RA XIMHAI
Vol. 18 Núm. 3 ESPECIAL
enero-junio 2022
267-301

GREEN INFRASTRUCTURE IN MEXICO CITY - RECOMMENDATIONS TO IMPROVE AIR QUALITY AND CLIMATE CONDITIONS

INFRAESTRUCTURA VERDE EN LA CIUDAD DE MÉXICO RECOMENDACIONES PARA MEJORAR LA CALIDAD DEL AIRE Y LAS CONDICIONES CLIMÁTICAS

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Abstract

Environmental alert in Mexico City: In May 2019, the air pollution situation worsened to such an extent that the environmental alert was declared for several days. The people in the metropolis of almost 22 million inhabitants were exposed to extreme concentrations of various air pollutants. But even when the environmental alert has not been declared, there is an increased health risk in the Mega City for almost the entire year.

Parallel to this, environmental precaution in urban development is gaining international importance. The "Health in all Policies" strategy of the World Health Organization makes it clear that spatial planning has a responsibility for the health of the population. This can be used to justify an obligation to develop strategies that counteract the causative factors of deficient conditions in terms of climate and air quality. In the case of Mexico City, the causative factors can be identified in particular as anthropogenic processes, such as road traffic, but also topographical conditions, enormous uncontrolled urbanization that took place in the past, certain weather conditions and, last but not least, climate change.

Green infrastructure offers a major contribution to environmental care in cities. Green infrastructure can filter air pollutants, brings cooling, and can also be a ventilation pathway for cold and fresh air flows. Beyond this, however, there are many more environmental synergies. The recreational function that Green Infrastructure provides should also not be underestimated.

The research work took place within the author's master's thesis. It is about the potentials that Green Infrastructure has to improve the conditions of climate and air quality in Mexico City. It examines the

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Recibido: 05 de noviembre de 2021. Aceptado: 25 febrero de 2022.
Publicado como ARTÍCULO CIENTÍFICO en Ra Ximhai 18(3): 267-301.
doi.org/10.35197/rx.18.03.2022.11.jp

possibilities of improving the general situation, the possibilities of preventing extreme climatic events, and the possibilities of contributing to a livable and healthy city. For this purpose, it analyzes where exactly the problems lie, which planning concepts in relation to Green infrastructure can counteract these problems and, furthermore, which lessons can be learned from previous policies and measures in this regard in order to be able to ensure the feasibility of recommended measures.

The result of this work is concrete proposals for a green and open space strategy that has its scope of application not only in Mexico City itself, but beyond that in the entire metropolitan region. The green and open space strategy proposes four fields of action to expand the stock of green infrastructure: the systematization of roadside greenery, the development of new green areas, the greening of roofs and facades, and the maintenance and upgrading of climatically effective and valuable areas. These fields of action are to be implemented in particular in the form of individual projects. Two concrete project examples illustrate possible organizational structures and potential spatial alternatives within the existing settlement structure.

This article presents the main analysis results and formulated recommendations and concepts from the research.

Resumen

Alerta ambiental en la Ciudad de México: En mayo de 2019, la situación de contaminación del aire se agravó a tal punto que se declaró la alerta ambiental por varios días. Los habitantes de la metrópolis de casi 22 millones de habitantes estuvieron expuestos a concentraciones extremas de diversos contaminantes atmosféricos. Pero aun cuando no se ha declarado la alerta ambiental, existe un mayor riesgo para la salud en la Mega Ciudad durante casi todo el año.

Paralelamente, la precaución ambiental en el desarrollo urbano está ganando importancia internacional. La estrategia "Salud en todas las políticas" de la Organización Mundial de la Salud deja claro que la ordenación del territorio tiene una responsabilidad por la salud de la población. Esto puede utilizarse para justificar la obligación de desarrollar estrategias que contrarresten los factores causantes de condiciones deficientes en términos de clima y calidad del aire. En el caso de la Ciudad de México, los factores causales pueden identificarse en particular como procesos antrópicos, como el tráfico rodado, pero también las condiciones topográficas, la enorme urbanización descontrolada que tuvo lugar en el pasado, ciertas condiciones climáticas y, por último, pero no menos importante, el clima. cambiar.

La infraestructura verde ofrece una importante contribución al cuidado del medio ambiente en las ciudades. La infraestructura verde puede filtrar los contaminantes del aire, brindar enfriamiento y también puede ser una vía de ventilación para los flujos de aire fresco y frío. Más allá de esto, sin embargo, hay muchas más sinergias ambientales. La función recreativa que brinda la infraestructura verde tampoco debe subestimarse.

El trabajo de investigación se desarrolló dentro de la tesis de maestría del autor. Se trata de las potencialidades que tiene la Infraestructura Verde para mejorar las condiciones de clima y calidad del aire en la Ciudad de México. Examina las posibilidades de mejorar la situación general, las posibilidades de prevenir eventos climáticos extremos y las posibilidades de contribuir a una ciudad habitable y saludable. Para ello, analiza dónde radican exactamente los problemas, qué conceptos urbanísticos en relación con las infraestructuras verdes pueden contrarrestar estos problemas y, además, qué lecciones se pueden extraer de las políticas y medidas anteriores en este sentido para poder asegurar la viabilidad. de medidas recomendadas.

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El resultado de este trabajo son propuestas concretas para una estrategia de espacios verdes y abiertos que tiene su ámbito de aplicación no solo en la propia Ciudad de México, sino más allá en toda la región metropolitana. La estrategia de espacios verdes y abiertos propone cuatro campos de acción para ampliar el stock de infraestructura verde: la sistematización de la vegetación vial, el desarrollo de nuevas áreas verdes, la ecologización de cubiertas y fachadas, y el mantenimiento y mejora de áreas climáticamente efectivas y valiosas. . Estos campos de acción se implementarán en particular en forma de proyectos individuales. Dos ejemplos de proyectos concretos ilustran posibles estructuras organizativas y posibles alternativas espaciales dentro de la estructura de asentamiento existente.

Este artículo presenta los principales resultados del análisis y formula recomendaciones y conceptos a partir de la investigación.

Introduction and approach

Environmental alert in Mexico City: For almost a week, the government of Mexico City declared an environmental alert in mid-May 2019. It had already not rained for several weeks, and with high temperatures and simultaneous windlessness, climatic conditions prevailed that no longer ensured air circulation in the metropolis. Enormous air pollution, especially from particulate matter, was the result (Reina, 2019). The health hazard of such a situation became clear through typical symptoms caused in people. Eye irritation, increased secretion on mucous membranes, and respiratory pain syndromes caused by lung irritation were symptoms that affected not only allergy sufferers, children, and other risk groups (Reina 2019). Rather, the extremely poor air quality endangered everyone who was in the smog-laden valley at the time. The Ministry of Environment of the Mexican capital appealed to the population to stay at home if possible, to keep windows and doors closed, and above all not to exert themselves physically. Partial driving bans were one component of how the extreme situation was countered. However, a measurable improvement in the situation, brought only the rains on May 17.

Vulnerability to climate change, topographical and geographic conditions, or simply the fact that there are many emitters in a large city - there are many factors that could have caused the environmental alert in Mexico City. There will not be one correct answer. There are likely to be interactions between the factors.

Dealing with the negative consequences of various environmental problems in cities has long been a ubiquitous topic in spatial planning. This is reflected above all in the strategy papers published by numerous cities worldwide in recent years on adapting to climate change, avoiding negative climatic changes, and avoiding and improving other environmental problems. In addition, the current discussion on livable and healthy cities, in which environment-related issues play a central role alongside social and socio-spatial trends, gives this topic special significance. In this context, urban green is also discussed, which also plays an important role in current research - as in the research project *The Role of Green Innovation Areas in Revitalizing German and Mexican Cities* (abbreviated: GIAGEM).

In addition to the social synergies of urban green space, which result primarily from its recreational function, the focus is on the environmental benefits. Particularly with regard to the urban climate and air quality, green spaces and other forms of Green Infrastructure have the potential to positively influence these under certain conditions. For example, certain gaseous as well as solid and liquid pollutant components can be filtered from the air. In addition, Green Infrastructure lowers the surrounding air temperature and can also produce cold and fresh air as well as ensure its transport. Air layers contaminated with pollutants can thus be diluted by fresh air and contribute to a functioning air circulation. However, it seems reasonable to assume that the benefits provided by urban greenery vary greatly due to a wide variety of conditions and determining factors. For example, green axes for the transport of fresh air do not make a statement about the conditions of fresh air production, which is largely determined by topographic and geographic conditions as well as the vegetation. Green spaces also often conflict with other uses. For example, urbanization processes, which often negatively affect the urban climate, may simultaneously be in tension with Green Infrastructure development, especially when a city has high settlement pressure.

There are many different factors that form the conditions for a benefit and for the development of Green Infrastructure and vary from case to case. Two examples of Green Infrastructure projects in Germany are the *Emscher Landschaftspark* in the Rhine-Ruhr metropolitan region and the *Tempelhofer Feld* in Berlin. The *Emscher Landschaftspark*, a regional park that has been under continuous development since 1989, is the most important climatic and air-hygienic compensation area for the central densely populated areas of the Ruhr metropolis (Regionalverband Ruhr 2013, 6). Characteristic conditions here are the former heavy industry sites revitalized for the purpose of green space development as well as the dense interconnections of the settlement area (Regionalverband Ruhr 2013, 2). The conditions at *Tempelhofer Feld* in Berlin, on the other hand, differ from those of the *Emscher Landschaftspark*. It is about the preservation of an inner-city open space against the background of an existing settlement pressure. In this context, the airport area of the former Tempelhof Airport was converted into a huge urban open space and as such protected from urban development. Although the social benefits are the main focus of this project (Grün Berlin, 2019), the enormous green space also holds environmental potential.

The examples show that individual green projects can make a contribution towards a healthier environment for people in terms of climate and air quality. However, the form that the projects must take to ensure that they have a realistic implementation approach and thereby bring the potential for climatic improvement to the area is largely determined by the respective spatial, social and cultural context. Thus, Mexico City also formulates its very own requirements for Green Infrastructure as well as its own possibilities that Green Infrastructure can bring forth.

The theme of the work is to show the expression of the potential of urban green in the specific case of Mexico City - with its spatial conditions and peculiarities.

The **overall objective of** the thesis is to demonstrate the potentials of an improvement of the climatic and air quality situation through urban Green Infrastructure in Mexico City and to develop concrete proposals for this purpose. The feasibility of the proposals will also be considered.

Two **subordinate objectives** associated with this revolve around the potential for preventing climatic extremes through Green Infrastructure in Mexico City, and the potential of contributing to a livable and healthy city.

The analytical part of the research consists of three modules:

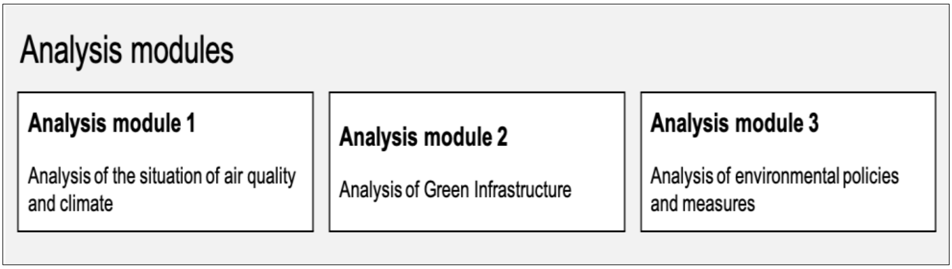

Figure 1. Structure of the analytical part.

Own representation.

As a direct result of the analysis, requirements for the planning of Green Infrastructure in Mexico City to achieve synergies in terms of climate and air quality are formulated. This leads to specific recommendations for an overall green and open space strategy. Finally, two tangible project proposals will be developed for the green and open space strategy. Part of this is in each case also a draft, which clarifies the spatial effects of the project examples as well as representatively those of the green and open space strategy.

Figure 2. Structure of the conceptual part.

Own representation.

Analysis of the situation in terms of climate and air quality

Key data and mesoclimatic conditions

Mexico City is home to nearly 9 million people (INEGI, 2019a). However, the huge agglomeration area does not end at the administrative boundaries of the capital. The settlement area extends far into the state of *Estado de México* and even into the state of *Hidalgo*. If one adds up the inhabitants living in this area, one arrives at almost 22 million inhabitants (Statista, 2021). This makes Mexico City one of the so-called mega cities and at the same time one of the largest agglomerations in the world. Geographically, the settlement area is located in a flat valley surrounded by several mountains, which extends to more than 2,000 meters above sea level. This valley is called the *Zona Metropolitana del Valle de México* (ZMVM). The origins of the ZMVM date back to 1325, the year in which the Aztec capital of *Tenochtitlán* is believed to have been founded. It was built on an island of Lake *Texcoco*, which extended over that plateau that is now encompassed by the agglomeration of Mexico City. When the city was taken by the Spanish in the 16th century, more and more parts of Lake *Texcoco* were drained to allow for a corresponding expansion of the settlement area of the island city, which had previously been severely limited in terms of spatial development (Ernst 2006, 2). After the Aztecs had previously attempted to expand the spatial boundaries of the city with floating islands, among other things, urban development was thus realized from now on on drained lakebeds (Krist,1983, 1). This not only resulted in the loss of an enormous water area, but also created difficult conditions for the expanding city, which from then on was confronted with the danger of soil erosion. After an estimated 175,000 to 200,000 people lived in *Tenochtitlán* in the early 16th century, depending on the source (Matos Moctezuma, 2006, 117), Mexico City developed into a settlement area with over 700,000 inhabitants by the beginning of the 20th century. From then on, the city grew faster and faster. The city experienced its most intense period of growth between the 1950s and 1980s (INEGI, 2019a).

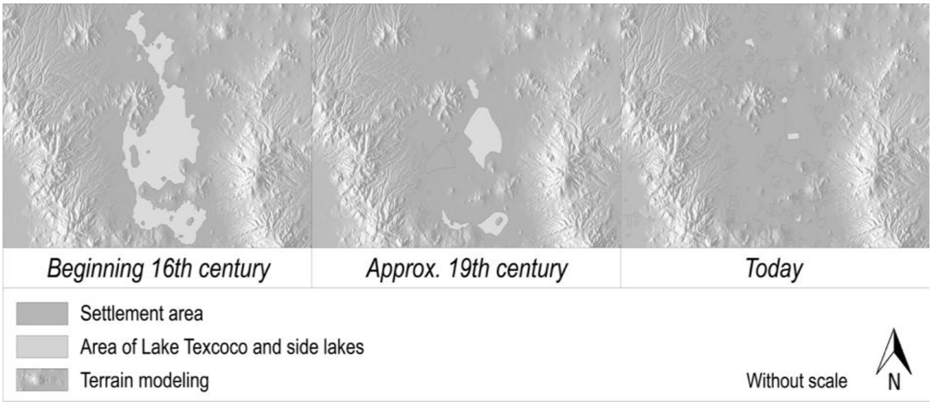

Figure 3. Development of the Mexico City agglomeration and Lake Texcoco. Own representation, vector data: Instituto Nacional De Estadística Y Geograpfía.

The metropolis finds itself in a climatically complicated entity. As part of the statistical recording of the climate, the *Instituto Nacional De Estadística Y Geograpfía* (roughly: National Institute of Statistics and Geography) catigorizes climatic area types according to average precipitation and temperatures. The majority of the valley is classified as a sub-humid climate area with moderate temperatures. This is also where most of the settlement area of the ZMVM is located. Only the eastern settlement areas are located in a zone with lower precipitation. They fall into the semi-arid climate zone with moderate temperatures as well. It becomes colder in the higher altitudes of the surrounding mountain ranges, which are classified as a sub-humid climatic zone with medium-cold temperatures and are predominantly not populated. At the even higher elevations, individual areas are simply classified as a "cold" climate area type (INEGI, 2019b). This applies, for example, to the peaks of the two volcanoes *Popocatépetl* and *Iztaccíhuatl*. Glaciers are still present at both peaks, despite the ongoing activity of *Popocatépetl* (Buth, 2019). Not far to the south of the capital metropolis, in the states of *Morelos* and *Puebla*, there is a sub-humid climate with high temperatures, which is therefore climatically very different from the climate in the ZMVM. The following figure shows how the different types of climatic areas are distributed.

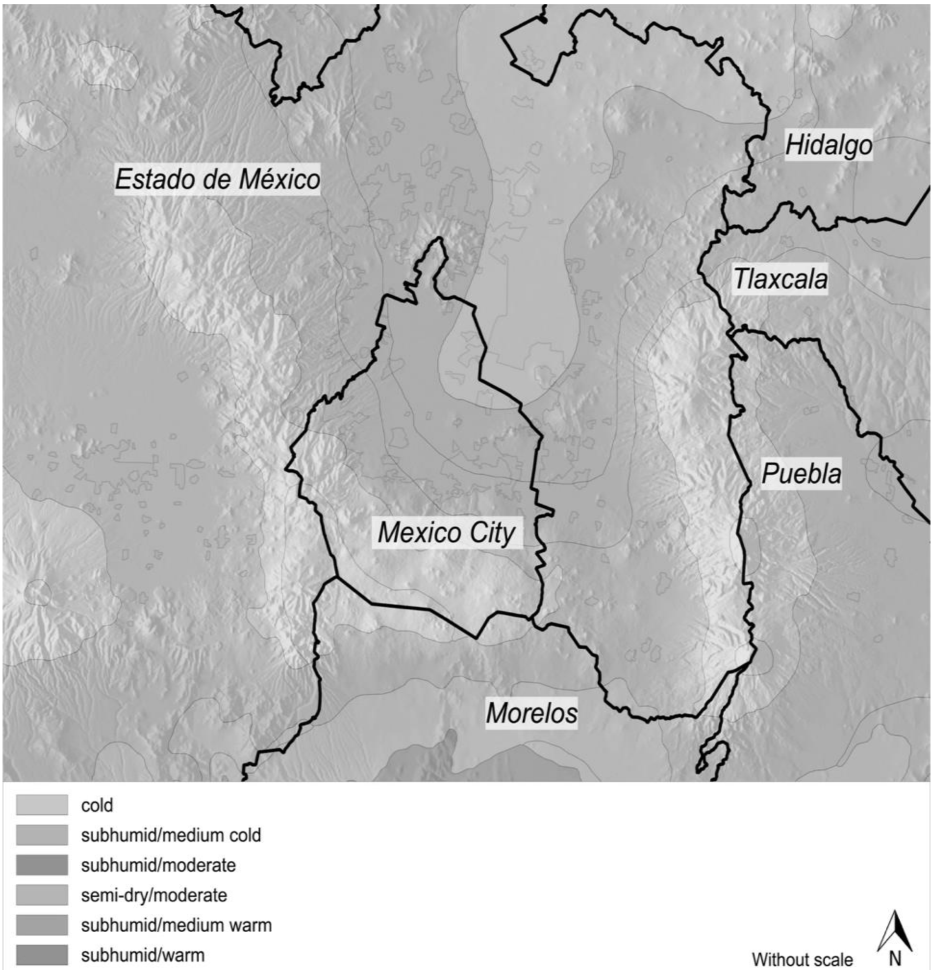

Figure 4. Types of climatic areas in the ZMVM.

Own representation, vector data: Instituto Nacional De Estadística Y Geografía.

When considering the mesoclimatic conditions in the ZMVM, it becomes clear that there are basically different spatial conditions that cannot be adequately considered in this regard.

Results of the climate data based research

The local climate in Mexico City is determined mainly by two factors: topography and land use (Estrada et al., 2009, 192). Thus, it is not only the natural circumstances, but also the anthropogenic influences, especially the intensity and density of land use, that can cause local differences in microclimate. Therefore, as part of the research work, it was necessary to discuss the microclimatic conditions, because air quality is also influenced by the local climate. For this purpose, data from different measuring stations of the *Sistema de Monitoreo Atmosférico of* the *Secretaría del Medio Ambiente de la Ciudad de México* were analyzed. The selected monitoring stations represent different spatial conditions according to the two main factors, topography and land use, that determine the local climate.

The climate elements studied for each measuring station are air temperature, relative humidity and wind speed. In addition, solid, liquid and gaseous pollutant components in the air relevant to air quality are considered. Specifically, particulate matter with particle sizes PM 2.5 and PM 10, ozone, nitrogen oxides, and sulfur dioxides were included in the analysis.

The data suggest that the ZMVM as a whole is extremely contaminated with air pollutants. According to the head of the *Departamento de Monitoreo Atmosférico of* the *Secretaría del Medio Ambiente de la Ciudad de México* Mirela Gálvez Carmona, on average more than 70 percent of the days in the year are hazardous to the health of the population. The overall situation must be considered critical, because the number of days in which the general air quality is assessed as poor or very poor is very high (Gálvez Carmona, Mirela, personal communication, December 04, 2019).

The evaluation of the selected climate and pollutant data shows a devastating picture of the situation in Mexico City as well as in the surrounding area. People in the metropolitan region are regularly exposed to partly extreme pollutant concentrations. The guideline values of the World Health Organization, which are used here as a reference for the international standard, are exceeded particularly strongly with regard to particulate matter and nitrogen oxide pollution. But ozone levels are also too high. Sulfur dioxide pollution, on the other hand, is mostly moderate. The frequently weak winds in the metropolitan region ensure poor air circulation, which can cause air pollutants to accumulate. Inverted atmospheric conditions, which are typical for spring, can cause a particularly strong dispersion of air pollutants. As climate change causes extreme weather events to occur more frequently, weather conditions that favor a strong accumulation of pollutants in the air may also become more frequent. This shows the extent of the vulnerability of the Mexican capital metropolis, although different topographical and structural conditions under the same mesoclimatic conditions can influence the situation of the microclimate positively as well as negatively.

The same climate and air pollution factors were then considered specifically for the environmental alert period in May 2019. The data were now evaluated in relation to the days from 10.05.2019 (from 6 am) to 17.05.2019 (until 9 pm). Again, the factors of air temperature, relative humidity, wind speed, particulate matter (PM 2.5 and PM 10), ozone, nitrogen oxides and sulfur dioxides were used. In contrast to the previous study, which focused on the general climatic situation an air quality in the ZMVM, where differences in local climate were also important, measuring stations were now selected here which, due to their location (mainly valley location in highly dense areas), are located in urban districts that are predestined to be particularly affected by problems in terms of climate and air quality. This was to ensure that conclusions could be drawn for the majority of the affected people through a sufficient and meaningful data basis; after all, most people live in the highly dense valley location.

It could be established that a correlation exists in particular between particulate matter and ozone pollution and the weather situation. A causal relationship cannot be established, but must be suspected based on the scientifically proven climatic processes of the individual climate elements (Henninger, Sascha, personal communication, December 02, 2019). Although the weak winds were nevertheless too strong for an ideal-typical inverted atmospheric condition, nevertheless a high atmospheric stability prevailed, so that a similar effect as that of an inverted atmospheric condition occurred. In addition, the weather situation favored the numerous forest fires in the vicinity of the metropolitan region (Gálvez Carmona, Mirela, personal communication, December 04, 2019).

Causation factors

It could be established that the weather situation can be mentioned as a definite cause of the environmental alert. At the same time, however, other factors should not be ignored. For example, although weather conditions have the potential to aggravate situations with increased air pollution, they originated, in addition to forest fires, mainly from anthropogenic processes, especially combustion processes. Obviously, emissions are correspondingly high due to the size and density of the ZMVM. However, the landscape changes that accompanied the settlement of the valley, i.e., the drastic reduction of water areas, green areas and open spaces, as well as the dense development, are also circumstances that favor limited ventilation with fresh and cool air, cause the urban heat island effect, and thus also play a significant role in the environmental alert in May 2019. In addition, topographical conditions also play a role, because even independently of landscape changes, the valley location of the metropolitan region makes it more difficult to draw off air pollutants and can, for example, be responsible for inverted atmospheric condition (Henninger, Sascha, personal communication, December 02, 2019). In turn, climate change can also influence the weather. Climate change makes extreme weather events more frequent and ensures a general increase in air temperature in the atmosphere. This favors the formation of secondary air pollutants in particular (Henninger, Sascha, personal communication, December 02, 2019).

It becomes clear that there are many different factors that were responsible for the environmental alert in May 2019 as an extreme climatic event in the Mexican capital metropolis, although the same factors also account for the generally poorly judged situation in terms of climate and air quality. It also shows that the various factors constitute a complex cause-and-effect structure in which numerous interactions exist.

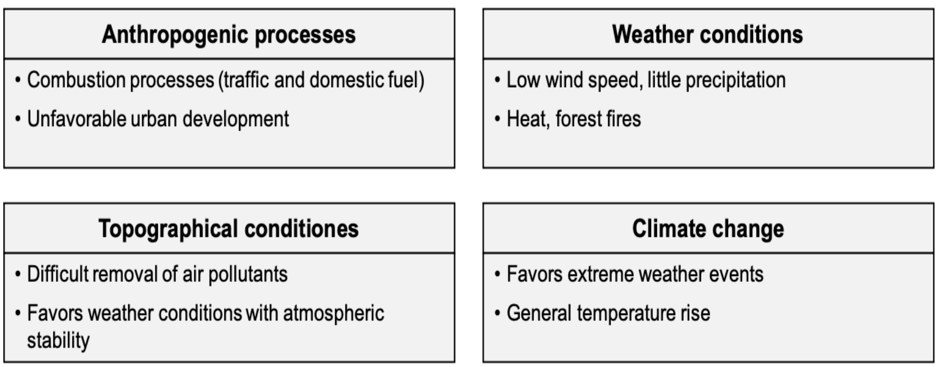

Figure 5. Causation factors.

Own representation.

Analysis of Green Infrastructure

Definition and benefits of Green Infrastructure

Basically, Green Infrastructure is everything that is green (Henninger, Sascha, interview, 02.12.19), i.e. all areas and objects that are not sealed and/or have vegetation. They generally have an impact on public space, regardless of whether they are on public or private property. However, based on the importance that Green Infrastructure has on settlement areas, it is much more than that. Benedict and MacMahon (2006) described Green Infrastructure as something comprehensive. According to them, it is a network of natural areas and other open spaces that preserves ecosystem functions, provides clean air and water, and offers a variety of benefits to people and wildlife. For people and the settlements in which they live, Green Infrastructure sets a framework for ecological, social, and economic health (Benedict and McMahon, 2006, 1).

Blue Infrastructure can also be a part of Green Infrastructure. This term includes all water surfaces that are located on the free surface. Green and Blue Infrastructure can be distinguished in terms of their climatic effects (Henninger, Sascha, personal communication, December 02, 2019).

In the course of climatic demands, a large number of scientific studies have shown in the past that urban greenery contributes to reducing the proportion of air pollutants in the atmosphere (Konijnendijk et al., 2013, 32). A distinction must be made between the claim of deposition of air pollutants, dilution of polluted atmospheric air by fresh air, and the claim of cooling air temperature. Depending on which goal is intended with the planning of Green and Blue Infrastructure, in particular whether it is about the climatic benefit or the air quality benefit, it must be adapted accordingly (Henninger, Sascha, personal communication, December 02, 2019).

There are many different types of Green and Blue Infrastructure. It is important to use the different types correctly. There are various strategic approaches to this in spatial planning. However, the planning of Green Infrastructure (also with components of Blue Infrastructure) as a measure in terms of climate and air quality first requires a precise objective. Planning measures must be adapted to the intended effect.

Two different effects can be aimed at when planning roadside greenery. The overshadowing effect provides cooling on site and also impedes the formation of ozone on the same. Another effect is the deposition of air pollutants. In conflict are both effects therefore that especially wide tree canopies can provide a lot of shade, but are problematic from an air-hygienic point of view due to the more difficult extraction of pollutants (Henninger, Sascha, personal communication, December 02, 2019). One approach to creating new green space in dense cities facing settlement pressure is to focus on the quantity of green space. Since there is often no potential to create green spaces of the size to have a citywide climatic impact, it makes more sense to develop a dense network of small green spaces that provide local improvements (Henninger, Sascha, personal communication, December 02, 2019). The creation of construction and building greenery also holds great potential for expanding Green Infrastructure in urbanized settlement areas (Henninger and Weber 2020, 211). Building materials can then heat up less, some air pollutants can be filtered, and evapotranspiration from plants provides cooling. One approach to diluting polluted air is to create or maintain areas that can act as cold and fresh air corridors or ventilation pathways. Settlements adjacent to the air streams can especially benefit from this. However, construction obstacles can limit this potential (Henninger, Sascha, personal communication, December 02, 2019).

Importance for livable and healthy cities

In spatial planning and development, the topic of livable and healthy cities is part of a current international discourse. In essence, livable and healthy cities are seen as a central concept, which represents a significant component for spatial planning and development (Baumgart et al. 2018, 5). This is made clear not least by the "Health in all Policies" strategy of the World Health Organization. According to this, the prevention of health hazards, health promotion, and health care are tasks that cannot be assigned to the health sector alone. Rather, the strategy sees this as a task for all areas of public action. In this context, urban planning and development are also to be identified as areas of public action (Köckler and Fehr 2018, 70). Corresponding points of contact in planning exist, for example, in the areas of housing, education, work, transport and the environment. The "Health in all Policies" strategy has already been the subject of numerous multilateral conferences and strategy papers (Köckler and Fehr 2018, 71-76). This also underscores the relevance of planning livable and healthy cities as a now central urban planning task.

The topic is also relevant for Green and Blue Infrastructure (Baumgart et al. 2018, 7). They form an important urban network of recreational areas in the city. Recreational areas are important for the health of the urban population, as they can provide an important compensation to a “modern” hectic lifestyle. For example, stress symptoms can be counteracted. Of course, the Green and Blue Infrastructure also plays a role here due to its urban climatic and air-hygienic synergy. It ties in with both the spatial trend of increasing exposure to air pollution and climate change. Due to the deposition effect of air pollutants as well as the cooling effect, the creation and preservation of Green Infrastructure, also including Blue Infrastructure, can be a central concept for counteracting health hazards in the course of increasing pollution, urban overheating as well as climate change. In this context, there are interactions between urban space, the health of the population, climate change, as well as anthropogenic air-polluting processes (cf. Baumgart et al., 2018, 7). The fact that Green Infrastructure is thus an important planning component in the creation of livable and healthy cities, and thus for urban planning as a discipline of public action an important part of fulfilling the "Health in all Policies" strategy, is also made clear by the fact that Green Infrastructure has long since become an important topic in numerous adaptation strategies of cities around the world.

A livable and healthy city is also a relevant topic for Mexico City. Relevant spatial trends here include the consequences of strong urbanization, an enormous volume of traffic, social and spatial segregation, and precisely also a climatic and air-hygienic condition that endangers health. Here, too, the connection between the health of the population and urban planning tasks becomes clear. Green Infrastructure as a central component of spatial planning to fulfill the "Health in all Policies" approach is indispensable here.

Lessons learned from Green Innovation Areas

The German-Mexican research project *Green Innovation Areas in Revitalizing German and Mexican Cities* (abbreviated to GIAGEM) provided scientific support for projects aimed at establishing Green Innovation Areas. The term "Green Innovation Area" originates from the *Master Plan for a sustainable Flint of* the US city of Flint in the state of Michigan. The *Place-Based Land Use Map* contained herein includes the *Green Innovation land use* category, i.e., green spaces with the potential for innovative development opportunities to address brownfields created by deindustrialization (City of Flint 2013, 5 and 10). The projects studied as part of the research community are intended to bring about a sustainable, innovative, and green alternative use while creating a functioning stakeholder structure (Pallagst, Vargas-Hernández, and Hammer 2019, 8). Important here is also the question of how the area is operated. In the context of the research project, this involves innovative forms of operation or innovative production methods for products that secure the long-term existence of the area. One approach is the implementation of a use in the sense of bioeconomy. Bioeconomy means replacing production with fossil resources by production with the use of renewable raw materials (Federal Ministry of Education and Research 2019). This is of particular importance for post-industrial cities.

The research project *Green Innovation Areas in Revitalizing German and Mexican Cities* illustrates how the creation or preservation of Green Infrastructure can succeed. Although it is difficult to create completely new and large-scale green concepts with the project-based approach, this would fail in most cases anyway due to a lack of land. Especially in the context of strong settlement pressure, in which the Mexican capital metropolis can also be classified, local individual projects can create organizational and actor structures tailored to local conditions. This also offers potentials for the implementation of climatically and air-hygienically effective areas, be it in the context of a new contribution to the Green Infrastructure or in the context of securing and sustainably restructuring an already existing green space. The project-based approach can also be considered positive because it is also in the spirit of quantitative planning of green structures in urban areas (Henninger, Sascha, personal communication, December 02, 2019).

Result of the analysis of the existing Green Infrastructure in the ZMVM

Part of the research work was also the investigation of the current characteristics of Green Infrastructure in the ZMVM. For this purpose, the green and open space structures were considered on a high as well as low scale level. In addition, several site visits were made to places representing different typologies of Green Infrastructure.

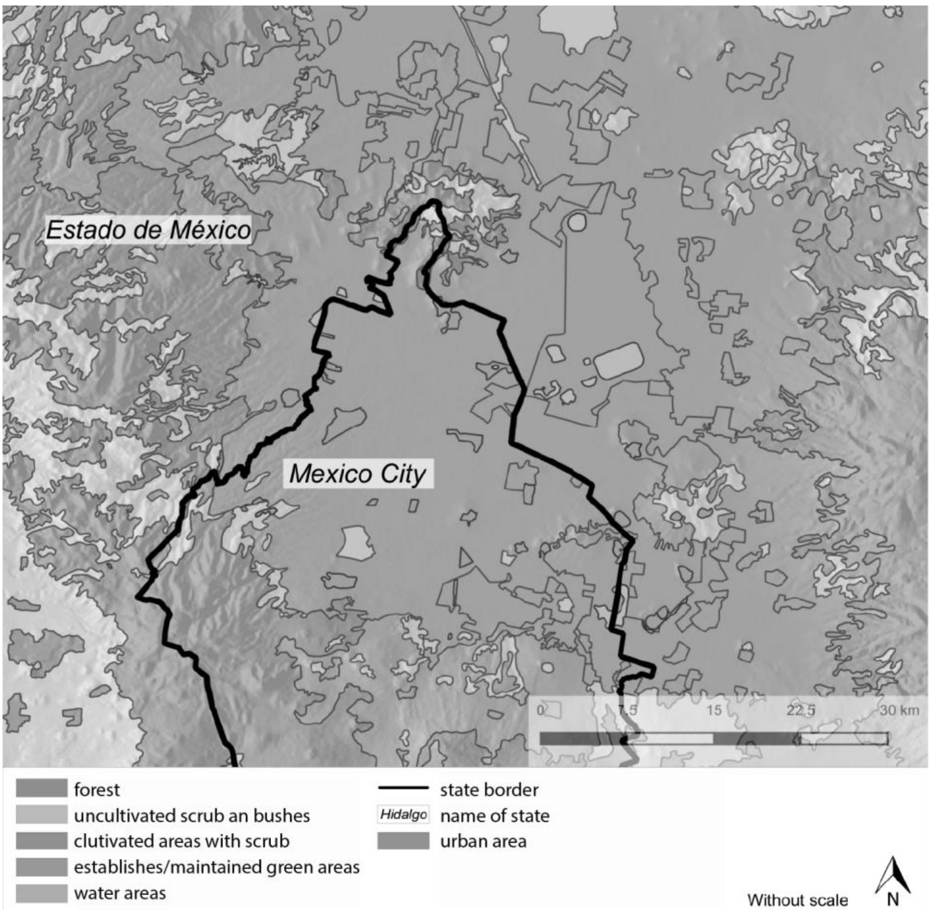

Figure 6. Overall open space and green structure of the ZMVM.

Own representation, vector data: Instituto Nacional De Estadística Y Geografía.

The studies have shown that the ZMVM has a very large and dense agglomeration, which opens up to large-scale greenery only in a few places. The proportion of green space within the settlement structures is very low. Green roofs could significantly increase the amount of green space. Roadside greenery is often present, but often shows a lack of system. The proportion of unsealed areas in the street space could be increased through better systematics. The proportion of green spaces in urban squares is also often low. Large-scale urban forests have a long-distance climatic and air quality effect. Larger neighborhood-based green spaces, on the other hand, provide local improvement. With the *Parque Ecológico de Xochimilco* in the south of the agglomeration area, an example of an area close to the settlement and effective in terms of urban climate and air hygiene, where cold and fresh air is produced, could be identified, which should be secured in its function.

Analysis of climate-related policies and measures

Air monitoring and risk assessment

There are currently 45 air monitoring stations in the ZMVM. However, the network is constantly expanding and even currently there are more sites planned for air monitoring (Gálvez Carmona, Mirela, personal communication, December 04, 2019). The monitoring stations are distributed throughout the metropolitan region. Thus, the monitoring takes place independently of administrative boundaries, which is required by the spatial structural conditions as well as the dispersion behavior of air pollutants.

There are various standards that precisely regulate the measurement of individual parameters as well as formulate legally binding limit values for some air pollutants. The *Norma Oficial Mexicana NOM-025-SSA1-2014, for* example, formulates legally binding limits for particulate matter. According to this, 75 $\mu g/m^3$ on a 24-hour average and 40 $\mu g/m^3$ on an annual average may not be exceeded for PM 10. The limit values for PM 2.5 are 45 $\mu g/m^3$ as a 24-hour average and 12 $\mu g/m^3$ as an annual average. The limits are thus significantly less stringent than the guideline values of the World Health Organization (WHO 2018); in addition, the standards do not make any statement about the case of exceeding the limits. The *Sistema de Monitoreo Atmosférico* in Mexico City assesses air quality based on the standardized limits and calculates an air quality index from this. The air quality index in the ZMVM is used to inform the population. The index is categorized into six different levels of air quality. It also identifies health risks and makes recommendations to the public (SEDEMA 2019a). The air quality index provides information about the current air quality situation around the clock. The population can get information about it through various media. Overall, however, communication about the risk to the people is still insufficient.

Programs and strategy papers in the administrative structure

In Mexico City, there are numerous strategies and measures aimed at improving air quality, although there are major challenges. For example, not all air pollutants can be influenced in the same way. Overall, particulate matter pollution can be better influenced than that caused by gaseous air pollutants. A general difficulty is also that there are often many different factors that cause pollution levels (Gálvez Carmona, Mirela, personal communication, December 04, 2019).

Climate-related measures are set out in numerous programs and policy documents issued by the municipal government, which set the legal framework for the implementation of those measures (Gálvez Carmona, Mirela, personal communication, December 04, 2019).

An analysis of different programs and strategies made clear how climate policy works in Mexico City. For example, the *Estrategia Local de Acción Climática de la Ciudad de México 2014-2020* as a topic-related strategy paper or program of measures refers to another program for coordinating implementation, which in turn refers to legally binding implementation instruments. It is positive that the numerous programs of measures and strategy papers for a respective environment-related area form a kind of master plan of political action. On the other hand, however, this also creates a very confusing construct of programs, which does not exactly favor rapid and targeted implementation of the measures being developed. Above all, it is important to distinguish between technical strategy and measure programs on the one hand and planning instruments that enable the implementation of spatial measures on the other.

In addition to the complexity in the structure of the many different strategy papers and programs of measures, it must also be criticized that most of the programs do not relate to the entire region. Although it is obvious to formulate measures for one's own spatial area of competence, it makes sense to coordinate the entire metropolis in order to ensure the effectiveness of environmental and, above all, climate-related measures. There are, however, obstacles in this respect due to the political-administrative circumstances. Since the metropolitan region consists of many different territorial authorities, which in turn consist of smaller sub-administrative zones, coordination in the ZMVM was already difficult at the time of the enormous urbanization process in the middle of the 20th century. Moreover, the additional increased legislative and executive powers that Mexico City has as a result of its status as a separate state and its former status as a selfgoverning capital district have made the political structure very complex. Over 70 government entities are involved in the administration of the ZMVM (Iracheta Cenecorta 2003, 232). This also complicates coordination in environmental and climate policy.

Corruption and organized crime, which have an impact on the administrative levels, must be seen as a further obstacle. Corruption in Mexico weakens the efficiency of the administration as well as economic and social development. In part, corruption is directed by organized crime (Estrada Rodríguez, 2013, 180). Purchasable licenses and permits thus also jeopardize intentions to protect the environment and the climate.

Requirements for the development of Green Infrastructure in Mexico City

Many requirements for the planning of Green Infrastructure in Mexico City or in the metropolitan region can be derived from the findings of the analysis. A clear set of objectives emerges from the findings on the climatic and air quality situation in Mexico City. The problematic air pollutants in the metropolitan region are especially particulate matter, nitrogen oxides and ozone. Therefore, it must be strategically considered that the goal is to reduce the concentration of those air pollutants or to minimize the formation and accumulation. Since there are also correlations with various climatic elements, in particular with air temperature, precipitation, relative humidity and wind speed, factors that can be influenced must also be part of the objective here. However, precipitation frequency and intensity as well as wind speed and main wind direction are factors that humans can partially influence indirectly (influence on climate change, choice of settlement locations, etc.) but not directly. Especially in urbanized contexts, heat can be influenced by the choice of land use, planting and materials, and thus air temperature. The goal in the planning of Green Infrastructure should thus be the reduction of air temperature in addition to the reduction of air pollutants (particulate matter, nitrogen oxides and ozone).

For the strategic planning of Green Infrastructure, it applies that this must be adapted to the objective. This means that typologies of Green Infrastructure, also in combination with Blue Infrastructure, must be selected in such a way that the defined objective can be achieved. Since the ZMVM is subject to strong settlement pressure, it is necessary to focus on quantity. It is more effective to create Green Infrastructure with a certain density where it is intended to bring a local improvement, than to create fewer but larger green spaces that are intended to have a long-distance effect on the city as a whole. What is needed, therefore, is a systematic large-scale identification of potential. Strategic planning of Green Infrastructure should also create diverse typologies so that the concept to be created has impact mechanisms that remain flexible according to current weather conditions. Typologies of Green Infrastructure that can be considered for the expansion of Mexico City's green structure are roadside greenery, smaller urban green spaces and green roofs and facades. More unsealed soils and green spaces can be created within the streetscapes by better systematizing the greenery that accompanies the streets. Smaller urban green spaces can be created on brownfield sites, if available, as well as on the few open spaces created by street and settelment development patterns. Ecological enhancement of such an area in terms of increasing the stock of woody plants and other vegetation can also be a concept here. In this context, specific forms of use that can ensure the long-term preservation of the area, such as urban gardening or urban farming, also offer possibilities. Elements of Blue Infrastructure should also be represented in the creation of green spaces, although not to the same extent as green areas. Green roofs in particular offer great potential for the creation of vegetation. In this regard, incentives should be created to encourage the large-scale development of rooftop greenery. In addition to expanding the green structure, consideration must also be given to securing and preserving the existing structure. For green spaces whose existence is endangered, solutions must be created to be able to save them. Especially against the background of settlement pressure and the emergence of informal settlements in protected areas, it is particularly important to preserve climatically significant areas, such as ventilation paths. The expansion or preservation of green structures requires adaptation to the corresponding objective in each individual case. In this context, plant species must also be selected accordingly.

A green and open space strategy for Mexico City requires overall coordination on the one hand and individual, case-by-case, project-based implementation on the other. The examples of previous environment-based programs have shown a lack of coordination in terms of content and space. In the long term, therefore, it makes sense to develop a multidisciplinary environmental program whose scope extends across the entire ZMVM and sets a legal framework in this regard. A strategy for the expansion and preservation of green and open space structures for Mexico City should therefore be an integral part of that environmental program. The case-by-case and project-based implementation requires the creation of suitable, individually adapted organizational structures. In this context, the benefits of each project area, its management, its maintenance, its legal implementation and its actor structure must also be regulated. In this context, participation processes can also be useful to create an exchange between residents and the professional side. The research project *Green Innovation Areas in Revitalizing German and Mexican Cities* can be used as an example of how the conditions and structures as well as strengths, weaknesses, opportunities and threats can be systematized. The goal should be that a well-functioning structure ensures the long-term preservation of the project area.

Recommendations for a green and open space strategy

The green and open space strategy and the recommendations made herein spatially address the entire ZMVM. This includes several administrative units and levels of government, including 42 municipalities located in three different states. For this purpose, the city-state of Mexico City is included as the largest administrative unit, as well as 40 municipalities in the state of *Estado de México* and another municipality in the state of *Hidalgo*. Green Infrastructure as a core subject of the green and open space strategy is related to urban climate synergies as well as air pollution control. The planning approach, which transcends administrative units, is necessitated by the fact that the challenges involved result from a problem situation that also affects not only specific administrative levels, but rather the entirety. The ZMVM and the municipalities included in it cover exactly the same area as the problem situation due to geographic, topographic and settlement structure conditions. This identifies the ZMVM spatially as the optimal application area for the green and open space strategy.

The overall goal of the green and open space strategy is to improve the situation in the ZMVM in terms of climate and air quality. This is to be achieved through the local reduction of air temperature, through the deposition or filtering of air pollutants, and through the targeted introduction of cold and fresh air flows. However, at the level of individual Green Infrastructure elements, these goals must be individually adapted and specified, as conflicts between goals may well arise at the local level. In addition, a number of other objectives arise in connection with Green Infrastructure functions. Although the climatic and air-hygienic synergies are in the foreground in this work, other environmental aspects, such as the improvement of water management conditions, the safeguarding of biodiversity and the safeguarding or restoration of a functioning ecosystem, as well as non-environmental aspects, i.e. in particular the use of the recreational function of Green Infrastructure, must also be taken into account in the overarching objectives. It is questionable to what extent objectives can be made measurable. Although it is possible to define concentration values for air pollutants to be achieved for the overarching air-climatic goals, since these are influenced by a wide variety of factors, this type of measurable goal makes more sense in the context of a comprehensive interdisciplinary environmental plan. However, measurable objectives in connection with individual fields of action make sense, whereby, for example, an expansion of urban green space to be achieved can be defined on an area basis. In summary, this results in the following goals:

- Overall abjectives

- Climatic and air quality objectives (temperature reduction, deposition of air pollutants and introduction or enabling the production of cold and fresh air).
- Other objectives (increasing recreational value, improving the groundwater situation, creating retention areas in the event of heavy rainfall events, safeguarding biodiversity, safeguarding and restoring a functioning ecosystem).

- Locally adapted and specified objectives, for example at the level of a individual project
- Measurable objectives per field of action

The concrete recommendations for action in terms of content for the green and open space strategy result from a total of four fields of action. These describe the strategic approach for achieving the set goals. Field of action 1 "Systematization of roadside greenery" represents a strategic approach to increasing the proportion of green spaces and the proportion of unsealed areas in the road and street spaces in the metropolitan region on a large scale. Field of action 2 "Development of new green areas" includes the expansion of existing urban green spaces. Field of action 3 "Greening of roofs and facades" involves the expansion of vegetation through the development of building greenery. Field of action 4 "Maintenance and upgrading of climatically effective and valuable areas", the last field of action, on the other hand, deals with larger-scale green structures and the long-term preservation and use of the climatic advantages of the corresponding areas.

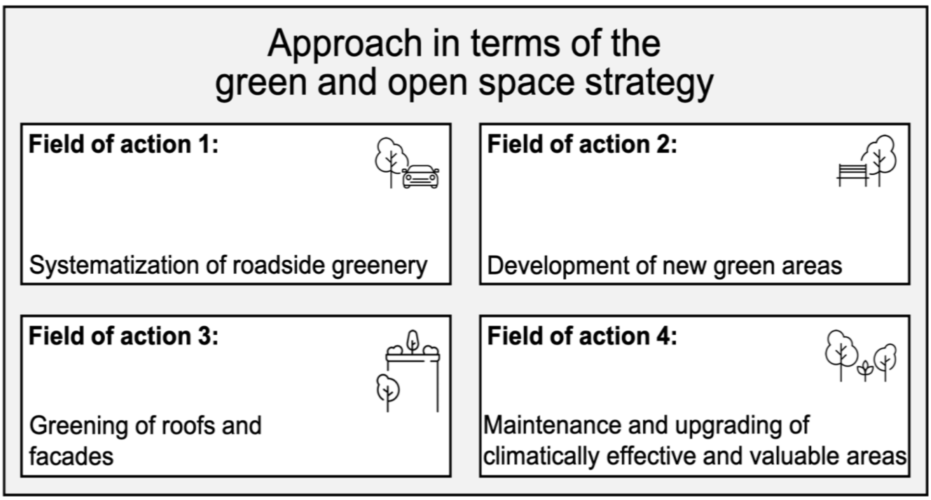

Figure 7. Fields of action.

Own representation.

All four fields of action are related to each other in terms of content and space. Together they change the overall spatial and local green structure in the agglomeration of the ZMVM. They are described in more detail below:

Field of action 1:

- Overall objectives: Temperature reduction and deposition of air pollutants, also: reduction of surface runoff of rainwater, contribution to biodiversity.
- Measurable objectives: Green space percentage of 20 percent in street space per neighborhood after 5 years of the green and open space strategy taking effect.
- Description: The aim is to increase the proportion of vegetation and unsealed surfaces in the road and street space. From an climatic and air quality perspective, a part of the air pollutants can thus be filtered out directly at the point of emission. A systematization of the roadside greenery is to take place according to an ideal-typical pattern.
- Area potential: The potential is great. In some neighborhoods, vegetation density can be increased. In some parts of the city, street greenery can be created for the first time.
- Impact/Financing: The implementation of the measures must be carried out by the public sector. The high costs incurred by the inventory, planning and implementation must be financed from public funds, which must be made available overall for the green and open space strategy. A publicly accessible green monitor by ZMVM should indicate to the population what the current status of the green structure is in the respective districts. This should create some kind of competition between administrative units to not leave their own districts unattractive.

Field of action 2:

- Overall objectives: Temperature reduction and deposition of air pollutants, also: increase of recreational value for the population, reduction of surface runoff of rainwater, contribution to biodiversity.
- Measurable objectives: Increase green space inventory by 20 percent per neighborhood after 5 years of the green and open space strategy taking effect, increase green space inventory by 40 percent per neighborhood after 10 years of the green and open space strategy taking effect.
- Description: It is especially about the creation or expansion of green areas within the existing settlement structure to filter some of the air pollutants from the atmosphere. The reduced temperature and radiation also counteract the formation of secondary air pollutants. A key point

represents the phase of identifying potentials. Implementation should be single-project related.

- Area potential: The potential is medium to large. By identifying areas regardless of their size, their sum can result in a significant gain in urban green space and unsealed areas.
- Impact/Financing: The implementation of the measures must be carried out by the public sector. The high costs incurred through the identification of potential areas, through planning and implementation must be financed from public funds, which must be made available overall for the green and open space strategy. A publicly accessible green monitor of the ZMVM should indicate to the population what the current status of the green structure is in the respective districts. This should create some kind of competition between administrative units to not leave their own neighborhoods unattractive. The green monitor should also draw attention to participation processes for citizens from the affected neighborhoods. Participation processes should create acceptance of an individual project on the part of the population and bring about additional pressure from the responsible administrative unit toward its own population.

Field of action 3:

- Overall objectives: Temperature reduction and deposition of air pollutants, also: reduction of surface runoff of rainwater, contribution to biodiversity and a functioning ecosystem, increase of recreational value for the population.
- Measurable objectives: Greening of 20 percent of roofs per district after 5 years after the green and open space strategy takes effect, greening of 80 percent of roofs per district after 15 years after the green and open space strategy takes effect, greening of facades of 10 percent of buildings per district after 15 years after the green and open space strategy takes effect.
- Description: The aim is to increase the proportion of greenery within the settlement structure by greening buildings. This can include green roofs as well as green facades. A part of the air pollutants is filtered out of the atmosphere. In addition, the waste heat effect caused by artificial building materials is reduced. For implementation, appropriate structural devices must be erected. The cost varies greatly depending on the intensity of the vegetation to be created.
- Area potential: The potential is enormous. Almost all roofs in the ZMVM are flat roofs, but they are almost never greened.

- Impact/Financing: The implementation of the measures must be carried out by the owners of the individual properties. Incentives must be created so that they can be persuaded to take on the effort (free advisory services, free or discounted provision of building materials, reductions in property fees).

Field of action 4:

- Overall objectives: Production and transport of cold and fresh air flows, also: reduction of surface runoff of rainwater, contribution to biodiversity, increase of recreational value for the population.
- Measurable objectives: Expand protected open space in the ZMVM by 20 percent after 5 years from the effective date of the green and open space strategy, no settlement development (except for development necessary to operate land) on protected open space.
- Description: This is about large-structured green and open spaces within the agglomeration or those adjacent to it. In contrast to the other fields of action, this is less about creating new urban green space and more about protecting open spaces that are still valuable for the urban climate and air pollution control from conversion in a metropolis characterized by strong settlement pressure, and optimizing the benefits for the urban environment accordingly by upgrading them. Authorities from all administrative units must work together to identify potential conservation areas.
- Area potential: There are still some large open areas in the ZMVM. Although these seem to be drowned under the thickness of the huge settlement area, they can still be identified as areas important for the environment. Some already have protected status, others do not. Regardless of protection status, some areas are threatened by the development of urban informality.
- Impact/Financing: The implementation of the measures must be carried out by the public sector. The high costs incurred through the identification of potential areas, through planning and implementation must be financed from public funds, which must be made available overall for the green and open space strategy. Participation processes for citizens from the affected neighborhood should create acceptance of an individual project on the part of the population.

The most important steps are first the identification of area potentials and the formation of individual projects (with the exception of field of action 3). As a result of these two steps, the green and open space strategy can then start at this point, listing each individual project as a single spatially defined measure, setting specified goals in each case, delegating responsibilities, allocating financial resources, and outlining the legal instruments for implementation. In this way, a legal framework can be set for the green and open space strategy. Since there is now a very complex system of a wide variety of environment-related programs, plans and strategy documents and they exist in parallel, the green and open space strategy would not do much to improve this situation. It is therefore recommended that an interdisciplinary environmental plan valid for the entire ZMVM be developed in the long term. The green and open space strategy as well as numerous other programs and strategy papers should be combined in such a plan and adapted to each other according to a technical-contentual as well as spatial coordination.

Ultimately, the green and open space strategy is only effective if it can be implemented. Hurdles exist, in particular, in financing and the risk of corruption associated with the money spent. The amount of funds required is difficult to estimate and will depend largely on the number and type of individual projects developed in the planning process. What is clear, however, is that the inventory, planning and development of the green and open space strategy alone will be costly. The costs must ultimately be borne by the administrative units involved. In the implementation of individual projects themselves, sponsorship by private companies can also be considered as a supporting contribution. However, previous environment-related programs and strategy papers show that public funds are definitely used for such projects. Especially in connection with a general environmental plan, planning costs could be saved in the long term, since parallel planning processes, which could possibly even lead to land conflicts, would be prevented. The risk of corruption is a condition that is difficult to circumvent. Implementation mechanisms and structures can be developed to minimize the risk of corruption, but it cannot be eliminated.

Project proposals

The project proposal 1 deals with the protection of the *Parque Ecológico de Xochimilco*. It can be classified as an individual project of the field of action 4 - maintenance and upgrading of climatically effective and valuable areas - of the green and open space strategy. Spatially, the project proposal can be classified in the south of the agglomeration. It is located in Mexico City in the district of *Xochimilco*, and is immediately adjacent to the district of *Iztapalapa* and *Coyoacán*. The area of the current park is approximately 300 hectares. However, the open space itself is much larger and difficult to delineate spatially.

Project proposal 2 deals with the redesign of the *Fuente de Cibeles*, an urban square and roundabout. It can be classified as an individual project of the field of action 2 - development of new green areas - of the green and open space strategy. Spatially, the project proposal can be placed in the center of the agglomeration. It is located in Mexico City in the district of *Cuauhtémoc*. The area of the square is approximately 1.3 hectares.

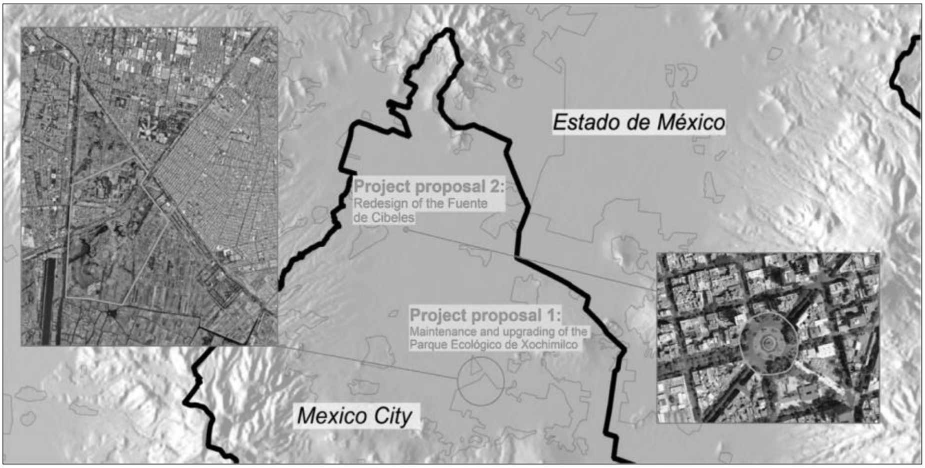

Figure 8. Spatial allocation of the project proposals.

Own illustration, vector data: Instituto Nacional De Estadística Y Geograpfía.

Project proposal 1

The first project proposal refers to the transformation and reactivation of the *Parque Ecológico de Xochimilco*. The open space where the park is located is part of the network of protected natural areas (original: Áreas *Naturales Protegidas*) and has a corresponding protection status (SEDEMA, 2019b). The area is an UNESCO World Heritage Site since 1987 (Hernández, 2019a). The element of water is constantly recurring in the landscape in the form of canals, lakes, and wet meadows. The heavily vegetated standing waters are also characteristic of the landscape.

The park used to be maintained by a private operating company and was once a highly frequented excursion destination. However, it has not been maintained for several years and was very run down. In addition to individual restroom stalls, there was still a visitor center in need of major renovation, an observation tower, and scattered aging children's playground equipment. At the end of 2019, Mexico City's municipal government reacquired the park from the former operating company with the goal of revitalizing it (Hernández, 2019b). Initial plans reveal that a park that attracts many visitors is once again the purpose of the planning. In addition, the vegetation of a big existing standing water body is to be removed (SOBSE, 2019). This plan must be criticized due to the fact that an extensive use of the area would better protect the landscape and climatic features. From an city climatic point of view, the current situation with wet meadows and heavily vegetated standing waters provides an optimal cooling effect. A single large body of water, on the other hand, would actually cause the surrounding area to heat up, especially at night (Gálvez Carmona, Mirela, personal communication, December 04, 2019). In the recent years, the plans for the revitalization of the *Parque Ecológico de Xochimilco* were implemented. In the summer of 2021, the park was reopened after two phases of renewal and renovation. It can be also noted from media coverage that the intention is to attract many visitors to the facility with attractive recreational and cultural offerings (El Finaciero, 2021).

Project proposal 1 has to be therefore understood as a counter-design to the former planning approaches and is also to be classified as an individual measure within the framework of the green and open space strategy. In order to redesign and reactivate the area, spatial obstacles to cold and fresh air flows in particular are to be removed and spatially redistributed. In particular, this includes the park's visitor center, which is in need of renovation; the six-lane main road, for which lowering or tunnelling is planned; and parts of the plant market, which can be organized more to the north. An important part of the planning is the preservation of the special features of the existing landscape. However, in one or two places, reforestation can still allow for enhancement. The park is also to be repurposed for a soft type of tourism that emphasizes environmental education.

Table 1. Evaluation of project proposal 1 (SWOT analysis)

Strengths	**Weaknesses**
Air-climatic synergies Increase of the recreational value Environmental education of the population Protection status of the area No dependence on the commitment of the population	Endangered by possible corrupt use of funds Permanent financing of the gap between operating costs and revenue from admission fees necessary High manufacturing costs

Opportunities	**Risks**
Positive external impact, good example for further projects	Risk that the project will be less accepted by the population because it is purely a municipal government project
Contributing to a transformation towards a more sustainable and resilient city	Public administration projects often have a bad image (corruption), difficulty to convey trust in the project

Own representation.

Now follows a concrete design proposal for the first project proposal. It clarifies the spatial measures regarding the maintenance and upgrading of the *Parque Ecológico de Xochimilco*.

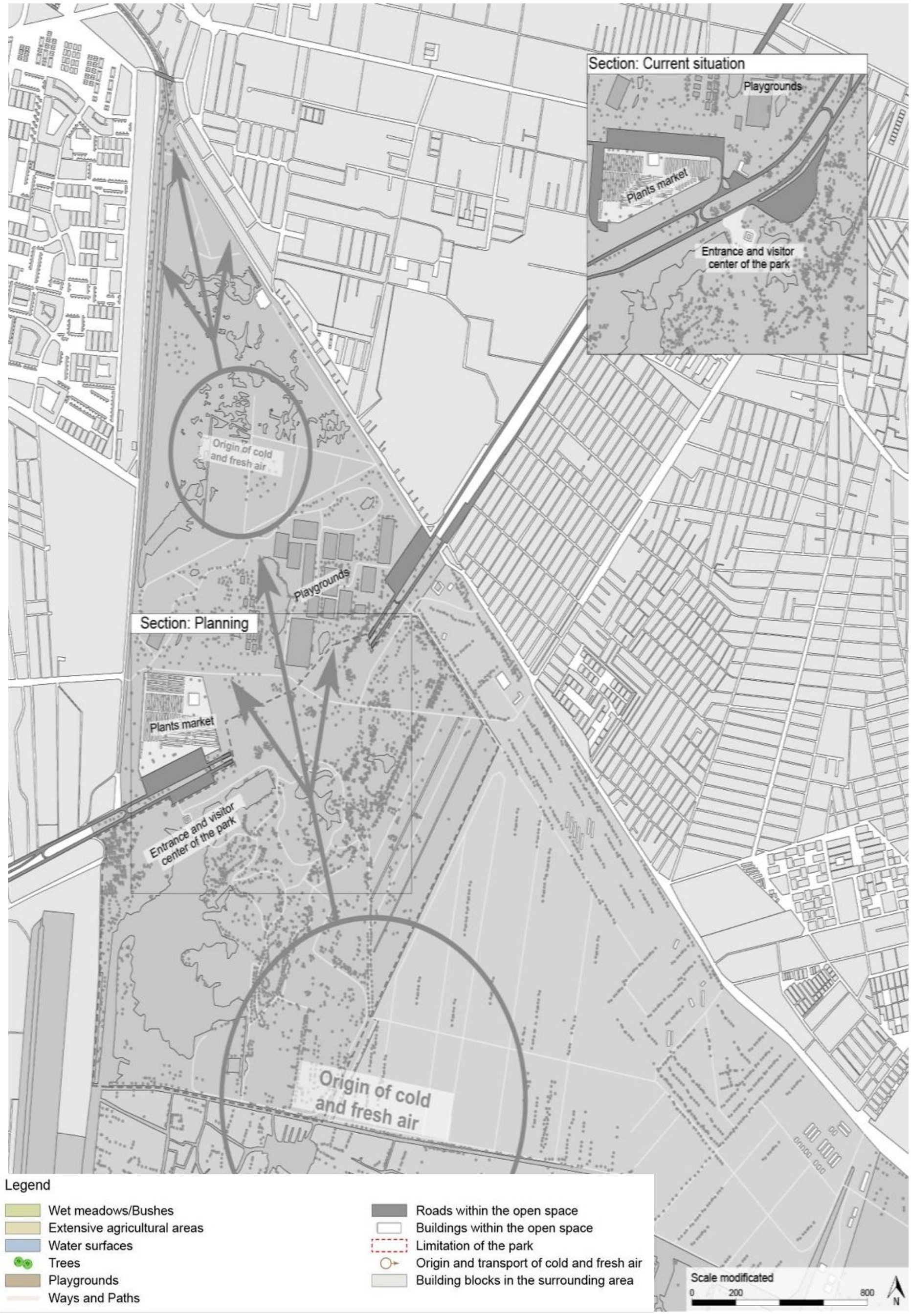

Figure 9. Project proposal 1.

Own representation, vector data: Instituto Nacional De Estadística Y Geograpfía.

Project proposal 2

The second project proposal refers to the transformation of the roundabout and urban square space *Fuente de Cibeles*. In the center of the square is a fountain on which stands a bronze statue. The square appears kind of green, but despite this, the percentage of unsealed surfaces is actually very low.

In the context of the green and open space strategy, project Proposal 2 is an example of how to expand the amount of green space in a densely built-up area. The design proposal is to allow the street traffic to end in front of the square so that more unsealed green space can be created. In addition, more trees will also be planted. Inside the public space converted from a roundabout to an inner-city green space, an area for urban farming will be created. Citizens and neighbors will have the opportunity here to acquire knowledge about planting food and also to produce food for their own use. With regard to the form of organization, the project offers a good opportunity to create a high level of acceptance on the part of the population through the involvement of the citizens and the neighborhood or through their self-management.

Table 2. Evaluation of project proposal 2 (SWOT analysis)

Strengths	**Weaknesses**
Air-climatic synergies Increase of the recreational value Sensitization of the population Centrally developed location, close to business districts, where a potential target audience would be present Long-term maintenance of the project through acceptance by the population, which can arise as a result of participation	Endangered by possible corrupt use of funds Change in traffic routing with possible worsening of the traffic situation in the surrounding area After a start-up phase, there is pressure to generate revenue and approach refinancing High cost
Opportunities	**Risks**
Positive external impact, good example for further projects Contribution to a change towards a modern and sustainable living in the city Testing of a modern form of organization, knowledge gain for further projects	Dependence on the commitment of the population, problem of a long-term continuation of the project if the commitment of the population fails to materialize or decreases Public administration projects often have a bad image (corruption), difficulty to convey trust in the project

Own representation.

Now follows a concrete design proposal for the second project idea, which illustrates how the redesign of the *Fuente de Cibeles* is spatially feasible.

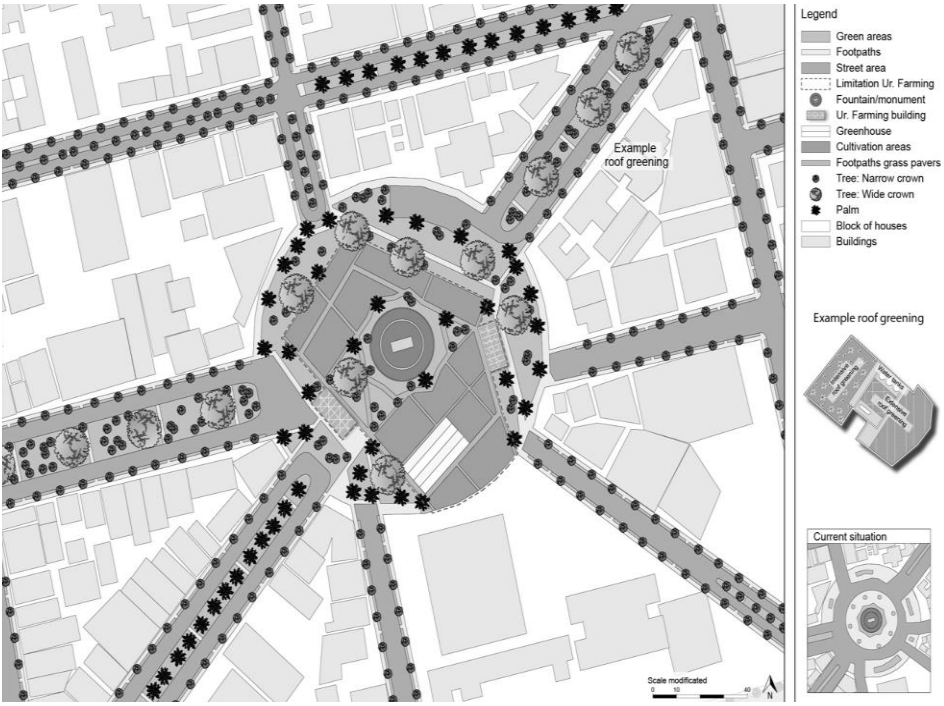

Figure 10. Project proposal 2.

Own representation, vector data: Instituto Nacional De Estadística Y Geograpfía.

CONCLUSION

In the work, causation factors were defined for the May 2019 environmental alert in the ZMVM, but their validity also exists for the general climatic and air quality problems in Mexico City and in the ZMVM. The factors defined were:

- Anthropogenic processes (emission of air pollutants by traffic, industry and combustion processes in private households, urbanization in topographically unsuitable locations, changes in the landscape)
- Weather conditions (drought, low winds, heat)

- Topographical conditions (valley location, favoring inverted atmospheric conditions).
- Climate change (more extreme climatic events, general temperature increase).

The proposed fields of action for the green and open space strategy and the typologies of Green Infrastructure used therein address these factors at different points. The defined fields of action show different spatial approaches on how a temperature reduction can be achieved in the urban context, how air pollutants can be filtered in the atmosphere and how the production and a targeted introduction of cold and fresh air into the settlement area can be enabled. The different fields of action can achieve local effects in particular. This has also been shown by the two project proposals.

When comparing the functions and effects of the use of Green Infrastructure recommended in the green and open space strategy with the causative factors of air climate problems, it can be determined where exactly the factors are applied. The filtering effect, the cooling effect and also the use of cold and fresh air start at the management of air pollutants emitted by anthropogenic processes. Concerning the factor of weather conditions, the filtering effect starts from a dry weather condition, when the so-called wash-out effect is absent for a longer period of time. The cooling effect is based on a weather situation with high temperatures and thus counteracts the formation of secondary air pollutants. The use of cold and fresh air starts at weather situations with only weak winds and offers an alternative by the dilution effect in the polluted atmospheric air, if the wind strength of the main air stream is not sufficient for a removal of the pollutants. Since the topography factor favors certain weather patterns, similar starting points apply to this factor. In addition, the Green Infrastructure envisioned in the green and open space strategy also addresses the climate change factor; first, because it can favor certain weather patterns (like topography), but also because Green Infrastructure is an adaptation measure with respect to the general temperature increase due to the cooling effect.

It becomes clear that the green and open space strategy and the concepts for the development of Green Infrastructure provided for therein affect the air quality and climatic situation on different levels. The scattering of approaches shows a great strength of the green and open space strategy, as this creates a mechanism of action that can nevertheless take effect in the most varied and changing circumstances. Furthermore, the strategy relies on the inclusion of the entire ZMVM, whereby the climatic synergies do not only hold potentials for Mexico City, but rather for the entire metropolitan region.

However, it also becomes clear that there are many more ways to address the problem. While Green Infrastructure mainly makes a positive contribution to counteracting the effects of air pollution, it cannot prevent the generation of pollutants (apart from secondary air pollutants). Air pollutants are mainly caused by anthropogenic processes. Therefore, it is obvious that Green Infrastructure can only be a component of a process towards an improved situation in terms of climate and air quality.

In addition, the implementability of the green and open space strategy also determines its potential. It is important that the right political, administrative and legal structures are created.

With respect to extreme climatic events such as the environmental alert in May 2019, it can be stated that Green Infrastructure has the potential in principle to create positive conditions that can reduce the level of air pollution during an extreme situation. However, it is questionable whether extreme air quality events can be prevented in this way. Similar to the potential of improving general conditions of climate and air quality, Green Infrastructure is only one of several components, but an indispensable one.

With regard to the topic of livable and healthy cities, it can be stated that this is very diverse and has relevance at different levels in spatial planning. This also applies for Mexico City and the ZMVM. The recommendations proposed within the framework of the green and open space strategy in connection with Green Infrastructure represent one of several important levels that can make the Mexican capital metropolis a livable and healthy place to live.

The question of the implementability of the green and open space strategy cannot be answered conclusively. In terms of implementation structures, it can draw on a wide range of evidence from different examples, but risk factors that can jeopardize comprehensive implementation still exist. However, every effort can be made to create adapted organizational structures that minimize the risks. Ultimately, however, it also depends on political will.

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