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Advances in Environmental and Engineering Research

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Research Article

Risk Assessment and Adaptation to Climate Change Impacts in Mexico for Indigenous and Women

Úrsula Oswald-Spring *

Regional Centre for Multidisciplinary Research, National Autonomous University of Mexico (CRIM-UNAM), Mexico; E-Mails: uoswald@gmail.com; uoswald@unam.mx

* **Correspondence:** Úrsula Oswald-Spring; E-Mails: uoswald@gmail.com; uoswald@unam.mx

Academic Editor: Leonel J. R. Nunes

Special Issue: Environmental Risk Assessment and Risk Management

Adv Environ Eng Res
2023, volume 4, issue 2
doi:10.21926/aeer.2302035

Received: November 06, 2022
Accepted: May 24, 2023
Published: June 06, 2023

Abstract

The present article studies the policy, numbers, and costs of disaster risk management (DRM) in Mexico, a country highly exposed to climate change, due to two oceans warming up. The PEISOR methodology facilitates interrelating complex interactions and pressures between the natural and the societal system (P), where dangerous effects (E) occur in extreme events, such as floods, landslides, and drought. The impacts (I) of global warming, the pressure of historical poverty, and vulnerable regions were affected by the COVID-19 pandemic. These societal outcomes (SO) are aggravated by gender and ethnic discrimination. The governmental response (R) has built up an alternative health system with access to medical attention. About DRM against climate catastrophes, loss and damage (L&D) policies prioritized cash transfers to affected people. This policy increased the dependency of poor people but produced electoral benefits for the leading party. Nevertheless, this DRM limits adaptation and resilience-building among social groups living in exposed regions mainly in the South, where indigenous groups suffer from low human development index and extreme poverty. The article also compares the quantitative costs of disasters in Mexico during the last five decades. Growing L&D invoices for the government and affected people occurred predominantly during the last decade. Worsening climate conditions, combined with the COVID-19

pandemic, public insecurity, and extreme poverty, represent survival threats for exposed people, where only a local bottom-up resilience-building may create an integrated DRM. In conclusion, the reactive policy of L&D has raised the electoral support of needed people but limited adaption to deal with extremer climate impacts. The official DRM policy impacts allocated 96% of the disaster budget for reconstruction and emergency management and only 4% for prevention. Especially affected are women, girls, and indigenous people with the highest death toll. Empowering these vulnerable groups would create greater resilience, where training in care economy, and environmental restoration could reduce the risks. The lack of adaptation also created a dependency on foreign countries for climate advice, hurricane tracking, early warnings, and disaster recovery, where affected people are trapped in poverty and often forced to migrate.

Keywords
Climate change impacts; PEISOR model; COVID-19 pandemic; poverty; gender and indigenous vulnerability; loss and damage (L&D) policy; disaster risk management (DRM); forced migration

1. Introduction

1.1 Some Introduction Comments

This article analyzes the numbers and the costs of the multiple disasters occurring in Mexico from 1970 to 2022, such as hurricanes, floods, droughts, earthquakes, and volcanic eruptions. The focus is on climate impacts because of the warming Atlantic and Pacific Oceans, even during the last two years of a Niña event [1, 2]. During the past two decades, the socio-environmental vulnerability of Mexico is increased by extreme events [3]. The socioeconomic costs and the affected people [4] have risen. In the American continent, Mexico suffers from disastrous climate events [5], whenever the disaster costs are higher in the USA, where most people account with insurance [6]. Mexico had a low Human Development Index [7] at the country level of 0.779 before the COVID-19 pandemic, which lowered to 0.758 in 2022. It represents 74 places among 189 countries. There are also important differences inside the country. Mexico City achieves the level of a highly developed country with 0.815, while the lowest levels are in Guerrero with 0.694, Oaxaca with 0.689, and Chiapas with 0.677 [8]. These three states belong to the south and southeast, highly exposed to climate extremes [9]. In these zones live an elevated number of indigenous people, characterized by extreme poverty [10], low educational level, and speaking only their indigenous language. These regions also suffer from limited preventive training and resilience-building against extreme events by local and state authorities.

In this complex condition, the change of government in December 2019 almost coincided with the beginning of the pandemic of SARS-CoV-2. His health system in Mexico was unprepared to deal with the aggressive transmission of the virus and hospitals were overcrowded. On November 20, 2020, the country surpassed the million infected people [11]. Hospitals lacked trained personnel, protective tools, protocols, drugs, vaccines, mechanical ventilation, and intensive care beds due to

corruption in the former government [12]. Six months later, a general lockdown closed schools and public services, and introduced a safe distance, playing with the female name in Spanish Su-sana [13]. Health authorities separated hospitals for COVID-19 attention, while private facilities attended the common diseases. The corruption of four pharmaceutical monopolies, which controlled the public acquisition of drugs from 2008 onward, resulted in shortages, unpayable prices, and excess mortality [14]. Basic hygienic measures such as frequent hand washing and vaccination reduced the infection and death rate in 2021 [15]. Additionally, INMUJERES [16] reported explosive gender violence inside the households during the lockdown. Human trafficking also increased in Mexico by 18% [17]. The Ministry of Health reported in 2023 officially 330,000 deaths from COVID-19 and excess mortality of 650,602 [18].

Furthermore, Mexico suffers in multiple regions from organized crime and public insecurity, which includes drug, human, and archeological trafficking, extortion, and kidnapping [19]. Regional insecurity, the outcomes of the COVID-19 pandemic, and climate disasters have obliged an increasing number of people to migrate [20], due to the loss of their basic survival conditions. Further high violence in Mexico [21] during the last two decades have also displaced people from their home [22] to safer regions. These factors' interrelations and negative feed-backs have created complex socioeconomic, health, and climate conditions, with limited adaptation, particularly in the highly affected regions.

1.2 Research Questions

The paper is searching why the governmental policy prioritizes a L&D approach to manage increasingly more severe disasters, instead of a preventive Disaster Risk Management (DRM) approach by creating resilience among vulnerable people. Why have multiple natural hazards, public insecurity, and the pandemic of COVID-19 increased poverty, gender discrimination, and domestic violence, especially among indigenous, women, and girls, limiting their capacity to adapt to the growing climate risks? How can the care economy reduce the impacts of climate disasters, support the governmental DRM policy, and build resilience in exposed regions, granting people dignified survival conditions?

1.3 Organization of the Article

The article first explains the methodology of data recollection with the systemic PEISOR model [23] and its negative feedback. Later, it analyzes the basic tools of DRM, the impacts of extreme events in Mexico, and the governmental cost to compensate for the affectation on people and public services. The global climate model exposed explains the direct effect of higher emissions of greenhouse gases (GHG) on rising temperature with climate-forced migration [24], where Mexico suffers from a higher increase and disasters than the global average. This impact is related to its geographical location in the tropic of Cancer, where the poorest indigenous regions of the South are more exposed to hurricanes, landslides, extreme floods, and droughts [25]. The costs of extreme events have increased each year, whenever the government has opted for a L&D policy instead of preventive DRM to climate change. Women, girls, and indigenous people are the most affected by these catastrophes. Later, the discussion explores alternatives for reducing the dual vulnerability [26]-the social and the environmental-by reinforcing the care economy [27]. The conclusion explores a preventive DRM for exposed regions and people, limiting deaths, economic loss, and

climate-forced migration inside and outside the country.

1.4 Methodologies

In methodological terms, the PEISOR model [23] offers a historical understanding of the systemic pressure on the Earth and the human system (Figure 1). Environmental effects of scarcity, degradation, and stress are related to hydrometeorological (hurricanes, floods, droughts, bushfires), geophysical (earthquakes, volcanic eruption, tsunamis), and technological or human-induced events. The rising temperature has produced catastrophic climate impacts, where the existing conditions of poverty and food scarcity are aggravating the livelihood of exposed people. The societal outcomes depend on the capacity of adaptation of vulnerable people, where especially women, girls, and indigenous communities have to deal with extreme events. The Mexican response is oriented to attend disasters through the military program of DNIII and cash transfer, a policy called L&D [28].

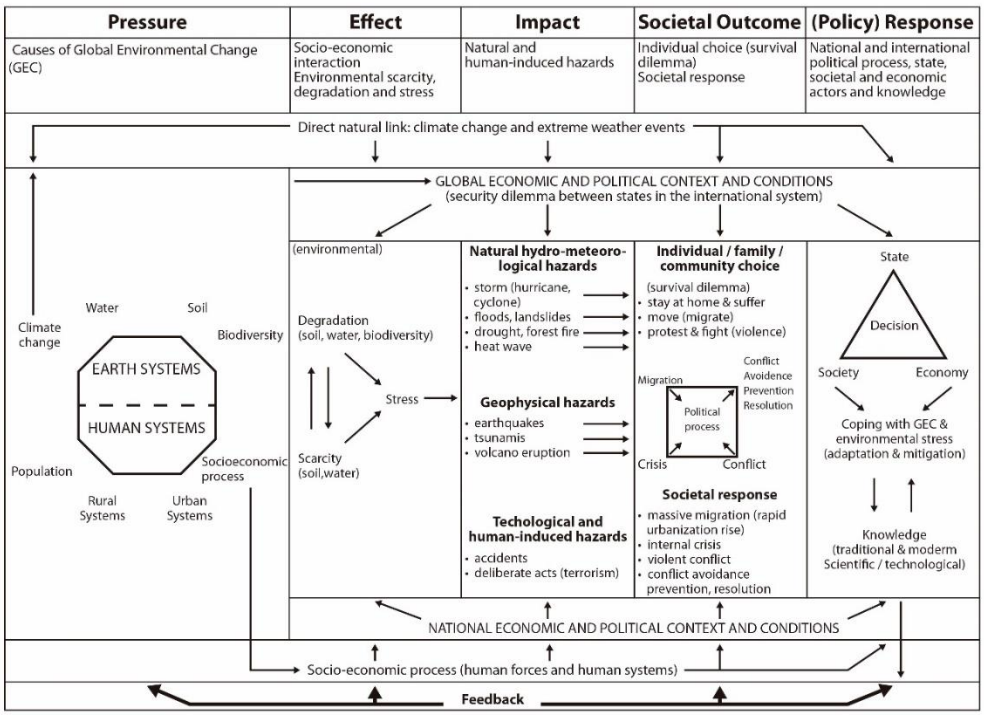

Figure 1 PEISOR Model [22].

In highly exposed southern indigenous regions, people often are forced to leave their homes and migrate [20], especially when drought or landslides have destroyed their survival in rainfed agriculture [29], where 80% of food crops must be grown in Latin America [30]. After an extreme event, people often lack water and food and lose their homes [1], increasing stress on vulnerable people [26]. When regional and local governmental disaster support fails or arrives late and is insufficient, many social groups start violent responses, sometimes even conflicts [31], and others are forced to leave [32]. Women, girls, and indigenous people are especially vulnerable during a disaster, in refugee camps, and forced migration by sexual violence [16]. Their lack of resilience has increased insecurity and death occurs along gender lines [33]. The policy responses involve all

affected stakeholders. It addresses coping strategies [34] such as reconstruction, adaptation, and resilience to increasingly stronger extreme events [2], often converted into disasters [35]. Knowledge [36], early warning [37], and investments by the state, business, and society offer negotiation processes for alternative DRM [38]. Collective preventive actions may reduce impacts, especially when forests and mangroves are restored, producing greater protection in exposed regions [39].

This article also includes documentary data from international sources such as the International Disaster Databank (EM-DAT, since 1988), La RED as a Network of Social Studies in the Prevention of Disasters in Latin America, and Desinventar from the United Nations, which have all elaborated disaster data banks. In México the National Center of Disaster Prevention (CENAPRED in Spanish) was built after strong earthquakes on 19 and 20 September 1985. In 1996, a National Fond of Natural Disasters (FONDEN in Spanish) was built and disappeared in 2020 due to past corruption. In 2022, an alternative fond called FORPREDEN substituted the former FONDEN. After a disruptive natural phenomenon, it offers food, water, mattress, hygienic materials, and medicines. This emergency aid is mostly offered by trained militaries (DNIII). Later, the Ministry of Social Development (SEDESO) replaced the affected population's damaged assets (refrigerators, stoves, furniture, etc.). It represents a Program of Well-being against Social and Natural Emergencies, linked to SEDESO, where direct cash transfers have increased these people's dependency on governmental aid [40]. As fragmented support, it limits adaptation and resilience-building, rebuilds houses in exposed regions, and does not prepare people for worsening climate conditions. The government has also promoted a National, State, and Local Risk Atlas for disaster prevention, whenever the changes every three years of the local authorities are limiting DRM training for people to manage better complex climate conditions.

The present article compares further governmental adaptation policies in Iberia-America. This risk assessment in Latin America, Spain, and Portugal indicated that Mexico is the highest exposed country to climate change impacts in Latin America, due to its geology, the location between the Atlantic and the Pacific, the high socio-environmental vulnerability of its people, and a chaotic urbanization process. This RIOCCADAPT Report [2], a collective work among 120 researchers from Iberia-America, was guided by a scientific committee. To understand a complex risk assessment, the present article studies in a transdisciplinary way, the existing data of Mexico, including bottom-up adaptation and resilience-building together with top-down governmental efforts, to understand the impact of highly vulnerable regions. Mexico also has many poor people [9] with informal work conditions and low salaries. In the southern regions, a great diversity of poor indigenous people, who mostly survive on small rainfed plots, producing their subsistence food [29].

The analysis of the complexity of social and environmental factors was synthesized in the political summary report by all member states of the UNFCCC [41]. Whenever, this global assessment promotes precise data about the physical studies and threats of climate change [23], at the same time it limits the political commitment of governments to deal with the growing threats of global warming [39]. This explains that only in 2014 a sensitive theme such as 'Human Security' was introduced by governments in Working Group II [42]. In these global assessments, the exposed regions are underrepresented, especially the research on women from the Global South [41].

A conceptual framework similar to IPCC was undertaken by scientists in Mexico, analyzing the physical knowledge, the policy implications of adaptation, and climate change mitigation efforts [3]. The collective effort integrated the climate science community from the country and multiple

further publications started to deepen in aspects of urbanization [43], gender and climate change [44], and disasters [45]. The Mexican government presented to UNFCCC its Six Communication [46], including climate change impacts, the origin of emissions, and the mitigation advances of GHG in the country.

Mexican also suffer from public violence related to organized crime and conflicts from mining and tourist resorts investments, where indigenous owners were often deprived of their collective land and culture. Thus, only a transdisciplinary systemic approach [47] allows us to understand that climate change impacts are crucial factors for poverty rise and political instability [48]. During the last 7 decades, these multinational investments have increased social and environmental vulnerability and risks, especially caused by deforestation of the tropical forest [49] in Tabasco for cattle growing and oil extraction [50]. This World Bank project missed an environmental assessment, forgot mitigation practices, and evaded applying the existing environmental laws. As a result, the state of Tabasco was twice severely flooded without the protection of the former tropical forest in a floodplain. Similar disasters occurred in the Riviera Maya, where protective mangroves were eliminated for beach tourism.

To understand the complex interrelations, the PEISOR model [23] was developed (Figure 1). It offers a historical understanding of the pressure on the Earth and the human system, where in Mexico environmental effects of scarcity, degradation, and stress are related to hydrometeorological (hurricanes, floods, droughts), geophysical (earthquakes, volcanic eruption, tsunamis) and technological or human-induced effects. The impacts of more frequent and dangerous catastrophes result from the rising temperature, where catastrophic climate events aggravate the existing conditions of poverty and lack of food. The societal outcomes depend on the adaptation capacity of vulnerable people, where especially women, girls, affected groups, and indigenous communities have to deal with extreme events by recovering with governmental and social support in an L&D policy [51]. The Mexican policy is basically oriented to cash transfers for lost assets. In highly exposed southern regions, after several extreme events, people are often forced to leave their homes and migrate [24]. Especially dangerous are the Niña events, when reiterative droughts destroyed their survival in rainfed agriculture [52].

When regional and local processes of governmental disaster support fail or are insufficient, many social groups produce violent responses and conflicts [21], and others leave [53]. After an extreme event, people often lack food, water, and shelter [22], increasing the stress on vulnerable people [26]. Women, girls, and indigenous people are especially vulnerable during a disaster. Their lack of resilience has also increased insecurity, sexual violence, and dead along gender lines [44]. The policy responses involve all affected stakeholders. It addresses coping strategies [34] such as adaptation and resilience to increasingly stronger extreme events [43], often converted into disasters [47]. Knowledge [36], early warning [37], and investments among the state, business, and society offer negotiation processes [2] for adaptation. Collective actions may reduce the impacts, when forests and mangroves get restored and produce greater protection in the highly affected regions [54].

1.5 Disaster Risk Management (DRM)

UNISDR [55] defined DRM, as “the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies, and improved coping capacities to lessen the adverse impacts of hazards and the possibility of disaster”. Mexico

has a highly fragmented DRM, where intervene CENAPRED, SEDSO, the army, and the marines with its DN-III-E plan, together with state and local authorities. All these organizations often interfere with the efficient and rapid support, where society is pushed away, once authorities appear. However, UNISDR insists that native stakeholders not only know the local conditions but can also save lives at the beginning of a disaster. "Trained leadership is especially challenging in the context of innovation for DRM as risks in experimentation can be high, management can be cumbersome (as it requires the participation of numerous and diverse stakeholders) and … difficult political issues need to be negotiated" [55].

Thus, training and planning of diverse stakeholders are crucial and related to a legal mandate of risk evaluation, including the local authorities who are directly responsible for early warning and preventive evacuation. In Mexico, a Federal Law of Civil Protection exists, and each state has its own Law and practices. Frequently, refugee camps are established in schools and sports facilities. In the case of serious impacts, children are therefore deprived of attending school, because refugees have occupied the facilities for more than a year as it has happened after the Stan disaster in Chiapas [56]. Often people cannot understand the data from a DRM and locally understandable maps and tools must also be translated into the indigenous languages. The Mexican compartmentalization of DRM should be improved with small-scale coordination, where federal authorities create actions for mainstreaming exposed people, and state and local authorities are efficiently trained. Missing participatory involvement of all stakeholders, especially girls, women, and indigenous people increase the number of death and produce greater damage. It also represents a political pitfall.

Climate and DRM financing could come from the Adaptation Fund of UNFCCC and the Pilot Programs for Climate Resilience [57] and reduction of GHG [58]. Additionally, national disaster funds are crucial in countries highly exposed to multiple disasters, such as Mexico. The lack of DRM at the local level also affects community integration, which is crucial in indigenous villages. Indigenous represents 5% of the population and protect 80% of the remaining biodiversity [54].

Mexico started in 2020 in poor and exposed regions a program called *Sembrando Vida* (Sowing Life) to reforest their localities yearly with 700 million native plants. This program involves 450,000 poor peasants, who grow staple crops to improve their nutritional level with an investment of 1.2 billion dollars. This project supports marginal people, gives them an investment for future years when the trees are grown, captures GHG, grants income, reduces the environmental vulnerability of exposed regions, limits climate-forced migration, and restore deforestation of megaprojects [40]. The next subchapter analyzes the DRM in Mexico.

2. Results of Disaster Risk Assessment and Management to Climate Change in Mexico

2.1 Evolution of Global Climate Mitigation

The empirical systemic analysis of the PEISOR model for México [23], obliges first to review the recent evolution in climate mitigation and adaptation, committed by UNFCCC in Paris in 2015. It was signed by 195 other countries and started as a legally binding agreement the 4 November 2016. The goal was to maintain global warming far below 2°C, preferably to 1.5°C by mitigating the emissions of CO_{2e} in the atmosphere. Hegglin et al. [59] analyze in Figure 2 the purpose, mitigation, adaptation, financial flow, technological support, and capacity-building strategies to achieve these ambitious goals and reduce the emissions of GHG, basically from fossil hydrocarbons [58]. Mexico should achieve its National Determined Contributions (NDC), most embedded in international trade and

different economic tools to contain the global temperature rise [59], including massive reforestation [60]. Mexico suffer also from higher temperature rise than the global average [61]

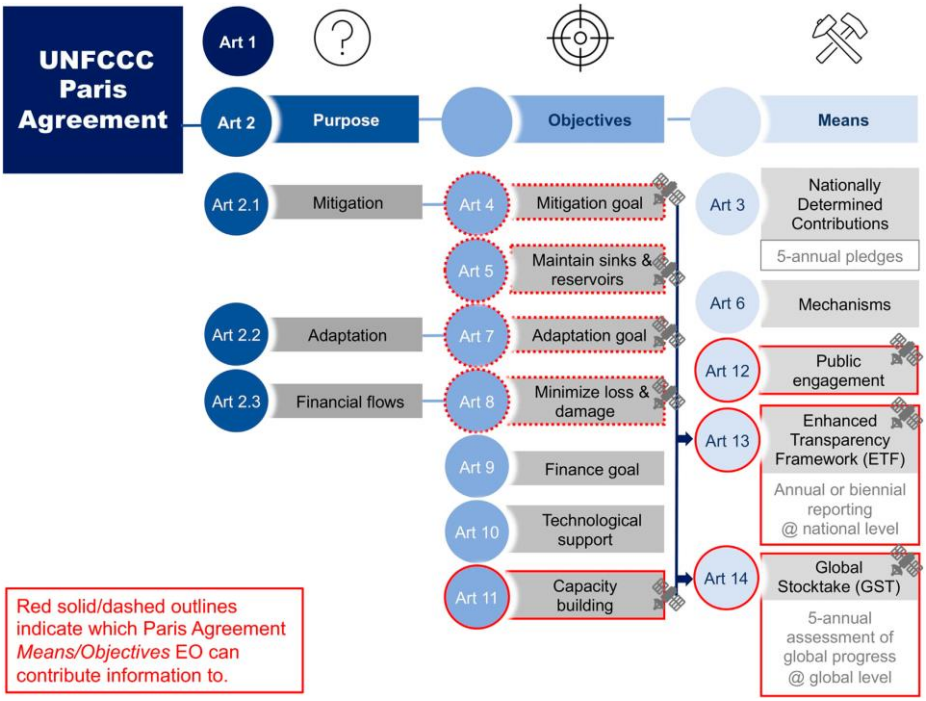

Figure 2 UNFCC Paris Agreement [41].

However, there are multiple obstacles to achieving these climate goals, which affects especially the countries in the Global South and their economy [61]. China alone produces 26.4% of GHG, and IEA [62] indicates that since 1989 100 multinational companies have been responsible for 71% of GHG emissions. All industrialized countries historically emit 79% of the GHG from 1950 on and generate connflicts [63]. The present mitigation processes agreed in the Paris Agreement could not achieve the agreed goals in Paris [41]. The GHG got reduced during the COVID-19 lockdown in 2021 but increased again in 2022 over the 2020 level. The war between Russia and Ukraine will further increase global warming. Most multinational enterprises are still unwilling to promote greener energies and threaten to lose their long-term profits. At the same time, they pressure their governments to use carbon again for energy generation, as happened in Germany.

As Figure 3 indicates, the global atmospheric CO_{2e} concentration has been rising [25] dramatically during the last seven decades. The efforts by industrialized countries and multinational enterprises were and continue to be insufficient to reduce their GHG. This behavior creates an ethical problem [64]: The industrialized countries are responsible for global warming, have limited legal reinforcement to reduce their emissions, and protect their multinational enterprises. However, these emissions are producing more frequent and severe hazards in the Global South [29] with very limited emissions of GHG. During the COP in Oxford, industrialized countries were reluctant to support funds for L&D, enabling poor countries to deal better with adaptation and mitigation to climate change impacts. Only in 2022 under pressure from the Global South a Loss and Damage Fund agreed in Sharm el Sheik, Egypt, whenever the expected reduction of NDC was not achieved.

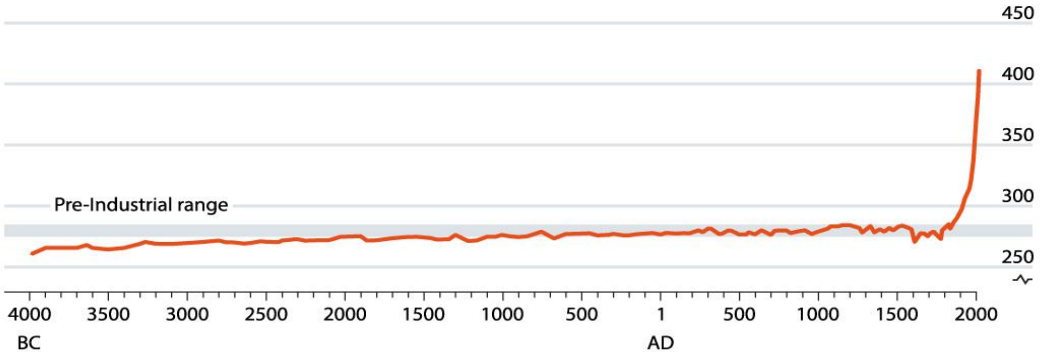

Figure 3 Global Atmospheric CO_2 concentrations (ppm) [65].

The historical emissions were stable during the last 6,000 years and only started to rise only during the last half-past century. The data exposed indicate a stabilization of CO_{2e} during the past 5,920 years and a steady rise from 1960 on. The industrialization process accelerated after WW II, thanks to the availability of cheap massive oil and gas [66]. The Mauna Loa Institute in Hawaii developed the first systematic measurement of GHG emissions in 1960, and NOAA started its own CO_{2e} assessments in May 1974. The measurements of carbon dioxide (CO_2), methane and nitrous oxide, the three greenhouse gases emitted by human activity are the most significant contributors to global warming. NOAA [67] measured that during 2022 a CO_2 rose by 2.13 ppm and in April 2023 there were 417.06 ppm of CO_2 in the atmosphere. This acceleration inspired Crutzen [68] to speak about a change in the history of Earth from the Holocene to a new era, called Anthropocene, where human activities are transforming Earth due to their unsustainable management of natural resources [69] and GHG emissions.

Therefore, more public engagement, private commitments, transparent legal frameworks, and a global stock-take every five years should measure the real global mitigation progress. The business company started in 2004 with green investments, called Environment, Society and Government (ESG) to promote mitigation and adaptation strategies against the stronger impacts of climate change. The coverage of ESG has generated 2020 about 81% of sustainable investments and reached 2022 $2.72 trillion dollars. Big financing multinational advisers such as Black Rock, State Street Global Advisers, and Vanguard offered multiple providers investment opportunities, whenever the regulatory requirements still depend on national jurisdictions and penalties. Environmentalists pressure, therefore, to lower the GHG and often call these funds greenwashing or speculation with national pension funds [70].

Climate change was scientifically assessed in the nineties when the first Assessment Report of IPCC [71] started with a systematic revision of published articles, emitting the first report for policymakers [72]. In 2021 IPCC published its sixth assessment report on the physical bases of global emissions. Impacts, adaptation, and vulnerabilities were reviewed systematically and the policy report was emitted in 2023 [73], explaining the worrying data on extreme events, climate impacts, and forced migration that have occurred basically in the Global South. Increasingly also the North is affected by hydrometeorological events, while global mitigation processes have failed and GHG emissions are rising. Confronted with extremer events, governments in the Global South promote DRM processes to reduce social and environmental vulnerability [26] in highly exposed countries [2]. Nevertheless, lack of financial support, historical vulnerability, new poverty due to COVID-19

[10], high inflation, and food price increase are raising poverty and hunger in multiple southern countries [74]. The following subchapter reviews the climate conditions in Mexico.

2.2 Disaster Risk Assessment and Management of Climate Change in Mexico

Evaluation of necessities and damages proposed by the Post Disaster Recovery, Needs Assessment, and Methodologies in Latin America [35], focused on social, institutional, and local cultural structures. This assessment proposed to include: 1) the needs and damage assessment, which should define the baseline and the objectives to be achieved; 2) the recovery of financing mechanisms, whether public, private, or mixed; and 3) the political design of participation and intervention in the specific contexts to be recovered, with the representation of strategic planning in the long-term. Paul [75] recommended covering the economic, health infrastructure, and housing sectors, including building back better houses with infrastructure, public services of quality, and the replacement of lost assets. Generally, the collective and individual trauma recovery is underestimated and communitarian participation is crucial to support losing loved ones, assets, and income. It reduces avoid corruption, increases respect for human rights, and avoids political conditioning [38].

PINCC [1] found that climate impacts in Latin America are more severe in Mexico and northern Central America. Some Mexican regions are especially vulnerable to temperature rise, hurricane impacts, and drought on the Pacific side. Estrada & Botzen [61] modeled with HadCRUT the confluence of risks and high exposure in some regions. Particularly susceptible to climate change (Figure 4). First, Estrada [9] insisted that the average temperature in Mexico raised almost 2°C, while the global average is between 1.1 and 1.2°C. This results from the two oceans warming up, which maintained higher sea temperatures during the last two Niña years (2021-2022).

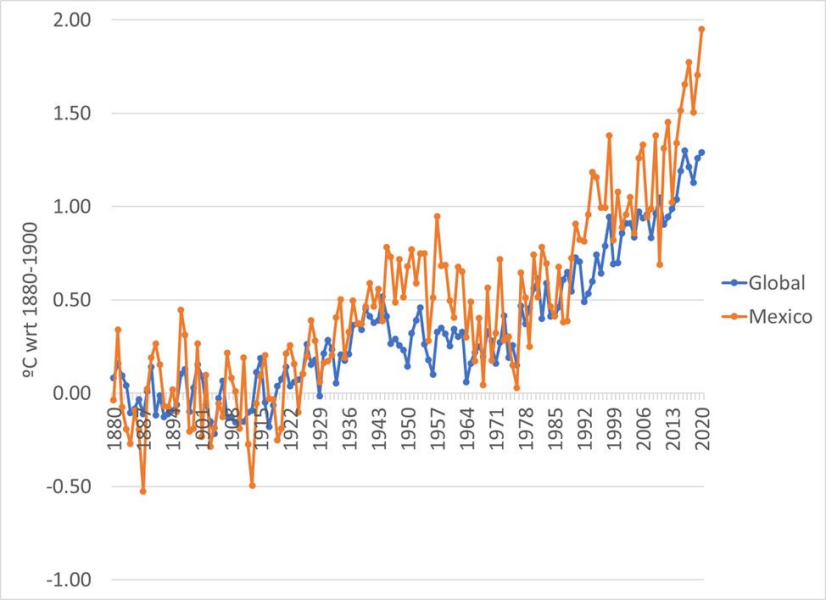

Figure 4 Comparison between global and Mexican Temperature Rise. **Source:** Estrada 2022 [9], based on HadCRUT.

When looking at the exposition of specific regions, the North-West of Mexico is highly affected by temperature rise. This hyper-arid region in Sonora and Baja California had suffered from the

highest temperature rise in the country. In May 2022, two satellites of NASA measured in the Desert of the Altar, Sonora's temperature of 80°C on the soil (not in the atmosphere). Big cities also suffer from urban heat islands, and Mexicali in Baja California on the border to the USA, belongs to the five hottest cities on Earth [76]. Mexico City, Guadalajara, and Monterrey, the three biggest cities also suffer during the dry season from heat islands. The estimated Mexican losses by climate change were estimated in 2020 in more than one billion dollars [4]. Under a scenario of global inaction, climate change could drastically decrease Mexico's agricultural production capacity. Yield reductions are estimated between 5% and 20% in the next two decades and up to 80% by the end of the century for some crops and highly affected states. The regions, which are currently most suitable for rain-fed corn, could lose between 30% and 40% in yields by the end of the century. Currently, 23 states have one ton per hectare of rain-fed corn yields, and only 11 may produce at least this ton per hectare by the end of the century. This could reduce the food security of the poorest people [46].

The combined climate change impacts could represent between 1 to 3 times higher costs, and up to 5 times in highly exposed regions. Inactions in the flood plains of Tabasco, Quintana Roo, and Veracruz, and the cumulative losses of the current agricultural production may represent 12, 11, and 10 years of loss in these three mentioned states. For Oaxaca, Campeche, and Colima, cumulative losses would be similar to 5 and 6 years of the value of their present agricultural production. For Chiapas and San Luis Potosí, two poor states, these reductions would be similar to 4 years of today's agricultural incomes [46].

Looking at the financial costs of DRM in Mexico, Table 1 compares the official disaster reimbursement from 1970 to 2020, without considering the contributions by the affected people and their families, often receiving remittances from the USA. During these five decades, 220 major extreme events have occurred, basically caused by climate change, equivalent to five times the former number of hazards. Between 2010 and 2021 the reimbursement was 23 times the expenses of the former decade, while prevention amounted to 0.3% of the total costs compared with the reimbursed costs. The budget accepted by Congress in 2023 assigned only 4.1% for prevention, while reconstruction and disaster support amounted to 96%. This lack of preventive and adaptive behavior is also reflected locally. In 2011, only 393 municipalities (16%) of the existing 2,446 local authorities in Mexico had elaborated a Municipal Risk Atlas to protect their citizens. This behavior may increase dramatically in the L&D in the coming years.

Table 1 Disasters, Impacts and Costs in Mexico, 1970-2022.

Years	Hurricane	Floods	Earthquake	Affected people	Dead	Costs
2021	Grace Ver 62 munic.	X	126 houses landslides	110,000	32	11 MMP; 22 disasters
2020	83.4%	X 435 events	X	858,735	398	1,1678MMD; 31.9MMP Fonden: 13.7643BP Ramo23: 27,321.1BP

2019	X (73.4%)			612,943	616	10.541 BP
2018	X (80%)	X		Heat wave	501	14.993 BP
2017			2 big ones	1,700'000	877	8.364'129 BD
2016	X			21,500	495	45.427 BD
2015	X (96%)	X	X	2.5 millions	468	17.782 BP
2014	X				485	2.5 BD 32.933 BP
2013	X			172,000	646	5.337262 BD 61.520 BP
2012					627	17.308 BP
2011	X			280,000; drought: 2,500'000	427	41.411 BP total 6.0 BD (drought)
2010	X	X	Extreme drought	1,020'000	535	5.1278BD 92.375BP
2010-2021			Prevention 323 mP; 2011-2021	Reconstruction 7,874 BP: 23x 2011-2021	10,626 total	576.311BD 2010-2021
1970-2019	600 BP	59 BP	Total 202 disasters	Drought 650 BP	6,655 BD in all events	5x more events & costs in 50 years
2022	Approved budget			Prevention: 207 mP 4.1%	Attention: 9.054 BP 95.9%	

Source: The Autor, based on EM-DAT, Red, Desinventar, CENAPRED.
BP: billion pesos; BD: billion dollars; mP: million pesos (taking into account the average of the period or the value of the pesos during the analyzed years).

CENAPRED [4], the National Center for Disaster Prevention, informed that from 2000 on during two Niña years, disaster reimbursements have increased dramatically (Figure 5). Especially difficult were the years 2010 with a high number of hurricanes and floods. In 2017 two earthquakes in September of 8.2 in Chiapas & Oaxaca and 7.1 Richter scale in Morelos & Puebla also affected Mexico City. Additional costly years were 2007 with floods in the states of Tabasco and Chiapas due to mismanagement of dams. In 2005 and 2020 the Latin alphabet required Greek letters to name the multiple hurricanes that had impacted the country. Several of these hurricanes were highly disastrous. In 2005, Wilma achieved category 5, the highest level on the scale of Saffir-Simpson, impacting the tourist resort of Cancun with the costly destruction of hotels and the international airport. During the same month, Stan was badly managed without early alert and preventive evacuation of indigenous people. The post-disaster management was chaotic, including the high corruption of the FONDEN. The cost of Stan affected almost half of the GDP of the state of Chiapas [57], the poorest entity in the country.

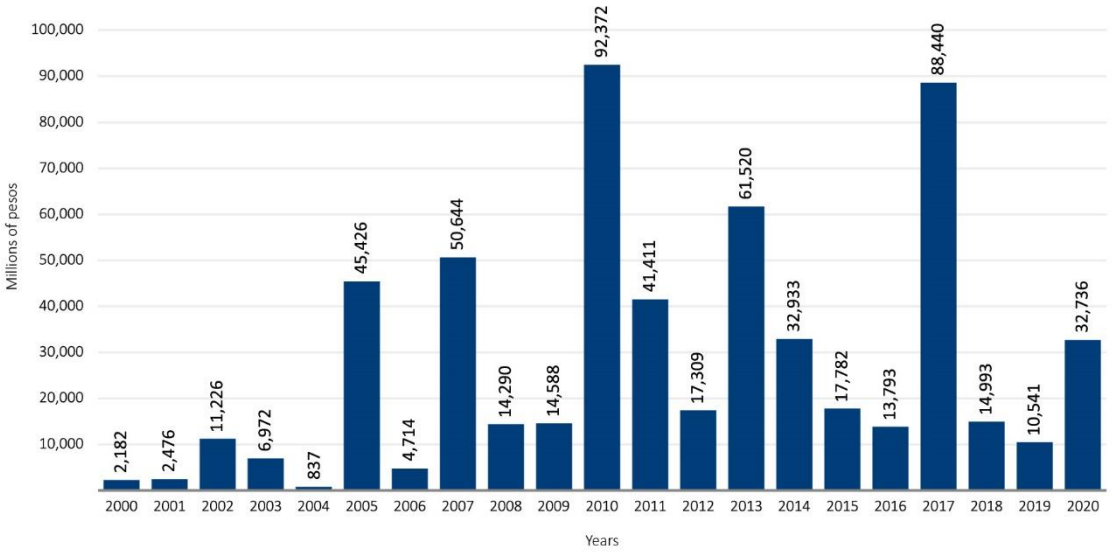

Figure 5 Evolution of official disaster costs in Mexico [4].

3. Discussion

One of the physical impacts and effects of environmental stress is the weakening of the thermohaline circulation due to the disintegration of the Antarctic ice sheet and the Greenland glaciers, both related to global warming [77]. This phenomenon could produce huge global impacts and uncertainty [3], especially in low-lying coastal regions, affecting in Mexico Tabasco, Campeche, and Veracruz. In the projections of economic and societal outcomes of climate change [4], the impacts are poorly represented and often ignore the survival threats for vulnerable social groups. An additional effect of climate change is the acidification of the oceans [78], affecting the highly productive reefs and the whole food chain of fishes, crabs, and mollusks. Globally, humans depend on 17% of seafood intake, which produces 6.7% of all protein intake for their nutrition and health [79]. Seafood is also essential for the survival of multiple aquatic animals, where climate impacts may destroy entire trophic chains with global repercussions. Another tipping point is related to the shutting down the thermohaline circulation [80].

As stated before, Mexico is highly exposed to climate change impacts because of its location in the Tropic of the Cancer and between the Atlantic and the Pacific Ocean. Their growing temperatures generate trade winds and the accumulated energy in the depth of the seas, producing dangerous climate events. Probable high-impact events are raising [42], and poor physical and economic modeling still increases the unknown physical and economic consequences of hazards. Steffen et al. [81] estimated potential tipping points with 2, 3, and 4°C scenarios, where Mexico will be highly impacted. Martin [82] insisted that humanitarian crises are increasing due to climate events such as hurricanes and floods or slow onsets, basically related to droughts, reducing crop yields, and lack of food and water, which harm the survival conditions of the people.

The policy response to these complex interactions with negative feedback (PEISOR model) produces governmental, individual, and social responses. The Internal Displacement Monitoring Center [83] estimates that between 2008-2014 every year 26.4 million people were displaced, creating internally and externally forced migrants with complex conditions for undocumented

people. The climate-forced and economic migrations are linked to the border between Mexico and the USA but occur in the Mediterranean from Africa to Europe [30]. These processes will increase with raising GHG emissions, extreme climate hazards, and stronger catastrophes, affecting vulnerable people, especially those living in drylands lacking water. The distinction between economic and climate migrants is complex and requires additional empirical research [84], especially when low ongoing events of reiterative droughts and food scarcity affect exposed populations' survival [85]. Additionally, climate and social tipping points may further increase the migration from highly affected countries to industrialized ones [83]. Women and girls are especially at risk during the emergency stay in a shelter after a disaster and during a migration odyssey, where human trafficking and sexual assault are frequent [17]. Forced migration [24] not only occurs by climate disasters and lack of preventive behavior, but is also related to public insecurity, criminal gangs, and political persecution [86].

Climate disasters in 2020 and the COVID-19 pandemic have created survival dilemmas and have increased the number of Central American and Mexican migrants to the USA. The IOM (2021: 1) [87] reported that "what they all have in common is that they lost everything to the hurricanes" and migration increased after the hurricanes Iota and Eta. Casillas [88] insisted that climate change poses risks to natural and human systems that increase food insecurity and lead to displacement. Mexico, El Salvador, Honduras, and Guatemala have increased the number of migrants to the USA after 2021. In 2022 more Haitian and Venezuelan refugees joined together with migrants from Africa and Asia. Jeffrey Sachs [89] has proposed an international migration regime, enabling people to find a legal way for the 11.3 million people who have arrived in the USA. Avoiding their legal limbo as undocumented migrants offers facilities for missing jobs and grants migrants respect for human rights and dignity. The Mexican government was pressured by Donald Trump in 2019, threatening the country with progressive taxes on their exports if they did not accept the deportees in their territory. The Trump administration used the Article 42 policy to avoid COVID-19 propagation [90].

During 2020, Mexico received 61,000 expellees from the USA awaiting the acceptance of their refugee applications in precarious conditions on the border [91]. These pressures continued through the imposition of judges during Joe Biden's administration, which immediately removed two-thirds of the 1.66 million undocumented arrivals by 2021 [92]. Between March 2020 and February 2023, 2.7 million migrants were expelled to the Mexican side under Art. 42. COVID-19 and climate change have produced poverty and forced 1.3 million conational to migrate, representing 60.3% of the returned undocumented persons [93].

The passive policy of the Mexican government can be explained by two main factors, which also indicate the lack of mitigation, adaptation, and resilience-building for its affected population. One is the arrival of remittances, which have grown 27.1% to 51.594 BD during 2021 and achieved 2022 58.4 billion dollars, with an increase of 13.3% in 2022 [94]. The second is the expulsion of Mexicans and other unauthorized Latin American migrants from the US to the Mexican border, based on Article 42 [95]. The political pressure from both administrations has obliged the Mexican government to accept to be a so-called third-safe country. Especially Venezuelans and Haitians were massively expelled in 2022 and are now gridlocked on the northern Mexican border, trying to get a legal permit to stay and work in Mexico or to return illegally to the US. “2.9 million encounters with migrants along the US-Mexico border between April 2020, the first full month after Title 42 went into effect, and March 2022, the most recent month with available data. Nearly 1.8 million of those encounters, or 61%, resulted in migrants being expelled under Title 42. The roughly 1.1 million

remaining encounters ended in migrants being apprehended under Title 8" [95].

4. Conclusions

Climate change will increase human tragedies with greater L&D to governments, people, and ecosystems. Higher vulnerability and fewer survival conditions in exposed regions are pushing factors for affected people to leave their homes and migrate to industrialized countries, especially when public insecurity exists. The remittances sent from the US to the family left behind are often the first alleviation for climate disasters, health, and schools. After a disaster, the money helps to bury the dead, buy food and water for survival, and rebuild safer destroyed houses. It also helps new migrants to pay for an illegal transfer to the USA, often safer because family members there pay only after the safe arrival of their family members.

The limited support of mitigation and the payment of L&D by industrialized countries is evidence of unethical management of intercountry justice [62] among emitters of GHG [96], causing disasters and refugees [82] in affected countries. Forced migration [84], survival dilemma [83], and environmental destruction create negative feedback on the entire planet, political stability, and biodiversity biodiversity. Climate change is affecting the entire planet [25], destroying ecosystem services [69], and limiting access to clean water, healthy food, and safe air [96]. As a global process, potential tipping points [81], unknown hazards also in the northern countries, increasing costs to rebuild infrastructure, destroyed houses, and affected landscapes are negative outcomes of the missing preventive behaviors to mitigate climate change impacts [3], pandemics and poverty [9]. As recent years indicated, the costs of L&D are much higher in industrialized countries than in the Global South with often highly precarious shelters and assets. Multinational insurance companies have therefore asked for governmental support to deal with the rising indemnification demands in the industrialized countries to cover the insured proprieties [6].

As the systemic PEISOR model indicated, societal outcomes and policy responses are still not fully understood and environmental effects of scarcity and pollution may create feedback unable to deal with the growing negative threats [43]. Increasing public insecurity [85], food scarcity [72], forced migration [61], refugees [82], and conflicts about natural resources [31] are destabilizing from inside and from outside vulnerable countries in the Global South. The fragility of governance [97] and preventive management of mitigation, adaptation, and resilience-building represent additional economic and societal risks [59], affecting especially women and girls [41].

Undoubtedly, hazards [98] and the COVID-19 pandemic have increased poverty in Mexico [10]. The loss of jobs and the lack of formal working conditions due to the lockdown were only recovered on October 2022. Women not only get the lowest salaries, and have the highest informal working conditions [99], but also suffered intrafamilial violence during confinement [16]. Lack of unemployment insurance has severely affected the lowest level of income and the high inflation in food items, including the basic food staple, the corn tortilla, is increasing malnutrition [10]. These precarious living conditions are forcing new wages of undocumented migrants to the USA [95], which will be raised during 2023, a Niño Year with more hurricanes expected. Further, more severe disasters and a fragmented DRM with a L&D policy are increasing poverty in the most vulnerable region and among the poorest social groups. A policy of prevention, adaptation, and resilience among exposed people, may reduce the impacts of multiple natural hazards, public insecurity, and the pandemic of COVID-19. All these processes have increased poverty, gender discrimination, and

domestic violence among women and girls. Precisely, women have cared for centuries about their families, the indigenous community, and the environment, granting people dignified conditions of life and the recovery of nature.

Forced migration processes in America and Europe represent compensation for the lack of support from industrialized countries for the missing mitigation of GHG [64]. Being responsible for 75% of their historical GHG emissions [96], industrialized countries are unwilling to pay the total L&D in the highly affected countries in the Global South [45]. Adaptation in the Global South frequently suffers from fragmented policies for integrated DRM. Mexico is an example of limited governmental management of mitigation, adaptation, and resilience-building, unable to reduce the socioenvironmental vulnerability of exposed people to more dangerous climate change impacts, pandemics, nutrition, and public insecurity [100]. Reactive behaviors after a calamity and some limited disaster support have increased on one side, the approval of the party in power (Moreno) but, on the other side, these policies could not protect people from new and unexpected catastrophes. An additional factor for social stress is the impact of the COVID-19 pandemic and the high number of deaths as a result of existing chronic diseases (strokes, diabetes mellitus, cancer) due to obesity [100], unprepared health facilities, and lack of medicaments and protective tools [101].

As analyzed before, the Global South is higher affected by climate disasters and has learned from five centuries of colonialism and exploitation to create bottom-up responses to deal with adversities, including climate disasters and pandemics. Their experimented models of 'living well' by the Aymaras [102], indigenous environmental protection [54], gift management [103], social collaboration [104], and women's care economy [25] offer a decentralized way to deal with the survival of affected people. These bottom-up efforts also include the protection of the biodiversity on Earth within complex and uncertain conditions of the future [80]. Women, girls, and indigenous [41] have promoted for centuries a care economy that has allowed them to survive colonialism, wars, and violence. CEPAL [27] claimed that female autonomy and equity would increase when their physical, economic, and decision-making autonomy is granted. By reinforcing their sexual and reproductive rights, their collective rights to a healthy environment, a life without violence, and economic, social, and cultural equality with political and civil equality are consolidated.

These integrated processes of empowerment not only recognize women as fully equal but open the way towards self-worth, enabling women and men to deal from the bottom-up with the growing complex socioenvironmental threats affecting humankind and nature. Precisely, the exploration of indigenous communities with gender equity and traditional knowledge opens ways for poor countries with limited governmental support to overcome the pressures and the impacts from both the human and the Earth system by granting both survivals.

The timeframe is getting shorter, due to the excess of GHG emissions from industrialized countries and their multinational enterprises during the last seventies years [96]. Therefore, examples from the Global South of the female care economy represent additional ways to the existing and often unfulfilled official policies to protect the highest biodiversity in their regions. It is not geoengineering [105] and other technical tools that will save Mother Earth but a care economy for humankind and nature, mitigation of GHG, and resilience-building in exposed regions and among vulnerable people that protect the beauty of our Mother Planet.

Author Contributions

Unique Author

Competing Interests

The author has declared that no competing interests exist.

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