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Water Security with Social Organization and Forest Care in the Megalopolis of Central Mexico

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Abstract

This article examines the effects of climate change on the 32 million inhabitants of the Megalopolis of Central Mexico (MCM), which is threatened by chaotic urbanization, land-use changes, the deforestation of the Forest of Water by organized crime, unsustainable agriculture, and biodiversity loss. Expensive hydraulic management extracting water from deep aquifers, long pipes exploiting water from neighboring states, and sewage discharged outside the endorheic basin result in expensive pumping costs and air pollution. This mismanagement has increased water scarcity. The overexploitation of aquifers and the pollution by toxic industrial and domestic sewage mixed with rainfall has increased the ground subsidence, damaging urban infrastructure and flooding marginal neighborhoods with toxic sewage. A system approach, satellite data, and participative research methodology were used to explore potential water scarcity and weakened water security for 32 million inhabitants. An alternative nature-based approach involves recovering the Forest of Water (FW) with IWRM, including the management of Natural Protected Areas, the rainfall recharge of aquifers, and cleaning domestic sewage inside the valley where the MCM is found. This involves recovering groundwater, reducing the overexploitation of aquifers, and limiting floods. Citizen participation in treating domestic wastewater with eco-techniques, rainfall collection, and purification filters improves water availability, while the greening of urban areas limits the risk of climate disasters. The government is repairing the broken drinking water supply and drainage systems affected by multiple earthquakes. Adaptation to water scarcity and climate risks requires the recognition of unpaid female domestic activities and the role of indigenous people in protecting the Forest of Water with the involvement of three state authorities. A digital platform for water security, urban planning, citizen audits against water authority corruption, and aquifer recharge through nature-based solutions provided by the System of Natural Protected Areas, Biological and Hydrological Corridors [SAMBA] are improving livelihoods for the MCM's inhabitants and marginal neighborhoods, with greater equity and safety.

Keywords: megalopolis of Central Mexico (MCM); water security; integrated water resource management (IWRM); forest of water (FW); participatory research; unpaid female domestic work in water saving eco-techniques; digital platform for citizens; water reduction, reuse, and recycling (RRR); System of Natural Protected Areas, Biological and Hydrological Corridors [SAMBA]; restoration by indigenous people; greening city; livelihood with wellbeing.

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1. Introduction

Integrated water and sewage management involves the interrelation of natural factors (IWRM), citizen participation, financial resources, and long-term policies in the Forest of Water (FW) surrounding the mountains of the Megalopolis of Central Mexico (MCM). In January 2025, the three key authorities from Mexico City, the State of Mexico, and Morelos and the federal environmental authorities jointly committed to protecting the Forest of Water around the mountains of the megalopolis. Indigenous communities led by women have cared for these mostly oak and pine forests, grasslands, and rain-fed agricultural plots used for subsistence crops for thousands of years. The Natural Protected Areas (NPAs), established on the surrounding volcanoes, represent vital natural resources and supply water to the MCM. Jaramillo [1] referred to these 807,060 hectares as SANBA (System of Natural Protected Areas, Biological and Hydrological Corridors), while many call it the Forest of Water. The reduction in tree cover from 2009 to the remaining SANBA in 2024 highlights the fragility of this forest, where human activities, bushfires, plagues, urban expansion, and illegal deforestation have decreased the primary forest area by 14.3% over 26 years (Figure 1).

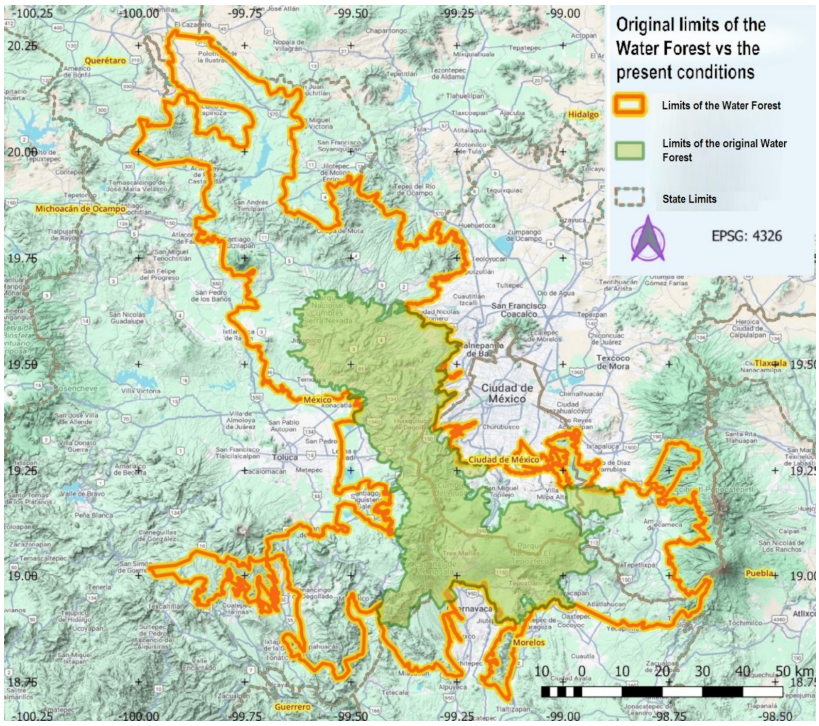


Figure 1. Forest of Water Polygon of the MCM and its transformation from 2009 to 2024. Source: [1].

This SANBA still contains 19 biological and hydrological corridors, establishing functional connectivity between the declared 65 Natural Protected Areas. The main corridor accounts for more than 300 hectares, and smaller Protected Natural Areas (PNAs) are integrated in several polygons. Several fragmented areas are also composed of ecosystems of grassland, agriculture, and indigenous villages in the mountain region [2]. These areas are crucial for rainfall infiltration into groundwater and the protection of the urban flood-plains during extreme climate events.

The largest corridor of the SANBA, called Ajusco-Chichinautzin, supplies the aquifers in Mexico City and the western part of the Morelos State. The two important indigenous areas in this SANBA (Cuentepec and San Juan Atzingo) are integrated by a system of ravines in the northwest of Morelos [3], which links its western border with Mexico State. Therefore, the sustainable management of the SANBA {1], together with the protection of

the National Park Sierra Nevada (Popocatépetl and Iztaccíhuatl volcanoes) in the east, is critical for long-term water infiltration into the groundwater [4] and flood protection in the MCM.

Indigenous people in the world represent only 5% of the global population, and they care for about 80% of the remaining biodiversity [5]. For millennia, these indigenous communities have also cared for the Forest of Water surrounding the MCM, offering free ecosystem services of water supply and flood protection to all urban citizens living in the basin. Alternative water management and greater protection of the Forest of Water may avoid the threatening prognostic water shortage in the MCM in 2028 [6]. Water security is limited for these indigenous people who protect the Forest of Water, because it is costly to deliver safe water to these communities living at higher altitudes. These regions obtain the highest regional rainfall.

Rainwater capture with filters for water purification can grant them a safe, vital liquid. Domestic sewage could be treated with small bio-digesters or wetland aquatic plants adapted to the different altitudes [7]. These communities are also exposed to organized crime, where the government is obliged to improve their security and control the logging of the Forest of Water, the kidnapping of family members, and the forced recruitment of youth for illegal activities [8].

Their participative research includes different social groups caring about the Forest of Water. FUNBA (Fundación Biosfera del Anahuac) has organized over the last 12 years indigenous communities, women, and farmers who are protecting the natural resources for all citizens in the plain of the MCM [2]. Alternative management projects are developed by authorities, academics, and social organizations, together with collaborative participants [9]. The rigorous urban planning in water and sewage (SDG 6) [10] is underfinanced in all states involved. These systemic, complex, and interrelated activities of climate risks, care of forests, safe water supply, and the infiltration of rainwater with treated domestic sewage into overexploited aquifers of the MCM could improve the livelihood and wellbeing of the 32 million inhabitants [11]. Policies of greater equality among marginal neighborhoods and poor colonies involve social participation in planning and alternative urban development, especially in the fast-growing marginal colonies [12].

The process of democratization is advancing slowly, and often municipal governments are limiting the involvement of their citizens due to the interests of political parties, the existing insecurity, and how to proceed with rising demands and a limited budget [13].

The World Resources Institute [14] indicated that the Megalopolis of Central Mexico (MCM), with more than 32 million inhabitants, could run out of clean water by 2028. In response to this threat, an interdisciplinary study group [11] was created, linked to environmental authorities, participative research with women's groups, and the indigenous communities [15] that live in the Forest of Water (FW) that lies at the heart of the MCM [3].

This investigation focuses on the negative impacts of extreme climate change events related to an unsustainable hydraulic infrastructure (overexploitation of aquifers and of water basins in neighboring states, with industrial and domestic sewage mixed with rainwater expelling out from the MCM endorheic basin [16], producing subsidence [17] in soils previously covered by lakes [18]). Most of the 191 agrarian communities living in the FW are ruled by collective land tenure (communal ownership by traditional indigenous peoples and ejidos that were distributed after the Revolution). The traditional leadership of most indigenous communities is in the hands of indigenous people, elected democratically in Assemblies. With their invitation, we collaborated with more than a hundred communities in 11 collective meetings during 2024–2025. We also organized a workshop for training these groups on how to manage a digital platform and have access to satellite data [15]. Over the last four decades, there has been intensive collaboration that has established

a relationship of distrust [7]. This is necessary in the forest region that is threatened by those involved in organized crime that is logging illegally, has assassinated people, and kidnapped youth to involve them in their illegal activities, for example [8].

Women and indigenous communities are highly affected by the lack of water, even though the Forest of Water on the mountains surrounding the MCM [13] may offer long-term rainwater to millions of citizens. This research includes a digital platform developed in collaboration with a specialized center [15], where training courses and workshops are offered to groups of women and indigenous communities who suffer from water shortages, using the data from 32 free available satellites [19].

These women have also learned eco-techniques for catching and purifying rainwater with filters, treating domestic sewage in small home wetlands with aquatic plants or bio-digesters, and reusing the cleaned sewage water in gardens and parks or infiltrating it into the subsoil [20]. Several women are trained in universities in forest engineering and have assumed a leadership role in organizing and integrating indigenous communities, belonging to one of the four indigenous groups existing locally (Tlahuicas, Otomíes, Mazahuas, and Nahuas). The digital platform also supports and trains indigenous communities that care about their environment thanks to their cosmovision [21] in the protection and recovery of the Forest of Water, a crucial source of water for the population living in the MCM.

The objective of this study is collective–participative research on shifting the MCM water security [22] towards nature-based management, an alternative water and sewage management approach inside the endorheic basin, to provide a long-term water supply for the entire population in the megalopolis [11].

In January 2025, the authorities of the three states in which the FW extends signed a commitment to protect the FW. In previous years there had been efforts to the same avail with business communities, organized citizens, and legislative bodies. Independent citizen auditing groups are analyzing the access in equal conditions to safe water and improved sewage as a basic human right to control corruption in Conagua [23]. The project focuses on mitigation and adaptation [24] in the MCM, where increasing droughts and extreme floods occur as a result of climate change impacts [6] and past unsustainable water management [25].

Participants in this research comprise citizens, government agencies, and women and indigenous communities to strengthen their regional organizational and management capacities [11]. This procedure may allow the collective development of sustainable socio-environmental alternatives for long-term hydrological security by catching rainfall from the Forest of Water and its relatively recent volcanoes at the heart of the MCM [26]. This article criticizes past hydraulic policies based on unsustainable water extraction from neighboring states and on the overexploitation of aquifers, including mixing sewage from industries with domestic drainage and rainfall, which is expelled to a deserted region in the neighboring State of Hidalgo [27]. During the 2024 monsoon, these toxic wastewaters inundated marginal colonies, such as during the 32-day flood to almost half a million inhabitants in Chalco, located at the eastern reaches of the Mexico City valley, linked to chaotic urbanization in what was formerly a lake, the lack of maintenance of the drainage system broken by earthquakes, and excess rainfall during the monsoon [11]. During the dry seasons, the lakes run out of water [28].

This research project also explores alternative hydrological approaches with integrated water resource management (IWRM) [29], the recovery of Protected Natural Areas (PNAs) [26], and the rescue of rivers, wetlands, and the integrated System of Natural Protected Areas, Biological and Hydrological Corridors (called SANBA) [1]. It includes urban planning with multiple eco-technologies, recovering overexploited aquifers and reducing the growing ground subsidence in the city [30]. Women are suffering seriously

from periodic water shortages, polluted drinking liquid, and frequent water supply interruptions related to the traditional division of domestic labor, where women cover most of the unpaid care activities, including responsibility for the water supply [31], through carrying and saving, reusing, and recycling water in their homes, rainwater collection, and sanitation of domestic wastewater.

This article explores water security [22,32,33] based on nature-based solutions [26]. It combines "high-tech with no-tech for achieving climate and sustainability objectives [34] and improving the livability of cities in hot and arid regions" [35]. A digital platform is developed with the participation of women, youth, enterprises, and indigenous communities, integrating surveys and collective working groups that are examining the data linked to the FW and training participating social groups in workshops to develop maps with their own data [15]. This platform is reinforced by collaboration with Academia Nacional de Investigación y Desarrollo (ANIDE) to access free available satellite data [19] and places emphasis on the prevention of upcoming climate change risks [36], where higher temperatures negatively affect the forests [37]. There are also threats related to the clandestine logging of trees and other illegal activities by organized crime [8], despite the National Guard's efforts to protect some threatened FW regions.

2. Water Security, Location of the Study Area, and Research Methods

2.1. Concept of Water Security

Water security is a new concept and goes further than the traditional military security, which is limited to realistic threats to territory and sovereignty [22]. Water security is based on an expanded vision of security [32,33]. This understanding of water management starts by broadening and deepening the conceptualization of humans, gender, and environmental security (HUGE security) [22]. HUGE security changes the reference object from traditional military security to human security, where water is basic for survival. Gender security refers to the daily unpaid household work performed by women throughout the world. Environmental security refers to the Forest of Water's capacity to produce and control rainfall. The main threat to HUGE security is patriarchy, which affects the environment through a neoliberal economy handled by a global limited elite concentrating wealth and downgrading poor people's wellbeing [38]. This approach includes the quality of life and happiness of all people in the MCM beyond the past political understanding of a determined amount of water per capita for survival, which was defined by 30 years of former neoliberal authorities with privatization [39] translating into inefficient services to poor people and increasing corruption among a limited elite. Such a determined amount of water per capita was never achieved in marginal colonies.

Water security includes permanent, sufficient, and clean water distributed by capable governments overcoming the present unjust temporary limited supply of water (called *tandeos* in Spanish) imposed on poor colonies in the MCM and also in multiple municipalities in the country. Furthermore, this limited supply of water is distributed through old pipes with millions of micro-perforations and damages caused by earthquakes [40]. When the hydraulic pressure inside the pipe changes, harmful microorganisms enter, often mixed with sewage, producing murky water quality. Therefore, water security includes a deepening understanding from individuals, mostly women who perform unpaid domestic work but up to families, colonies, and megacities. The provision of permanent and safe drinking water, purified by filters [41], includes a widening process [42]. Economic, environmental, societal, and technological interests are involved in the water supply, including the improved treatment of domestic wastewater (SDG 6) and the safe disposal of solid waste [10]. The mixture of toxic industrial sewage with domestic wastewater and rain deprives the MCM of a resource necessary for life. Industrial sewage must be recycled

inside factories or treated with physical–chemical processes that remove the dangerous toxins [43].

This deepening and widening conceptualization of water security [22] is oriented to human consumption, productive processes, and environmental conservation [41] that should guarantee everybody a good quality of life regardless of their socioeconomic level [12]. It should preserve human and natural health, within a biodiverse environment, and provide wellbeing and health [41] to humans and nature. It should allow adequate food production [44]. Public and private investments that value water in economic terms must make the necessary investments in reparations and new systems of water distribution and sewage facilities [45]. Thus, water consumption fees should be invested in water infrastructure [46], thereby enabling women their daily tasks of cleaning and caring [47], reducing the risks of diseases related to contaminated water [48], and limiting the effects of extreme weather events produced by climate change [13].

The World Resources Institute [14] reported that the MCM is one of the ten megacities in the world that could find themselves without water security during the present decade. This alert requires collective work for alternative investments and governance in water management between the public administration and citizens [49]. Today, the available resources are barely shared with poor neighborhoods, and policies must be developed to provide the equitable use of water for natural, human, food, and productive activities. Water security should grant access to sufficient and safe water for everybody, respecting their human rights by promoting policies of reduction, recycling, reuse, infrastructure improvements, and saving of this vital liquid [50].

The Global Risk Report [51] also indicates that Mexico was considered in 2024 the fourth most exposed country to climate change and the second in terms of socio-environmental vulnerability [52]. This is due to the complexity of its territory, the geo-hydrological differences in the country, and the existing socio-environmental conditions in mountain, desert, agricultural, and coastal ecosystems. Climate change has further exacerbated more prolonged droughts [6], and the population density in megacities [53] has increased urban heatwaves, resulting in growing water scarcity [36] and limiting the achievement of the Sustainable Development Goals (SDGs) [10,54].

Acute poverty in rural and indigenous areas with higher temperatures has also created additional insecurities for people who are losing their rain-fed plots for corn and bean production [55,56]. The conjunction of these processes describes the conditions where multiple conflicts, gender discrimination, extreme climate events with forced migration, public insecurity due to organized crime [8], and diverse socio-environmental vulnerabilities [52] are increasing the threats not only to water security but even to the survival of people. In this interacting and complex context, only novel and nonviolent mechanisms of conflict conciliation [57] and sustainability [39] with a gender perspective may allow a desirable and sustainable future for the MCM and the entire country. Before analyzing the irrational water supply and sewage system developed in the MCM, this paper first reviews the research methods and later analyzes the chaotic management of water security [22,46].

2.2. Location and Growth of the MCM

The megalopolis is located in the center of Mexico. It is the most populated region in Mexico, with 32,928,495 inhabitants in 2025 [53]. The extensive urban sprawl of the MCM encompasses (Figure 2) the 16 municipalities of Mexico City, representing 28.67% or 9,440,380 inhabitants [41]. It also includes 56 of the fastest-growing municipalities of the State of Mexico, corresponding to 30.73% of the population in the whole state with 3,299,800 people [58–62]. It also includes the cities and smaller urban settlements in the State of Morelos. The eastern marginal colonies of the MCM are highly affected by periodic sewage

floods expelled to the ten municipalities in Hidalgo [58–62]. The Morelos State and Mexico City obtain their rainfall from the volcanic chain called Ajusco-Chichinautzin, the largest Natural Protected Area in the Forest of Water [3]. The Sierra Nevada of Popocatepetl and Iztaccíhuatl is a crucial Natural Protected Area for water in Mexico City, Puebla, Tlaxcala, and Morelos. Important industrial development exists in Mexico City, in the State of Morelos, and in the eastern part of Mexico State. All these industrialized regions have undergone intensive population growth [40–42,44,45,53,58–63]. Gentrification has begun in downtown Mexico City [62].

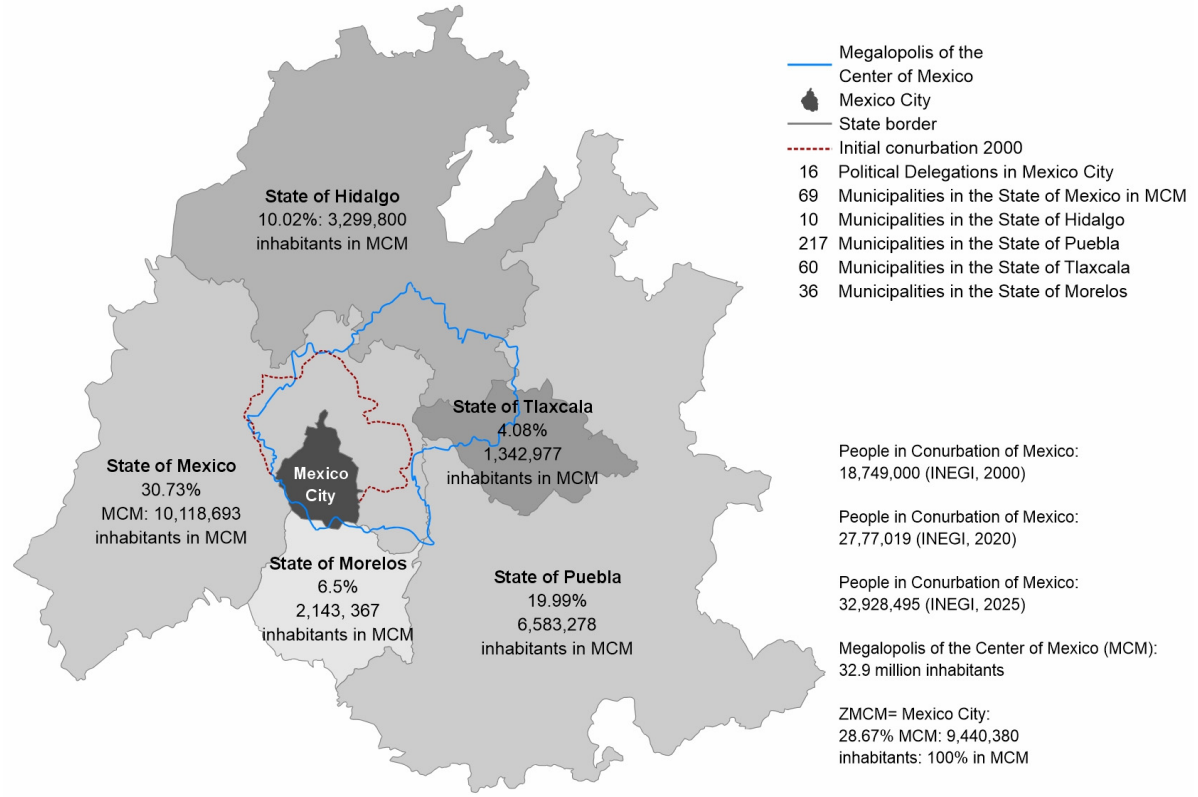


Figure 2. Megalopolis with state limits. Own elaboration.

The National Institute of Statistics and Geographic Information (INEGI) [53] estimates a population of 32.9 million inhabitants in 2025. The urban growth of the MCM during the last 20 years has been calculated at 79%, especially in the eastern part of Mexico State [53,58–62]. The areas of high population growth are related to the cost and the availability of land, although they have established marginal colonies, frequently without basic urban infrastructure and services (Figure 2).

The present study area in the central part of MCM covers an area of 7.180 km^2, of which 2.884 km^2 is urbanized and another 4.296 km^2 is used for agriculture, grassland, forests, and 807,060 hectares of Protected Natural Areas. The MCM is spread alongside recently formed volcanoes that ease the infiltration of rainfall to the aquifers on both sides of the mountainous chains. The volcanoes are covered by exceptionally biodiverse forests giving birth to six rivers and 32 smaller basins. The Moctezuma River represents 43% of the FW area, Amacuzac 34.25% (Balsas Basin), and the Lerma–Santiago Basin 22.44% [1,15]. The Cutzamala River covers 0.12% and integrates into the Panuco Basin that flows towards the Atlantic Ocean [26]. This hydro-biological biodiversity includes 15.3 % of Protected Natural Areas (Figure 3).

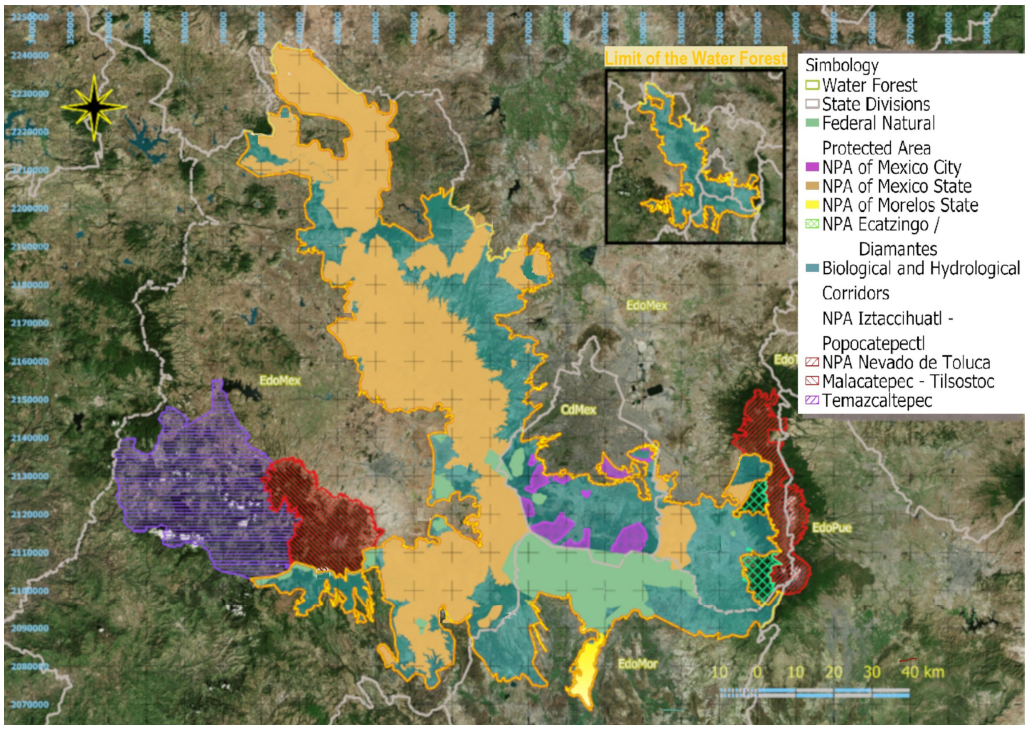


Figure 3. Natural Protected Areas in the study region. Source [26].

2.3. Research Methods

This research is based on two complementary methodologies, enabling communities to systematize their data using different statistical methods, with the participation of academics, especially young people and indigenous professionals trained in system model analysis [63] and in the elaboration of maps [15]. There is a nexus [47] that integrates four interrelated subsystems: (1) environment, including hydrology, Natural Protected Areas, territory, and quality of soils. (2) The urban-productive subsystem analyzes the water dynamics of the whole MCM, institutions, economic activities, investments in the hydraulic infrastructure, especially the Lerma–Cutzamala System (L-C), the expelling of sewage from the MCM valley, and political organization. (3) The socio-cultural subsystem reviews population growth, wellbeing, social stratification, inequality in access to services [64], and ethnicity. This cultural part researches the impact of water scarcity, compensated partially by women's unpaid care work and the long-term protection of indigenous communities of the Forest of Water. And (4) climate change impacts are assessed with the model of the IPCC [65] for short- (2030), mid- (2050), and long-term (2099) threats in the MCM, focusing on precipitation, temperature rise, changes in evaporation, and greenhouse gas emissions [66] (Figure 4), also including socioeconomic variables.

Territorial and communitarian segregation explains the social status of people settled in neighborhoods with services, employment, and infrastructure, while marginalized sectors suffer from a permanent lack of water supply and are frequently flooded by toxic water [67,68]. Poor women try with eco-techniques to store rain and filter water for human consumption, while domestic wetlands are cleaning their sewage. Indigenous communities live on mountains with greater rainfall without a public water supply; therefore, they are storing rain for household and productive activities. Ecosystems and their services are also affected by higher temperatures, forest fires, and plagues in the FW. Urban settlements have deforested areas crucial for water infiltration, and organized crime is cutting down mature trees and often threatens the life of indigenous communities who care for the FW. All four dynamic subsystems mentioned above interact and affect water security [32,33],

aggravated by unsustainable infrastructure, climate impacts, economic factors, territorial segregation, and socio-cultural behaviors.

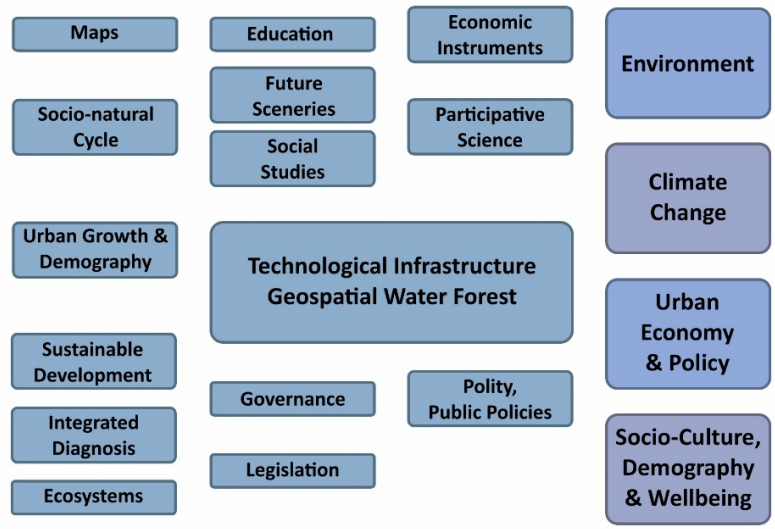


Figure 4. System organization of the platform. Source [9,15,22].

The second methodology links the physical and economic processes with a participative research methodology. Gautier [69] inspired our research group with her transformative 3-dimesional modeling that recognized local and indigenous wisdom to resolve complex intertwined problems from the bottom upwards, increasing greater equality among socially relegated groups such as marginal women and indigenous communities living in the FW. Their practices enabled these marginal groups to increase epistemic justice and equality among involved participants. Based on surveys developed by the affected social groups, the maps respond to their existing and upcoming problems. Periodic Zoom meetings, due to growing insecurity, and training by workshops on the use of the digital platform developed by CentroGEO [15], detect changes in the forest areas (bushfire, plagues, and logging), which are discussed inside the communities, including the protection of exposed participants to organized crime. CentroGEO provides a Web Service, firewall, maps, a feature, and processing and coverage services [15], while the desktop users employ GvSIG, QSIC, and ArchMap on their computers. For security reasons, communications and doubts are mostly managed by cellphone calls and WhatsApp groups. Different historical stages of the FW are graphically exposed and explain the transformation of the region, where the participants live, the development of the megalopolis, the expansion of urban sprawl on protected areas, and the threats to the FW by climate change impacts.

Climate change in the region was assessed with IPCC's AOGCM [65], which divides the planet into three-dimensional quadrants and uses equations to simulate physical processes (atmospheric dynamics, ocean circulation, atmosphere–ocean interactions, hydrological cycle, solar radiation, greenhouse effect, among others), along with geological and social processes to project climate change. CMIP6 manages 23 AOGCM, each with different equations and simulated parameters. The model accesses minimum temperature, average temperature, maximum temperature, and precipitation for four SSPs or possible paths or scenarios (126, 245, 376, and 585) for 20-year periods (2021–2040, 2041–2060, 2061–2080, and 2081–2100) for resolutions of 10 min, 5 min, 2.5 min, and 30 sec. For the study region, the research group has included socioeconomic, demographic, environmental, and political factors [66].

The mountains of the region are part of the Sierra Madre del Sur Chain. In the past, they were covered by high-altitude forests, mainly pines and oaks [26]. These ecosystems

surrounding the MCM constitute the so-called Forest of Water (FW) or SANBA, which traditionally supplied vital liquid to the inhabited areas in the plain of Mexico City. In the past, multiple lakes, bodies of water, and wetlands were formed, fed by rivers and smaller tributaries [70]. Still today, they hydrate 47 types of vegetation. This high biodiversity is being affected by rapid land-use change. The empirically studied region represents 807,060.713 hectares, and agriculture, induced pasture, and human settlements occupy the largest proportion of the study area. The territory of the FW is now fragmented into 1378 plots of vegetation with different land use, especially induced pasture [1].

Jaramillo [26] calculated that between 1992 and 2018 there were reductions in primary vegetation from 47.31% to 32.58% and in water bodies from 1.24% to 1.07%; there were increases in secondary vegetation from 8.87% to 19.66%, in human settlements from 0.03% to 2.66%, and in rain-fed agriculture from 41.54% to 44.03%.

Furthermore, from 1992 to 2018, 14.73% of original forest, jungles, scrublands, and grasslands were lost, transforming 95,022 hectares, equivalent to 11.77% of the NPAs [26]. Therefore, the conservation of the Natural Protected Areas (Figure 2) represents 402,565.7 hectares, where 39.69% is located inside the study area. The Sierra Nevada of both volcanoes Popocatepetl and Iztaccíhuatl in the eastern part, shown in Figure 2, includes 12,070 ha or 9.79% of the FW belonging to the study area. The protected area embodies 123,331.3 ha, and the NPA Ajusco-Chichinautzin has 126,396.2 ha, where 99.72% is part of the FW and recharges aquifers in Mexico City and Morelos. It is also the origin of the Balsas River, which discharges into the Pacific Ocean. The Nevado of Toluca in Mexico State represents 13.96% or 21,252.5 ha of the total 152,478.9 ha of the FW. Rainfall and the melting of snow are crucial for urban and productive development in the Toluca Valley [68].

The maps that are being developed by participating communities document the loss of hydro-biology, crucial for the economy of the indigenous communities and the conservation of their cosmogony and care of their societies [21]. Gautier [69] recognized that her participatory 3-dimensional modeling promoted a knowledge system for marginalized people and their empowerment, establishing a bridge between women and indigenous communities to overcome the existing inequality in traditional and modern environmental knowledge.

The participative-created platform is dynamic and includes the results of the analysis of the interdisciplinarily elaborated data from the physical environment, including data sets on water availability, conditions of soils, biodiversity, and climate projections compiled by Mexican authorities [6,15]. The satellite data are managed by Vicente Torres (ANIDE) [19] from 32 free available satellite systems, such as Galileo, CubeSat, Lansat, Sentinel, NOAA Data Access Viewer, Sentinel-1, ISRO, and INSAT, among others, and crucial research data are actualized every 10 days. The ecosystem services offered are quantified, and industrial activities are assessed [71].

The IPCC Atmosphere-Ocean General Circulation Models, modeling details for an integration of both atmospheric and oceanic GCMs, accounting for interactions between the atmosphere, sea surface temperature, and land surface parameters, also including for this research socioeconomic and demographic data [66], providing a regional hydrological balance. Water availability was projected for short- (2030), medium- (2050), and long-term (2099) socioeconomic scenarios for the Ajusco-Chichinautzin area that provides water directly to Mexico City and the State of Morelos. The initial data indicate stronger droughts due to higher temperatures, and the water demand in the most populated regions is increasing. In addition, there is an alteration of the monsoon season with more extreme weather events, such as floods, and more frequent and extensive bushfires are destroying crucial natural areas [72].

3. Results of Unsustainable Water Supply and Sewage in the MCM

History of Unsustainable Water Supply and Sewage in the MCM

Population growth, new hygiene habits, and industrialization in the MCM have increased the demand for clean water and have spurred chaotic urban sprawl over crucial natural areas, increasing the scarcity of the water supply. Conagua [25] developed an expensive, unsustainable, and corrupt water supply system, Lerma–Cutzamala, building 72.5 km of canals, 44 km of tunnels, and six siphons, where water was extracted from the neighboring states of Michoacán and Mexico and pumped up 1100 m to the elevation of Mexico City (2350 m) and Toluca (2660 m). Two mountains were perforated (the San José Tunnel and the Atarasquillo Dos Ríos) [68] (p. 16), affecting National and Regional Protected Areas. The existing engineering alternatives were unable to grant safe water to the growing megacity increasingly more affected by climate change [35,36]. Since the 1950s, farmers in the Lerma Valley of Mexico State have been deprived of water for agricultural activities [46]. Up to 13,700 L/s of the vital liquid was delivered to the metropolitan area in the 1960s. Farmers protested, and new demands for clean water forced Conagua [25] to develop an expensive, unsustainable, and corrupt water supply system, called Lerma–Cutzamala (L-C).

This L-C system provides 20–23% of the water to the MCM. Its supply has dramatically reduced during the last decade due to drought. During 2024, the strong La Niña year forced water authorities to totally suspend the supply from the L-C system due to the alarmingly low levels of water in dams and lakes in the neighboring states, from which the pipes and pumps of the L-C system source water. The remaining 80% of the water supply to the MCM is pumped from 970 wells of over 400 m deep. This overexploitation of aquifers in a former lacustrine subsoil is producing up to 40 cm per year of subsidence and micro-seisms [17], which are deteriorating urban infrastructure such as the underground public transportation subway system, the airport, drainage, and the water pipe system [17,73]. However, increasing droughts in the central part of the country, expensive pumping costs from well aquifers, and the reduction in supply from the L-C system are pressuring the public administration authorities elected in 2025 to create an alternative water management system. Forbes [74] reported in 2021 that the water authority is no longer able to pay MXN 3000 million per year to pay the electricity for the six pumps of the L-C system, equivalent to 60% of the current expenditure of Conagua, drastically limiting other activities.

The MCM inherited a second problem from the Spaniards, where cholera epidemics and gastrointestinal diseases forced first the colonial and later the Mexican authorities to promote sewage facilities in the metropolis, which started to export the sewage from an endorheic basin to the neighboring state of Hidalgo [27]. This second problem of destructive water management in the MCM is the discharge of sewage (SDG 6.2) through the open-air Great Drainage Canal of the Valley of Mexico in the Orient, built initially by the Spaniards and modernized later by Mexican authorities. To avoid unpleasant odors in Mexico City, two additional underground water collectors were constructed, the Occidental Interceptor and the Central Emitter, which discharge the sewage to the Tula River, heavily polluting it. Once it reaches the State of Hidalgo, the water is sanitized and then irrigates an arid region in Ixmiquilpan, Mezquital [75]. The industrialization process in the capital, the Valley of Toluca, Morelos, and Puebla have created employment for the growing population but have introduced highly toxic products, often forbidden in industrialized countries and affecting the health of people [48,76,77].

The insufficient water supply and inadequate sewage disposal indicate the unsustainable management of hydraulic engineering, polluting the Tula River, flooding marginalized colonies with sewage during the monsoon, overexploiting the aquifers in the MCM, and aggravating subsoil subsidence. Pumping water from the subsoil and neighboring states

and discharging the sewage is costly [27], polluting the air with greenhouse gases and deteriorating drinking water quality [76,77], which is charged with hazardous minerals when extracted from deep aquifers [48]. Santos et al. [68] established a hydraulic balance of water in the MCM. Urban demand is 67,746 m^3/s with a reuse of 4.184 m^3/s; industries use 4.060 m^3/s and recycle only 1.000 m^3/s, while agriculture employs 23.804 m^3/s with a recharge of 0.528 m^3/s, resulting in a consumptive use of 89.906 m^3/s. The requirement is not always covered by the 58.322 m^3/s extracted from groundwater and the 19.884 m^3/s provided by the Lerma–Cutzamala system. Additional water is entering the system from precipitation of 53.322 m^3/s. By stopping the degradation of the FW and strengthening its water infiltration potential, rainfall could directly recharge the abated groundwater level inside the Mexico City endorheic basin without having to import water from other states.

The key question is as follows: how long will it take to change the policy of expelling 32.107 up to 50 m^3/s of mixed sewage from the endorheic basin? The very separation of rain and its direct infiltration into the aquifer could reduce the existing overexploitation and ground subsidence. Domestic sewage could be treated by cheap bio-digesters and small wetlands with aquatic plants in residential complexes, which could slowly infiltrate water into the ground and enable its reuse in urban gardens and parks.

THE FIRST STEP IS TO PREVENT RAINWATER FROM MIXING WITH SEWAGE THAT INSTANTLY CONVERTS IT INTO A HAZARDOUS LIQUID. THE SECOND STEP IS TO CLEAN DOMESTIC SEWAGE WITHIN THE MCM BASIN. THE THIRD STEP IS FORCING INDUSTRIES TO TREAT THEIR TOXIC WATERS OR RECYCLE IT IN THEIR OWN FACILITIES.

Local authorities are unable to enforce this legal obligation to provide safe drinking water and improved sewage to meet SDG 6 for the benefit of all.

4. Alternative Proposals: Integrated Water Management with the Forest of Water

Wang et al. [44] documented that the most crucial resource for people's lives, plants, animals, and humidity in the air is water. They insisted that there will be an increasing loss of safe water by 2050, both in the quantity and quality of water. Sustainable water management implies the elimination of present engineering technologies of water supply and sewage [68] that are unsustainable and costly for nature and people [41]. This policy implies the elimination of corruption among water authorities [23], of disadvantageous privatization processes [39], and of illegal concessions and the implementation of rigorous transparency for alternative sustainable water management [29]. Continuing with this historical water supply and sewage management may create threats for the 32 million inhabitants in the MCM by a growing lack of safe drinking water [14], sewage pollution [27], excessive electricity and maintenance costs [74], and air contamination [78] by pumping water from deep aquifers and neighboring states.

A self-regulating system approach with the nexus of the four subsystems mentioned above [7,9,63] proposes a critical analysis of the negative and unsustainable hydraulic system processes by exploring feasible, nature-based alternatives and progressively reducing costs. To attain sustainable water security, the whole society of the MCM and the government must be involved. This includes at least 16 interrelated processes, which should be developed simultaneously. Table 1 indicates an alternative proposal for integrated water management and for a long-term sustainable and safe water supply in the MCM.

Table 1. Integrated water and sewage management in the MCM.

Policies for SDG 6	Actions on the MCM and Surrounding States
Water security in the MCM with safe supply for everybody	• Prevent rainwater from mixing with sewage. • Clean domestic sewage within the MCM basin. Improve the sewage system [27] for safe reuse [76]. • Force industries to treat their toxic waters or recycle them in their own facilities [48]. • Offer safe drinking water [77] with high supply standards [41] • Greening of urban areas [36] to improve the recovery of aquifers and atmospheric humidity.
Integrated water resource management (IWRM)	• Clean domestic sewage management [27,75]. • Restore rivers, wetlands, water bodies, dams, wetlands, and soils [29]. • Conservation and recovery of aquifers [79]. • Rainwater catchment in every possible niche [80]. • Limit flash floods by catching and infiltrating rainwater [81].
Capacity building and citizen participation in water-use reduction, reuse, and recycling (RRR)	• Citizen participation and women in water management [82]. • Include the vision and needs of local native communities in the design and management of the type of protection of their territories [18,21]. • Citizen control of public water works in collaboration with the Environmental Ministry [83]. • Controlled and standardized water supply to aquifers for their conservation and recovery [15]. • Institutionalization of rainfall catchment and water-saving practices [80].
Restoration of the FW with nature-based solutions and proper management of Natural Protected Areas	• Strengthen the water infiltration capacities of the Forest of Water (SANBA) and its natural flows [2,26]. • Restore the health of forests, biodiversity, and soils to facilitate infiltration from the mountains surrounding the MCM, where the highest rainfall occurs [84]. • Conserve the hydro-biological diversity of the FW (SANBA) and reforest its 807,000 ha with local species [26]. • Stop illegal forest destruction [85,86]. • Restore protected natural areas [2,3,26]. • Implement proper forest fire management [85,86]. • Control plagues [72]. • Limit the expansion of the MCM on natural areas and forests [26].
Rainfall infiltration into aquifers	• Separate rainfall from domestic and industrial sewage [75]. • Capture rainfall in houses and promote its reuse [70]. • Infiltrate rainwater into the ground with drainage systems, ditches, and special wells [80]. • Increase Protected Natural Areas [26]. • Reverse illegal private concessions granted by Conagua [87].
Institutional framework to guarantee equal access to water, transparency, and proper wastewater management	• Overcome decades of inefficient and unequal management by lack of transparency by water authorities [23,87]. • Increase water consumption fees to stimulate water-saving practices and recycling practices [88]. • Apply proven engineering practices that truly grant safe and sustainable water to the growing megacity so that the water in each basin is harvested from the basin itself instead of bringing it from other watersheds [46]. • Separation of domestic and industrial sewage and rainfall [75]. • Sustainable wastewater management by an improved sewage system [27] and safe reuse [49]. • Toxic sewage must be recycled or sanitized inside enterprises themselves according to legally authorized norms complying with the physical–chemical cleaning [48].

Table 1. *Cont.*

Policies for SDG 6	Actions on the MCM and Surrounding States
Eradication of water pumping from overexploited aquifers and from neighboring states	• Eliminate the Lerma–Cutzamala System and substitute its water supply with recycled rainfall and controlled sanitized domestic drainage in situ inside the endorheic valley [16,68]. • Macro- and micro-measurement of water input and extraction from the ground [80]. • Protection of ecosystems in the MCM and neighboring states {1}. • Recovering wetlands, rivers, and water bodies [25]. • Increasing the recharge of groundwater with rainfall and sanitized domestic sewage [79].
Sustainable urban planning and greening	• Planification of the Ministry of Urban Development and Housing (SEDUVI) [64,83]. • Rigorous urban planning in water and sewage (SDG 6) inside the MCM [27,64,71]. • Avoid chaotic urban sprawl over crucial natural areas [25]. • Planification of new human settlements protecting sensible water infiltration areas and avoiding flood-prone areas [1]. • Limit gentrification in the capital [29,62]. • Provide urban services to marginalized colonies, including bio-filters for safe drinking water [83]. • Rigorous application of existing laws and protection of natural areas, SANBA, and water infiltration regions [25]. • Buildings and enterprises must use bio-filters for rainwater reuse [64,80]. • Reforestation in avenues and parks [36]. • Reuse of cleaned domestic sewage in gardens and avenues [79,80]. • Supporting women in environmental activities [20,31]. • Promote economy of care and of recycling [89].
Legislation based on human rights	• Human rights to water and improved sewage for everybody (SDG 6) granted in the Constitution in Art 4. • Mexico is still missing a legal framework with a 13-year delay in the declaration of the National Water Law (LNA) substituting the present one (LAN), which allows illegal private concessions on overexploited aquifers. Elimination of existing corrupt Law of Water for the Nation (LAN) and establishment of the Legislative of the Law of National Water (LNA) granting the human rights to water for all citizens [90]. • Legal changes towards equality in water supply and sewage [13,70]. • Create legislation for the protection from climate impacts [24,81].
Training of women in eco-techniques	• Development of women's culture [31,47] of saving, reusing, and recycling water in their homes. • Provide funds for rainwater collection, safe drinking water infrastructure, wastewater sanitation, and domestic water recycling [80]. • Promote conflict resolution due to lack of water [22,54]. • Respect women's defense actions for a steady water supply [82] and fights against imposed unsustainable projects of industries, mining, and real estate. • Promote social and governmental transparency [23,29,71].
Respect of indigenous cosmovision and wisdom	• Recognition of indigenous communities that have for thousands of years protected the Forest of Water [5,20,21]. • Provide eco-techniques to the indigenous communities that own and protect the FW's ecosystem services and yet are without a safe water supply and proper sewage [21]. • Payment to the ethnic communities for the ecosystem services provided by their FW lands according to the magnitude of the benefits that the MCM receives from the FW [29,71].

Table 1. *Cont.*

Policies for SDG 6	Actions on the MCM and Surrounding States
Adaptation to and mitigation of climate change in the flood-prone plain of the MCM, especially new marginal colonies established on former lake areas	• Restoration of forests, agriculture, and soils covering the volcanoes [25] to limit extreme flash floods in the valley; early alert from satellites [19]. • Training of people for evacuation during disasters [66,81]. • Restore the FW and its soils to reduce climate change impacts of floods and droughts [1–4,91].
Cross-sector shared financial responsibility for IWRM	• Creation of suitable infrastructure [92] with cost optimization [88]. • Increase in water and sewage fees to build and maintain infrastructure [29,30,36]. • Citizen audit of public works in water works [83,87]. • Alternative eco-technologies instead of the costly and unsustainable current water management systems [22]. • Participation of social groups and the business community to cover the expenses of improving water supply, rain recharge and drainage, and proper sewage management [22,84].
Eradicate corruption among water authorities	• Elimination of illegal water concession [39,83]. • Transparency with citizen audit to limit the corruption of water authorities [7,22].
Sustainable agriculture	• Safe food production [7,44,55,56] without toxic agrochemicals, especially in the high mountains. • Control of deforestation perpetrated for the establishment of commercial grasslands for cattle [85,86].

5. Conclusions

Water security is at stake [7,22,32,33], with intertwined problems where only complex solutions can overcome the historical destruction of natural resources and failed engineering technologies; this has resulted in the overexploitation of aquifers, subsidence in lacustrine subsoil, and polluted water and air, with uncertainty about safe water supply for the next decade [14] and sewage disposal problems (SDG 6.2). All these processes are interrelated with other SDGs [10] such as good health, sustainable cities, climate action, and life on land. The Megalopolis of Central Mexico (MCM) is the second most populated urban area after Tokyo [92]. A self-organizing system [22,63] establishes a nexus among the socio-cultural, urban-productive, environmental, and climate change subsystems. It prioritizes among the fifteen solutions, where the participation of different stakeholders offers the government at the three levels [66] feasible alternatives. The proposal includes nature-based solutions [81] and the protection of the remaining 807,000 ha of the Forest of Water [26] surrounding the megacity, managing solid and liquid waste, separating rainfall from sewage, and recovering aquifers.

The potential to restore the SANBA with organized groups of women and indigenous people opens up sustainable alternatives to the MCM and its water, alternatives that do not destroy ecosystems or flood suburbs in neighboring states. It involves restoring trust between the communities that have cared for this FW with the newly elected federal and state governments to achieve a participatory governance arena [22] where past mistrust can be overcome [23]. It means infiltrating rainfall and treated domestic sewage inside the endorheic basin, which would allow overexploited aquifers to be recovered in the medium term [79] and protect low-income neighborhoods from flooding. Payment for ecosystem services to mountain dwellers would support the organization of women and indigenous peoples to prevent bushfires, logging, and human settlements that would permit the restoration of the FW with native trees, protecting an invaluable natural resource in times of climate change impacts. With more water available in the MCM aquifers, the government could suspend the costly L-C pumping system [68], thereby reducing air pollution [78] and restoring ecosystems in neighboring states [9,26]. Regulating the chaotic expansion of the MCM over the FW and neighboring regions would require rigorous

laws that guide urban growth toward areas with lower climate risks, where these suburbs would be provided with basic services and the local economy would be stimulated. It would also be overcoming the inequalities created in the southeastern region of Mexico for centuries [12], which could limit migration to the MCM with greater socioeconomic, health, and welfare opportunities.

Priorities are linked to justice [69] in water security [32] for everybody, safe drinking water [41], adequate supply standards of drinking water and sewage [73], maintenance of natural flows [91], greening urban areas [36], sustainable wastewater management with safe reuse [80], the conservation and recovery of aquifers [75], and legal changes towards water supply and sewage [90]. This promotes just human rights for everybody and recognizes women as key actors for saving, reusing, and recycling water [80] and Indigenous communities that protect the Forest of Water [18,21]. This includes the right to safe water, especially for women [47], citizen participation in water management [69], the creation of suitable infrastructure [80], cost optimization [88], the limitation of subsidence [17,40], the elimination of illegal water concession [83], safe food production [44,55,56], climate change mitigation and adaptation [24,66,83], sustainable water management of the megacity [71], and transparency with citizen audit to control water authorities [83]. Changing the current engineering model, which has benefited companies and corrupt officials and increased electric costs with pollution over the last five decades, would mean changing the national development policy in favor of a minority and involving marginalized groups in an inclusive development that complies with SDG commitments. Conflicts have emerged in the entire MCM [9,13]; the water supply in poor colonies was missing for weeks in 2024, and women have denounced sexual harassment by male water pipe distributors [93]: a formal complaint is now before the Mexico City Congress.

THE PRESENT PROPOSAL IMPLIES A RADICAL CHANGE AWAY FROM THE FORMER COSTLY, CORRUPT, AND POLLUTING ENGINEERING SYSTEM, SERVING LIMITED ECONOMIC INTERESTS [83]. ON THE CONTRARY, THE PROPOSED MODEL STARTS BY UNDERSTANDING THE ENTIRE WATER CYCLE. JUST WATER SECURITY INCLUDES THE EXISTING PRESSURES RELATED TO THE USE OF SAFE WATER [7,32,33], THE OVEREXPLOITATION OF AQUIFERS [37], CHAOTIC URBANIZATION [30], MISSING FINANCIAL RESOURCES FOR REPARATION [88], COMBATING EXTREME HYDRO-METEOROLOGICAL EVENTS [66], AND STRENGTHENING THE FOREST OF WATER'S CAPACITY TO PROVIDE CLEAN WATER TO LOCAL AND SURROUNDING COMMUNITIES AND TO THE ECOSYSTEM ITSELF [26].

The complexity of the proposal is permanently challenged by climate threats, vested interests, and new demands for improvement in quality of life. It includes social aspirations, the reduction of poverty, health aspects, wellbeing, security, income, work, and leisure. Society, government, and business communities are called to establish a negotiated, fragile, and dynamic equilibrium among the interrelated requirements for safe water and improved sewage, including the environment, people, urbanization, food, health, hygiene, economy, investments, water fares, technology, and climate risks [14,51,66]. The past expensive and unsustainable technological solutions have produced greater inequity in water access, destroyed urban infrastructure, and increased disasters in dried-out lakes, severe health problems, and human-induced disasters by exporting untreated sewage out of an endorheic basin of the MCM [27]. An integrated system approach indicates that the megalopolis is approaching a dangerous water scarcity stage, where only drastic changes with integrated socio-natural solutions, including the protection of the SANBA [26], with a people-oriented governance can turn the tides towards the water feasibility of Central Mexico's Megalopolis.

Multiple obstacles [49] exist that bar this drastic change in the water sewage policy and the SAMBA nature-based solution option. The entire water administration in Mexico

suffered for decades from inefficient management [88], a lack of transparency [23,83], and water fees that did not stimulate water-saving and recycling practices [49] with participation of women [31] and that did not suffice to invest in water management improvements. Multiple social stakeholders, vested economic interests, organized women, and indigenous communities in the forest have lost confidence in the authorities due to the irrational expansion of the megacity, often at the expense of destroying the Forest of Water as a result of the neoliberal policies of the Patriacene [13]. They have understood catastrophic water management as the sole feasible solution. New authorities have to recover this lost confidence [90] and involve society as a whole in the alternative.

Time is pressing, and policy must be oriented towards sustainable water management based on human rights, granting long-term, stable, just, and healthy water and integrated sewage management (SDG 6) [10] for a growing population [53,58–61].

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