

Climate Change in North America: Risks, Impacts, and Adaptation. A Reflection Based on the IPCC Report AR6 – 2022

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Abstract

The impacts of climate change are global in scope and unprecedented in scale, and the increasing frequency and severity of extreme events, from rising temperatures, droughts, extreme rainfall, and rising sea levels, have increased throughout North America. Without immediate action, adaptation to climate change will be more difficult and costly, particularly for the most vulnerable social groups and economic activities and ecosystems in the area. In this article we reflect on the evidence recently produced by the Working Group 2 of the IPCC - the UN Intergovernmental Panel on Climate Change - in relation to the North American region (Canada, USA, Mexico). The evaluation methods of the information used for the report on "Impacts, adaptation and Vulnerability" are based on impacts and adaptation assessments revised in the available literature on the topic. We also seek to highlight their economic and financial dimension for the North American region. In the future, it is necessary to delve into the impacts of climate change at the subnational level in the North American region and in Mexico.

JEL Classification: Q51, Q54, Q56.

Keywords: Climate Change, Global development, Adaptation, Risks, North America.

Cambio climático en América del Norte: riesgos, impactos y adaptación. Una reflexión basada en el Informe AR6 del IPCC – 2022

Resumen

Los efectos e impactos del cambio climático tienen un alcance mundial y una escala sin precedentes y la creciente frecuencia y severidad de los eventos extremos, desde el aumento de las temperaturas, las sequías, las precipitaciones extremas y el aumento del nivel del mar, han aumentado en toda América del Norte. Sin una acción inmediata, la adaptación al cambio climático será más difícil y costosa, particularmente para los grupos sociales y las actividades económicas y los ecosistemas más vulnerables de la zona. En este artículo reflexionamos sobre la evidencia recientemente producida por el Grupo de trabajo 2 del IPCC - el Panel Intergubernamental para el Cambio Climático de la ONU - en relación con la región de América del Norte (Canadá, EE. UU., México). Se emplean para el estudio, los métodos de evaluación de la información utilizada para el reporte sobre Impactos, adaptación y Vulnerabilidad y se analizan riesgos, impactos y medidas de adaptación, buscando resaltar su dimensión económica y financiera para la región de América del Norte. Es necesario en futuro, profundizar sobre los impactos del cambio climático a nivel subnacional en la región de América del Norte y en particular en México.

Clasificación JEL: Q51, Q54, Q56.

Palabras clave: Cambio climático, Desarrollo global, Adaptación, Riesgos, América del Norte.

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1. Introduction

United Nations considers climate change one of the biggest challenges to humankind in the 21st century (IPCC, 2022). The slow pace limiting greenhouse gases emissions (GHG) to maintain warming between 1.5oC or 2oC considered by the United Nations Framework Convention for Climate Change (UNFCCC) as essential to reduce the risk of extreme climatic impacts is a relevant indicator. There is also growing evidence of observed climate change impacts that stresses the urgent need to create ambitious mitigation and adaptation responses to climate change at the national and subnational level throughout the world. The repeated call for action from United Nations is now strongly supported by the recent publication of the International Panel on Climate Change (IPCC).

This article addresses some of the implications of climate change in North America and its economic dimension. The first part of the paper summarizes key messages of IPCC Sixth Assessment Reports. The second part presents selected data and information of North America as a context for the paper. The third part addresses scientific background of climate change in this region. The fourth one considers the challenge of climate change for economic growth in North America, and the last part. The fifth part briefly discusses financial options for mitigation and adaptation. The last part of the paper presents our conclusions. We use one of IPCC's key messages, there is a small window of opportunity (10 years) to strengthen and enhance adaptation responses to climate change to guide the discussion in the paper.

2. IPCC Contribution

We begin this article with key messages of IPCC Sixth Assessment report of its three working groups that help set the context for the messages we want to communicate about the implications of climate change in North America³. The reports of IPCC working groups I, II, and III represent the most comprehensive scientific assessment of the state of climate change undertaken by hundreds of scientists from all regions working on voluntary basis during almost four years. Working Group I focused on the physical basis of climate change, Working Group II on impacts, vulnerability and adaptation, and Working Group III on mitigation.

The following key messages emerging from the IPCC Sixth Assessment Reports are essential to be included in the way societies manage growth in coming decades. Working Group I (WGI) stresses the following messages: global warming is occurring faster than anticipated in recent years and it is a phenomenon without precedents in the last 2000 years; every increase in global warming will cause more changes in the mean temperature, precipitation, and soil humidity in regions of the world and every ton of CO₂ emissions increases global warming; extreme events (heat waves, drought, extreme precipitation, hurricanes, etc.) have increased since the 1950s and they are projected to continue to increase according to the level of future warming; compound extreme events (i.e. drought and heatwaves) have also increased in recent decades. IPCC WGI final message is that unless there

³ Working Group I report was published in August 2021, Working Group II in February 2022, and Working Group III in April 2022.

are rapid and extended reduction of GHG emissions, it will not be possible to keep global warming under the threshold established by the UN (1.5oC to 2.oC by the end of the century).

IPCC Working Group III (WGIII) provides detailed information how far the reduction of GHG emissions should be. To limit global warming at 1.5oC in 2100, carbon use should be cut 90 %, oil 60% and natural gas 45% by 2050. To achieve a warming level of 2oC by the same date will require cutting carbon use 80%, oil 30% and natural gas 20% also by 2050. IPCC emphasizes the technology to achieve these changes is available for key sectors (energy and its demand, transport, cities and other human settlements, industry, trade and services, land use, etc.), together with the technology needed to remove carbon from the atmosphere to reduce GHG emissions (reforestation, carbon sinks, etc.). The report highlights a significant decline in the cost and a important increase in the use of renewal energy during the last decade. However, one the key messages in WG III report is that GHG emissions should begin to decline in 2025 to limit global warming between 1.5oC and 2oC. Unfortunately, IPCC also reports that GHG emissions have continued to grow, and they achieved an historical level between 2010 a 2019. (IPCC, 2022a) Changes needed to reduce the use of fossil fuels are needed in every sector of human activity (production and consumption patterns, lifestyles, land use, urban function, and form, etc.). These changes need to be deep and immediate but given the challenge to implement them it is essential to consider climate change impacts on ecosystems, biodiversity, and societies. (Sánchez – Lucatello, 2022)

IPCC Working Group II (WGII) report assesses these impacts, societies and ecosystems vulnerability to them, and action taken so far to adapt. One of the key messages in this report is that scientific evidence is inequivalve, climate change is a threat to human wellbeing and planetary health. Global warming has already caused extensive and dangerous alteration to nature and affected the life of millions of people in all regions of the planet. Observed impacts and projected risks on ecosystems and biodiversity indicate the support they provide to main human life and the economy in the planet is at risk. The growing number of climate related disasters in all regions are also an indicator of the threat to human life, the economy, and our lifestyles. (IPCC, 2022) IPCC estimates that between 3.3 and 3.6 billion people live currently in regions and places with high vulnerability to climate change. IPCC reports advances in adaptation actions to climate change. The report includes a comprehensive data base of adaptation up to 2021. Despite progress made so far in adaptation efforts, IPCC clearly highlights actions are not as comprehensive as needed, particularly in the most vulnerable regions where most developing countries are located. Additional problems with observed adaptation are actions that are short-term oriented in specific sectors and without considering middle-term and long-tern needs; there is a growing gap between adaptation planned and adaptation implemented; there is little monitoring and evaluation of adaptation actions implemented. An additional problem with adaptation is that further delays implementing adaptation will reduce options available and it will increment their cost, particularly at higher global warming levels observed up to now. IPCC considers there is a small window of opportunity (approximately 10 years) to strengthen and enhance responses to climate change both mitigation and adaptation.

WGII highlights Climate Resilience Development (CRD) as an operational concept that combines adaptation and mitigation actions to enhance opportunities for sustainable development in the short-term and long-term. Combining adaptation and mitigation simultaneously reduces conflicts and enhances synergies among them. IPCC recognize there are multiple trajectories for CRD according to national and local context. A further contribution of IPCC WGII report is stressing the

role of inclusive governance, strengthening institutions, access to funding, and climate justice as essential elements in CRD.

3. North America: impacts, risks, and vulnerability

North America is a geographical region that stretches from the extreme areas of the Arctic in northern Canada and Alaska all the way down to Mexico and the nations of Central America and the Caribbean Islands (Nat-Geo, 2022). Geographers, policy makers, economists, and a wide array of academic disciplines and scholars have been discussing the historical making of the region by using cultural, natural, physical, political - among others - boundaries to define North America as such. Typically, is divided into two distinct worlds based on variations in physical and cultural geography: both the United States and Canada have a common physical topography and a shared development history that is either influenced by British or French colonial history. More tropical climates predominate in Mexico and Central America, which were primarily colonized by the Spanish. The Caribbean is usually considered a world apart though its connections and relations with the US, Canada and Mexico are deeply rooted. More than 18% of the world's landmass is made up of the United States, Canada and Mexico. Their eastern border is formed by the Atlantic Ocean, while their western border is made by the Pacific Ocean. The Arctic Ocean is to the north. About 80% of people reside in cities in the North American region, but other large areas, particularly in Canada, remain sparsely populated. The majority of North America's diversified population is made up of immigrants or the offspring of immigrants from other world regions, however some natives are still there. The region is home to almost 515 million people, and it contributes to one third of the global GHG emissions. (WB, 2022).

In climate terms, the region encompasses diverse climate zones and weather. Cold in the winter and warm in the summer, with moderate to severe precipitations, North America embraces every climatic zone, from tropical rain forest and savanna on the lowlands of Central America to areas of permanent ice cap in central Greenland. Subarctic and tundra climates prevail in Canada and Alaska while desert and semiarid conditions are found in interior regions. (Rumney, 2006)

Over the past decades, the region has been suffering, likewise many other world regions, the impacts of climate change. The region will not only receive impacts from climate change but is having a large impact on climate change too. The region has produced a greater share of greenhouse gas emissions over time than any other continent and this is due mostly to the contribution of the US, historically the world's largest single emitter of human-released greenhouse gases and now the second-largest emitter after China. Climate change is already being observed in North America, including shifted rainfall patterns and dramatic warming in the Arctic. (IPCC, 2022, Ch. 14).

4. Scientific Background on climate change in North America

In North America, numerous impacts of climate change have already been seen. From 1955 through at least 2005, the average air temperature rose, with Alaska, northwest Canada, and the interior of the continent seeing the highest warming. Since 1950, the growing season has gotten longer in Canada and the US by around two days every decade, largely because of earlier springs. Mexico has warmed up since the 1960s and researchers anticipate further temperature increases. Northern Mexico could experience an increase in average annual temperatures of 3 to 4 degrees Celsius (about 5.4 to 7.2 Fahrenheit) by the end of this century. Average temperatures in the country could rise by 1.5 to 2.5 degrees Celsius (INECC, 2018). The effects of climate change in North America are evident: sea level rise, longer and more intense wildfire seasons, and disastrous droughts are among effects that climate scientists have noticed. Both natural and human-related factors, including the release of gases and fine particles (aerosols), have contributed to this warming. However, it is important to mention that there are uncertainties in determining “exactly how climate change will affect North America and different world regions. Although scientists are starting to project regional climate impacts, their level of confidence is less than for global climate projections. In general, temperature is easier to predict than changes such as rainfall, storm patterns, and ecosystem impacts. It is very likely that increasing global temperatures will lead to higher maximum temperatures and fewer cold days over most land areas. (IPCC, 2021). In general terms and according to the recent IPCC report (AR6), the region has been experiencing increased frequency and intensity of climate change, affecting millions of people from every area and industry. Climate change risks are becoming more serious and dangers to the health of populations in are dependent of human interferences. Addressing these issues has become more important as delays brought on by inaccurate knowledge regarding climate science and political impasse has led to confusion and made it difficult to recognize the compounding risks associated to the region. Key hazards to North America without limiting warming to 1.5°C towards the middle of the century are anticipated to accelerate. These hazards will cause permanent modifications to ecosystems, increasing housing and infrastructure damage, stress on economic sectors, disturbance of livelihoods, and issues regarding pleasure, safety, and physical and mental health. The report noted that North America has seen severe damage to local economies, ecosystems, and social systems from recent extreme weather, including floods, storms, droughts, heat waves, and wildfires. Extreme weather events are happening with major frequency. Indigenous people, urban areas will remain more vulnerable than others to climate-change impacts. At the same time coastal development and precipitations due to increase storms and hurricanes will interact with climate change impacts to stress coastal communities and habitats. Storm impacts are likely to be more severe, thanks to rising sea levels, along the Atlantic and Gulf coasts. Settlement continues to accelerate along coasts, increasing the monetary value of the property at risk. Major changes are also occurring in the ecosystems and vegetations of the region and strong impacts are expected to occur in Western US, North and Southeast of Mexico, and the Artic Canada. (IPCC, 2022)

Concerning Mexico, the country is deeply affected by the impacts of climate change. Not only because of its geographical position located in the tropical strip of the planet where the most extreme events are recorded, but also because it suffers from socioeconomic conditions such as poverty and inequalities that make the country extremely vulnerable to the effects of climate. The scientific evidence produced by different national studies in recent years, indicates that in the last half century,

the average temperatures in Mexico have increased approximately 0.85°C above the registered climatological normal. The minimum and maximum temperatures show a tendency towards an increase in warm nights and a decrease in cold nights throughout the country. Between 2015 and 2039, the average annual temperature in the country is expected to have increased by 1.5°C and 2°C in the north of the territory. There are also several economic studies on the costs of climate change in Mexico and that could affect the growth of the national GDP per capita by around 7% to 12%. (IMF, 2021)

The latest IPCC report and its chapter on North America also consider vulnerability to the impacts of climate change and its consequences for the well-being of ecosystems, biodiversity, and society. Extreme events in Mexico have also increased in the form of tropical storms, hurricanes, fires and heat waves at different times of the year with much greater frequency and intensity than in the past. The increase in the intensity of tropical cyclones can affect 60% of the national territory and these extreme hydrometeorological phenomena create torrential rains, floods, and landslides with serious effects on populations in rural and urban areas. Regarding agriculture and food security, there are severe impacts: as a result of changes in both temperature and precipitation, low yields are expected in crops such as: corn, sugar cane, sorghum, wheat, rice, soybeans (5- 20% next decades and 80% by the end of the century). At the end of the century, states such as Jalisco, the State of Mexico, Nayarit, Morelos, Michoacán, Guerrero and Colima could lose between 30 and 40% of their seasonal corn production yields (IPCC, 2022 Ch14).

In the following section we provide an overview of the major climate hazards that can affect the North American region. The issue of rising sea levels is also highlighted as an alarming phenomenon and in the face of the challenge of adaptation, with increases throughout the world, especially in tropical areas. The three countries of North America can suffer severe floods and its average level can rise between 20, 40 or even 60 centimeters depending on the projections and the models used (IPCC, 2022 Ch. 14). In relation to the increase in the concentration of carbon dioxide in the atmosphere, this has caused the acidification of the oceans, especially on the Pacific coast, where a decrease in pH of 0.5 has been observed, which can have serious consequences on the rates of calcification and growth of corals, as well as in the generation of sargassum and other marine pests that can affect tourism and coastal urban areas.

4.1 Extreme events

An important issue concerning climate impacts in North America is the question of recent extreme occurrences in the region. There is mounting scientific evidence that climate change is already making extreme events in North America more intense and frequent, and they pose significant threats to future climate change adaptation agendas for the three countries. People, communities, and ecosystems are all directly impacted by torrential rain and other extreme weather conditions. At the same time, droughts, floods, or wildfires are a few examples of how certain kind of extreme weather events can affect the region. Here an overview of the major extremes that are affecting the region.

Storms:

Storms are the primary cause of weather-related losses, accounting for 805 billion US dollars in total losses since 1980 and, thanks to strong insurance penetration, 454 billion US dollars in insured losses. The significant hurricane years of Katrina, Rita, and Wilma happened in 2005, Sandy in 2012, Harvey and Mary in 2017, and the record year for thunderstorm-related losses, occurred in 2011 and 2016. (Smith-Katz, 2016)

Tropical storms

Nearly the whole East and Gulf Coasts of North America are susceptible to the effects of tropical cyclones, particularly if they intensify into hurricanes that combines increasing storm surge and high wind risk. The concentration of people and assets along the shore, coupled with high and likely increasing vulnerability, is a major loss driver. Adaptation to these impacts is essential given that it entails a significant risk of negative impact on key economic infrastructure, sectors, and social wellbeing and security, including a growing number of fatalities.

Thunderstorms

Thunderstorms represent the most significant severe weather danger for the region. Severe thunderstorms were responsible for 43% (or US\$ 180 billion) of insured property windstorm damages between 1980 and 2011 only in the US. Over the past 40 years, losses brought on by thunderstorms have increased (Munich Re, 2012). As pointed in the WG2 IPCC report, urban sprawl exposes higher destructible values to the forces of thunderstorms, which is one contributing reason (IPCC, 2022 Ch. 6). Parallel to this, IPCC report gives compelling evidence that the visible effects of changing climatic conditions are occurring.

Droughts and heat waves

The total losses from severe weather events increased by 15% (US\$ 160 billion), with heat waves, droughts, and wildfires accounting for more than half of this. Extremely dry and hot weather will occur more frequently because of climate change. Droughts and heat waves have a high potential for loss since they influence every sector, from agriculture to individual houses, infrastructure, and electricity supplies over a wide area, yet their effects are only gradually noticed. Long dry spells also contribute to optimum circumstances that encourage the start and spread of wildfires. In recent years, new high-temperature records have been set. 2012, with a mean temperature 3.8°F (2.1°C) above the norm for the 20th century, has been the warmest year in the US thus far (including September) since the start of weather records in 1895. The 2012 drought, one of the worst occurrences in the previous 50 to 100 years, had an impact on about two thirds of the area that was under cultivation. Diverse studies stress the West part of the U.S. and Northern Mexico will suffer longer and more intense droughts together with extreme temperature in coming decades putting significant stress on ecosystems, the economy, social wellbeing, and water resources. IPCC (2020 Ch. 4) identifies this part of North America as one of the regions in the world with significant water stress that will aggravate by 2050. As climate change intensifies, crop insurance will become even more important but not sufficient. Changes in crops and agricultural practices are needed to adapt to new growing conditions in several part of North America (Novoselov, 2022). New model of sustainable water management are also needed.

By reducing snow and ice cover and increasing extreme weather, climate change threatens North American aquatic ecology, water quality, water availability for human uses, and flood exposure. Adaptation will be difficult if water supplies in North America are still being impacted by ongoing effects of global warming, led by a decline in snow and ice, as well as decreased precipitations. (Fleming and Dahlke; 2014).

5. The Challenge of Climate Change for Economic Growth in North America.

In this section we focus on the challenges of observed climate change impacts and projected risks to maintain and improve economic growth and open opportunities for sustainable development in the North American region. Our attention is centered in key sectors highlighted in IPCC reports: energy, industry, food system, health, and key infrastructure and cities.. These sectors are interrelated and positive or negative outcomes in one of them will impact others.

a) Energy.

Observed climate impacts (i.e., heatwaves, drought, storms, extreme precipitation) illustrate current vulnerability of energy facilities in several parts of North America. Particularly in the case of extreme compound events. Heat waves and extreme temperature have impacted electricity facilities in almost all subregions of North America. In the case of hydro-electric power, drought is major hazard, particularly in the case of compound events (heat waves and drought) has already significantly affected the snowpack and melting patterns in the West part of the U.S. creating water stress and limiting hydroelectric power generation. ⁴ Water shortages can also affect cooling systems of thermoelectric plants in the West part of the U.S. and Northern Mexico.

Projected impacts of extremes events will affect North America regions both in energy infrastructures as well as consumption. For example, the economic impact of climate change risks on power systems in the U.S. is estimated to reach \$50 billion by 2050 (Jaglom et al., 2014). Disruptions to oil and gas operations in the Southeast, Southern Great Plains, Alaska and Northern Mexico will be felt by increasing and frequent storms, hurricanes, and greater temperatures. Increasing demand for electricity, especially in hotter areas, will drive new demand for energy. Past experiences show that heatwaves have increased spot market prices affecting disproportionately the most vulnerable social groups (Cronin et al., 2018). Damage to electricity distribution is expected to growth in areas projected to experience more ice or freezing rain (Canada) or wildfires (Western U.S. and Mexico) (Ohba and Sugimoto, 2020); windstorm frequency and intensity associated with tropical storms (U.S. and Mexico) (Tyusove et al., 2017). Electricity outages can have significant consequences in economic

⁴ Binational watersheds like the Colorado is a good example. Water level in Hoover dam have declined to critical levels after 22 years of continue drought in this watershed threatening the capacity to generate electricity (ref).

sectors and critical services (hospitals, water systems, transportation, etc.)⁵. Water shortages can affect hydro-electric and thermoelectric plants (cooling system).

The performance of renewable energy can also be affected by changes in climate. Higher temperatures improve the efficiency of solar heating but decreases the efficiency of photovoltaic panels (Patt et al., 2013; IPCC, 2022 Ch.6).

b) Industry.

Productivity and investment effects are two of the primary ways that climate change may impact GDP in the short and long terms in the region. Long-term economic growth is heavily influenced by productivity because as it rises, countries can produce more products and services with the same number of resources, which in turn tends to raise well-being and income. Insofar as it adds to the domestic capital stock, which is directly tied to the economy's overall productive potential, business investment also influences long-term growth. Literature used in IPCC assessment document that global warming has a detrimental effect on corporate investment and productivity since higher temperatures and heat waves cause workers to produce less overall (IPCC, 2019). In a situation where physical capital is frequently destroyed or damaged due to extreme climatic occurrences, a decline in efficiency and production could make businesses less motivated to invest, making additional investment undesirable (CRS, 2022). Due to its link to long-term economic growth, the impact of climate change on investments is of special importance. Over short time periods, business investment may vary dramatically as a result of catastrophic weather occurrences: this concern is justified by the idea that if climate change results in decreases in output, income, and productivity, it will reduce businesses' incentives to invest, hence lowering the investment rate.

Other economic activity vulnerable to climate change is Tourism. Attention has been centered on the impact of climate change on ski resorts in Canada and the U.S. (Steiger et al., 2019; IPCC, 2022 Ch. 14). The economic impact of climate change on these resorts is mostly significant at the local. The importance of tourism for Mexico is significantly different. It is one of the country's major economic activities and an important driver of regional and development in several parts of the country. A recent study analyzes the vulnerability of tourism to climate change in countries (Scott et al., 2019). The study shows Canada and the United States are among countries with low vulnerability, but Mexico was the largest tourism economy in the high vulnerable group of countries. Mexico was ranked sixth largest destination country (arrivals) by the United Nations World Tourism Organization (UNWTO, 2018). A final aspect we would like to mention is a recent study using a large dimensional intertemporal CGE trade model to account for the various effects of global warming (e.g., loss in agricultural productivity, sea level rise, health effects) on Gross Domestic Product growth for 139 countries by decade and over the long run (Kompas, et al., 2018). Its results show significant differences among Canada, the United States and Mexico, particularly on the long run. Canada would experience minor negative effects on GDP percentage change per year (-0.218), the U.S. a higher effect (-0.622) and Mexico (2.277) in the long run. Climate change has and it will continue to have significant differentiated impact in North America. In general terms, impacts are expected to increase for the frequency and intensity of extreme weather, both in the U.S., Canada and Mexico and they

⁵ For example, in December 2017, Atlanta's International Airport was shut down for nearly 11 hours due to a catastrophic power outage, which caused the cancellation of 1,400 flights.

will damage factories, supply chain operations and other infrastructure, and disrupt transport. (IPCC, 2022 Ch. 14).

c) Health.

Climate change extensive consequences of climate change are on health. IPCC (2022 Ch.7) assesses a wide range of climate-sensitive diseases: cardiovascular; respiratory tract infections; non-communicable respiratory illness, vector-borne (mosquito, rodent, and tick), waterborne, and food-borne; mental health. All of them are relevant in North America. However, our research found no comprehensive assessment of the health implications of climate change at the national and subnational level in the three countries despite the cascading effect of the health implications of climate change and the economic and social consequences. IPCC assesses that financial support for health adaptation is currently less than 0.5% of overall dispersed multilateral climate finance projects and considers it insufficient to protect human health and health systems from most climate-sensitive health risks (IPCC, 2022 Ch. 6 and 7).

A recent study on the health consequences of climate change in Canada estimates the emergence of infectious diseases northward spread from the U.S. or introduced from other parts of the world via air or sea transport. These include emergence of tick-borne diseases in addition to Lyme disease, the possible introduction of mosquito-borne diseases (dengue, West Nile virus), and increased incidence of foodborne illnesses (Odgen and Gachon, 2019). A recent analysis of policy action on public health in the context of climate change in the U.S. found that the public health response to climate change has been promising in the area of assessment, mixed in the area of policy development, and relative weak in communication, workforce development and evaluation (Fox et al., 2019). A study on the health consequences of climate change on children in Mexico considers the implications of changes in temperature and precipitation on water-borne diseases and acute respiratory tract infections, nutritional issues, dengue, and asthma (Riojas et al., 2018). Mexico's vulnerability to climate change deserves broader attention to the health dimension.

IPCC provided broader attention to the mental health implications of climate change in this assessment cycle. Much of the research in this research area has been carried out in the U.S. and the U.K. but it has received little attention in Mexico. IPCC considers pathways through which climatic events affect mental health are varied, complex and interconnected with other non-climatic influences that create vulnerability (IPCC, 2022 Ch. 7). Climatic exposure may be direct (extreme event i.e., heatwaves or hurricane) or indirect (i.e., malnutrition, anxiety about climate change). Some of the studies so far show an observable association between high temperatures and mental health decrements, extreme events (heatwaves, wildfires, drought, hurricanes⁶) have significant consequences for mental health, and mental health can also emerge as result of climate impacts on economic, social, and food systems (Ciaconi et al, 2020; IPCC, 2022 Ch. 7). A study on the effect of higher temperatures on suicide rate in the U.S. and Mexico found that suicide rates rise 0.7% in U.S. counties and 2.1% in Mexican municipalities for a 1oC increase in monthly average temperature

⁶ Approximately, 20-30% of those who live through an hurricane develop depression or post traumatic-stress disorder (Obradovich et al., 2018).

(Burke et al., 2018). The study projects that unmitigated climate change (RCP8.5) could result in a combined 9-40 thousand additional suicides across the United States and Mexico by 2050.

d) Food production.

Crop-based agriculture in North America is highly dependent on climate conditions, and climate change is projected to have a large impact on the agriculture industry. The frequency of some catastrophic climate change-related occurrences, such as droughts or floods, can dramatically reduce crop yields and alter crop growth, resulting in lower crop production overall. If other environmental conditions required for crop growth are met, it is predicted that a warming temperature and rising carbon dioxide levels in some places will boost yields of some crops in some locations but decrease them for other crops. The overall impact in North America is also conditioned by locations: crops may no longer produce acceptable yields in certain regions. Climate change may also have a harmful influence on fisheries and livestock. Heat waves, droughts, and rising temperatures can all have an impact on the wellbeing and viability of livestock. Fish and aquatic ecosystems could be negatively impacted by changes in water temperature and acidification brought on by rising atmospheric carbon dioxide. In fact, the climate has a significant influence on both agriculture and fishing. In some regions of North America, mostly coastal areas, rising temperatures, and carbon dioxide (CO₂) levels can affect crop yields. The availability of water, soil moisture, nutritional levels, and other factors must also be satisfied to reap these benefits. Food safety may be at risk because of changes in the frequency and severity of floods and droughts, which could present difficulties for ranchers and farmers. The natural habitat of many fish and shellfish species are projected to change as a result of increased water temperatures, which could disturb ecosystems. Overall, climate change may make it more challenging to cultivate crops, raise livestock, and catch fish in the same locations and ways as in the past. Along with other changing elements that influence agricultural production, such as changes in farming practices and technology, the consequences of climate change must also be taken into account. (EPA, 2018).

e) Key infrastructure and cities.

Infrastructure is vital to economic health and social wellbeing. Infrastructure services including water, sewage, roads and railroads, ports and airports, telecommunications supply societies with a wide range of products and essential services. Evidence of the importance of extreme climate events on infrastructure is clear in all regions of the world. Some studies estimate losses of \$4.2 trillion of projected climate change impacts on infrastructure under a 2oC scenario of global warming and \$13.8 trillion for a 6oC scenario globally in 2100 (The Economist Intelligence Unit, 2015; IPCC, 2022 Ch.6). These losses can be associated to disruption, repair or complete loss of infrastructure and they can cause significant consequences on the economy, social wellbeing, and people's health and safety. Data available for North America indicates that total annual damages from temperature- and precipitation- related damages to paved roads in the U.S. are estimated at up to \$20 billion under RCP8.5 in 2090; inland flooding threatens approximately 4,600 bridges across the U.S., also under RCP8.5, and it is anticipated to create annual average damages of \$1.2 to \$1.4 billion each year by 2050 (Newman et al., 2015). In the case of Mexico, the impact of climate change on its road infrastructure is projected to require additional national expenditure on road maintenance between \$1.5 and \$5 billion by 2050 (Espinet et al., 2016). Climate risks to transport infrastructure (heat and

cold waves, droughts, wildfires, river and coastal floods, windstorms), can disrupt global supply chains (Becker et al., 2018). The risk that climate change poses to infrastructure could alter the incentives for both private and public infrastructure investment, as well as the types of infrastructure that should be funded (ref).

Cities have a key role in addressing climate change. Global urbanization offers a critical opportunity to expand and improve mitigation and adaptation responses to climate change. How cities are constructed, and function define patterns of GHG emissions and vulnerability. On one side, IPCC WGIII estimates that total urban emissions based on consumption-based accounting were 67-72% of global emissions and considers diverse sources of these emissions and the potential to reduce them in cities (IPCC, 2022a). On the other side, IPCC WGII analysis the broad array of climate change observed impacts and projected risks on cities, the driving sources of their vulnerability, and a comprehensive analysis of actions taken to adapt to them. It is estimated that \$90 trillion will be invested in new urban development by 2030 (IPCC, 2022 Ch.6). This investment has long lasting implications given the long lifespan of urban structures and a significant risk of locking in future GHG emissions and vulnerabilities if current patterns of urbanization continue to neglect its climate change implications (mitigation and adaptation) (Ürge-Vorsatz et al., 2018). Population and the economy in North America are concentrated in urban areas. Some of the major cities in the world are in this region but also significant number of small and medium size growing cities, particularly in Mexico. A number of these cities are vulnerable to climate change. Evidence of the consequences of climate related disasters in cities of North America is extensive. For example, the direct economic costs of all extreme events reached 210-268 billion USD in 2020 (Smith, 2021). Just Hurricane Sandy had over \$60 billion in reported economic damage in New York and the East coast in 2012 and a recent study estimates that approximately \$8.1 billion of those damages are attributable to climate-mediated anthropogenic sea level rise (Rosenzweig and Solecki, 2014; Strass et al., 2021).

Several cities in North America have adaptation plans, but many of them are still to be implemented (Heikkinen et al. 2019; IPCC, 2022 Ch.6). A second important point is the still large number of small and middle size cities without adaptation plans, particularly in Mexico. A third aspect is the gap between financial support invested and needed. There is no specific data available for North America but IPCC reports that globally \$384 billion of climate finance has been invested in urban areas per year in recent years, but this remains at about 10% of financial resources needed for low-carbon and resilient urban development (IPCC, 2022 Ch. 6). Delaying actions for increasing the resilience of urban infrastructure to climate change from 2020 to 2030 is estimated to have a median cost of at least USD 1 trillion (Hallegatte et al. 2018).

A final topic to be considered is the issue of Sea Level Rise (SLR) in the region: in the past 20 years, flooding has increased on average by 233% only in the US, according to the National Oceanic and Atmospheric Administration (NOAA). Even though the sea level has increased by 20 cm. since 1950, only the previous 20 years account for roughly half of that (almost 8 cm.). In the United States, tidal flooding has increased by 233% on average as a result of this little sea level rise. From Texas to Florida to New York, to Tabasco in southern Mexico, sea level rise is posing serious issues. More water and worse flooding during hurricanes, high tides, and rainstorms result from higher sea level are also expected to increase and create compounding effects in the region (IPCC, 2022 Ch. 14).

6. Financing climate change for mitigation and adaptation in North America.

Significant developments and improvements are taking place in North America related to financial resources to deal with climate change, but with significant regional differences. After the US re-joined the Paris Agreement under the current Biden presidency, a new set of investments and financial solutions may become available, but they still face challenges in US Congress and recently in the Supreme Court. The importance of financial institutions in accomplishing climate change mitigation is also important for Mexico which is capturing the attention of environmental institutions and initiatives such as the creation of an Emission Trading System to promote the development of GHG mitigation schemes. In North America, banks, investors, and insurers frequently are discussing how to finance the transition to a low-carbon economy and reach the targets established by the Paris Agreement (Lucatello, 2021).

In this regard, key issues that climate change presents to regulators, supervisors, and central banks must be tackled. The rising understanding that climate change is a source of financial (and pricing) instability since it is likely to produce physical changes in the environment should be stressed. The responsibility for addressing climate change rests not only with central banks, regulators, and supervisors, who oversee and preserve financial stability, but also within the overall financial community. Overcoming climate tipping points might result in consequences that would be devastating and making it hard to calculate the financial losses. (Bis, 2022).

It is worth noting that financial sector interest in climate change is small and it is mainly concentrated on mitigation not adaptation. Global financing for climate-related activities remained a small part of development finance (over 7%) from 2010 to 2018. Only 33% of those funds were committed to adaptation and only about 1.6% of adaptation finance came from private sources⁷ (IPCC, 2022 Ch. 17). Global adaptation finance is almost equally supplied by bilateral and multilateral sources, but these values vary regionally. The United Nation Environment Program estimates the cost of adaptation will reach \$140-300 billion per year and by 2050, \$280-500 billion (UNEP, 2016). Multilateral development banks (MDBs) collectively committed \$61.5 in climate finance in 2019, 76% for mitigation and 24% for adaptation and the largest flows went to energy, transport, built environment infrastructure including water and wastewater (ADB, 2018). Public sources of adaptation finance are relatively small and cannot bridge the investment gap. Only a small minority of international public adaptation finance is delivered as grants, while the majority is delivered as loans by MDBs (IPCC, 2022 Ch. 17).

⁷ 70 percent of private sector adaptation investment was concentrated on water and wastewater projects. Most private adaptation investments were in high-income countries (IPCC, 2022 Ch. 17).

7. Conclusions

It is difficult to finish this paper on a positive note. IPCC's assessment clearly states that North America is experiencing more frequent and severe climate impacts. The article summarizes some of the relevant implications for the economy, social wellbeing, and ecosystems in the region. Our assessment of the IPCC report suggests that system transformation to adapt to climate change are advancing slowly and unevenly in the region. Climate change implications for the regional economy and social wellbeing in North America deserves and requires a broader discussion, recognizing there are significant regional differences among and within the three countries. Development levels, technical, financial, and human resources available, and institutional strength create different options, capacities to respond to climate change in Canada, the USA, and Mexico. IPCC highlights that key economic sectors, financial markets, government budgets, and household welfare are unevenly affected by climate impacts in North America (IPCC, 2022 Ch. 14). High exposure or sensitivity to climate impacts in economic sectors mentioned above have experienced larger losses and adaptation costs. IPCC assesses with high confidence that extreme events have damaged economically important supply-chain infrastructure and disrupted regional and international trade, increased public expenditures on emergency and recovery response, and affected property and financial market (IPCC, 2022 Ch. 14).

We would like to come back to the introduction of this paper and recall the importance of United Nations call for immediate action to respond to climate change. The paper leaves no doubt this is an essential step in North America. Unfortunately, immediate, and comprehensive adaptation actions in the region faces significant challenges. National administrations have had different approaches to climate change due to domestic circumstances, political constraints, and ideological positions. It is also important to recognize that adaptation has received less attention than mitigation in national responses to climate change, particularly in the U.S. and Mexico. National political support to expand and improve adaptation actions is essential but it is currently difficult to envision a significant change in the short-term. Adaptation actions at the subnational level face also challenges. While Canada has a more balanced approach, subnational actions in the US are contrasting, from states and cities very engaged and advanced in planning and implementing adaptation to others where no action has been taken also due to political and ideological positions. For instance, a recent survey on local adaptation to climate change of 231 cities in the U.S. reported weak leadership, lack of funding and staffing, and low political will (Fu, 2020).

Mexico is an interesting case. Climate change policy at the national and subnational level has had ups and downs in recent administrations. A National Climate Change legislation and Strategy have been in place since 2012, institutions have been created, and most states in the country have a climate change legislation and a State Climate Change Action Program. A recent independent evaluation of the national and subnational climate change policies identified they have had limited achievements in adaptation. The gap between adaptation planning and implementation is particularly evident in the local States and the very small number of municipal climate change action programs. The urgency to adapt to climate change has gone unattended despite the increasing cost of observed impacts and projected risks discussed in the paper.

We conclude this paper highlighting societies currently face a critical moment in North America. Despite declining yields in economic activities, aggravating conditions in social wellbeing, and increasing degradation of ecosystem caused by climate change, attention to adaptation continue to be limited, short-term focused, fragmented or even inexistent in many cases. Scientific evidence seems to have had limited impact in decision making by significant parts of the public, private and social sector. Recent studies suggest that high risk perception is in itself insufficient to motivate people to undertake adaptation (Roder et al., 2019; Gibbs, 2020) and highlights the importance of strong institutions, financial resources, inclusive governance, and political leadership to support and expand local adaptation strategies.

One final point, IPCC stresses that current trends and increasing global warming will continue to limit options to adapt to climate change and increase their cost. We believe it is important to highlight those negative consequences of inaction because they are already high in the region, and they will continue to increase, particularly for the most vulnerable groups. Evidence shows early adaptation actions have significant economic benefits for societies. The World Bank found that every \$1 invested in resilient infrastructure in low- and middle-income countries yields \$4 in net benefits (Hallegatte et al., 2018). The Global Commission on Adaptation reached similar conclusions (GCA, 2019). It estimates that investing 1.8 trillion globally in 5 target areas (early warning systems, climate resilient infrastructure, improved dryland agriculture crop production, global mangrove protection, and making water resources more resilient) from 2020 to 2030 could produce \$7.1 trillion in total benefits. Spending \$800 million on early warning systems in developing countries could reduce climate-related disaster losses by \$3 to 16 billion per year. Responding to climate change will require significant behavioral changes in society, but a new approach to decision-making mainstreaming adaptation to climate change in development policies is an essential step.

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