permeable areas in Patches 3 and 4, through the use of permeable pavements, rain gardens, rain beds and swales.
	Encourage residents and entrepreneurs to implement green surfaces (walls, ceilings and roofs) in the common areas of Patch 3, as well as in the buildings of Patches 2, 4 and 6.
	Implement the Jardins Mangueiral Ecological Park in Patch 5, using native species for afforestation, and combining it with swales, rain gardens, and permeable pavement.
	Implement a rainwater harvesting system and cisterns in Patches 2, 3, 4 and 6 for storage and reuse for buildings cleaning and maintenance.
	Establish cultivation areas in Patches 1 and 3, such as vegetable gardens, orchards, and nurseries.
Mobility	Implement and improve public spaces along the blue axis (which corresponds to a DF-463 domain strip) and the green axis, through sidewalks and cycle paths complemented by afforestation, permeable pavement, rain bed, gardens of rain, among other solutions. The objective is, therefore, to provide safe, accessible and attractive spaces for pedestrians and cyclists to move between regions (Patches 7 and 9), as well as enabling the population to access roads (DF-463 and Av. Mangueiral), offering public transport
	Adopt traffic calming strategies, through pluvial beds, rain gardens, drainage pavement and swales, in the inner stretch of Patch 5 and delimited by the green axes.
	Qualify sidewalks and cycle paths along the secondary axis through the implementation of permeable pavement, rain gardens, rain beds, swales, afforestation, gardens, and squares.
Sanitation	Preserve Patch 8, due to its environmental and social relevance.
	Promover a integração entre o sistema de drenagem natural e a infraestrutura tradicional nas manchas que compõem o setor e, quando couber, nas regiões vizinhas (Mancha 7 e 9). To promote the integration between the natural drainage system and the traditional infrastructure in the sector and, when applicable, in the neighboring regions (Patches 7 and 9).
	Use biological wastewater treatment and/or micro wastewater treatment with bioreactors and flooded areas in Patches 2, 3, 4 and 6.
	Promote the requalification of São Bartolomeu River Watershed in Patches 5 and 8.

Source: Authors.

In addition, four flows are envisioned: the main axis, next to DF-463 road; the secondary one corresponding to Avenida Mangueiral; the blue one, which comprises the domain strip of DF-463 road, adjacent

to the SHJM; and the green one, perpendicular to the secondary axis and to the others. Patches 7, 8 and 9 correspond, respectively, to the Jardim Botânico 3 Housing Sector, the SHJM expansion polygonal and São Sebastião city. Table 2 shows the proposed guidelines for the application of NbS to the Jardins Manguelral Housing Sector.



Source: own elaboration, based on Federal District Spatial Data Infrastructure – IDE/DF (2021) – Geoportal/DF. Available at: <https://www.geoportal.seduh.df.gov.br/geoportal/>. Access in May 2022.

**Figure 6. Thematic map for Nature-based Solutions application in Jardins Manguelral Housing Sector**

## CONCLUSION

The Jardins Manguelral Housing Sector, in Brasília, Federal District, was conceived as a sustainable development implemented in an environmentally sensitive area. As a result, sustainability measures were adopted in the design, execution, use and maintenance stages, as well as environmental compensation actions as part of the licensing process. However, such measures were not enough to make the site truly sustainable. Based on the proposed methodology, it was possible to perform the systematization and categorization – in the housing, mobility, and sanitation sectors – of the NbSs considered most appropriate to the context and challenges existing in Brazilian cities, highlighting the multiple benefits and integration possibilities. In addition, guidelines were proposed for the application of the NbS to the Jardins Manguelral Housing Sector. We conclude that NbS have potential to contribute to an integrated urban planning in SHJM and surrounding regions, providing several benefits, such as creating attractive and functional spaces; promoting active mobility; improving urban drainage; increasing environmental comfort; promoting energy efficiency; controlling urban sprawl; recovering the ecosystem; and mitigating climate change.

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