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Vulnerability Assessment

and adaptation strategies of the triangle-city region

Avaliação de Vulnerabilidade
e estratégias de adaptação na região trinacional

Evaluación de la vulnerabilidad
y estrategias de adaptación en la región trinacional

Triangle-city cooperation

Building climate-resilient development in the Parana basin

CDKN Climate & Development Knowledge Network

futuro latinoamericano diálogo, capacidades y desarrollo sostenible

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The authors recognise the valuable contributions made by Andy Gouldson, Julián Baez, Genaro Coronel, Alberto Ramírez and Gary Dymski, who are part of the Triangle-City Cooperation project.

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This report should be cited in the following way:

Sakai, P.; Sakai, M.; Schneider, T.; Oberling, D. F.; Oreggioni, F.; López, L.; Franzini, A. C.; Aquino, C.; Tischner, A.; Caballero, N. and Penagos, J. (2017) Vulnerability Assessment and Adaptation Strategies of the Triangle-City Region, a report by the Climate Resilient Cities in Latin America initiative, Climate and Development Knowledge Network (CDKN) and Canada's International Development Research Centre (IDRC).

July 2017

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1. Executive summary

Cities represent essential actors in the combat against climate change. It is expected that the majority of people in the planet will live in cities by mid-century. In the case of South America, the UN (2016) expects that around 80% of its population will live in urban centres by 2050. Concurrently, cities are expected to increasingly face climate effects in the form of more intense and frequent extreme weather events, putting millions of people at risk, especially those that are more vulnerable. Regarding South America, existing studies have shown that the region is particularly exposed to extreme climate-related events and displays numerous vulnerabilities (e.g. poverty, economic and political instability, lack of resources and infrastructure, etc.). In this sense, it is vital for cities to undertake actions to reduce their vulnerability to climate change and build climate-resilient development.

The aim of this study is to assess the climate vulnerability of the so-called triangle-city region, comprised of three neighbouring cities located in three South American countries. The cities are Foz do Iguazu (Brazil), Puerto Iguazu (Argentina) and Ciudad del Este (Paraguay), which share borders at the confluence of the Parana and Iguazu rivers.

Apart from sharing the same geographical area and a common historical background, these cities also face similar challenges and have shared climate vulnerabilities. Consequently, city-to-city cooperation plays a crucial role in order to successfully address these challenges.

This assessment represents the first attempt to examine the vulnerability of the triangle-city region to climate-related events. Furthermore, this study constitutes a novel effort to analyse the concept of vulnerability as a shared phenomenon, placing a particular emphasis on city-to-city cooperation as a paramount element to successfully face the climate change challenge. This examination thus provides an initial understanding of the climate vulnerability of the region, offering valuable insights and highlighting gaps and areas of urgent attention. It also pretends to be a stepping stone for future research, as it reveals various issues that require a deeper exploration. The findings presented here are of interest to policy-makers, practitioners, academics, as well as individuals and organizations concerned about the climate resilience of the region and the well-being of its inhabitants.

This document reports the main findings derived from the study and its implications. It also provides a brief historical background of the region and describes the characteristics and socio-economic structure of the three cities. In addition, past climate trends are analysed, focusing on the main extreme weather events that have affected the region during the past decades. This examination is supplemented with a look at climate projections to determine the challenges that the region is likely to face in the future. Moreover, this document presents a scrutiny of the legal, policy and institutional settings in each city in relation to climate change adaptation. Regarding the vulnerability assessment, the report presents an Urban Vulnerability Index (UVI), which is a useful tool to compare the cities. Indices were constructed using different climate and socio-economic indicators to measure the various dimensions of vulnerability (sensitivity and coping/adaptive capacities). This empirical analysis was complemented with a view on the strategies that the cities have adopted to react and respond to impacts caused by extreme weather events in the short-term, as well as the plans that are being undertaken to face future impacts. The report also presents an overview of the level of cooperation between the three cities and presents a set of preliminary solutions proposed by a group of stakeholders.

This study involved the participation of numerous actors from the three cities, who were instrumental in providing valuable advice and information. Our Steering Committee was key in granting us access to data and sharing their knowledge and experiences. Without their participation and support, this study would not have been possible.

Background

Since the 1960’s, the triangle-city region has experienced rapid growth and continues to expand. Its population has increased more than 7 times, mainly attracted by the construction of the Binational Hydroelectric Plant of Itaipu (Brazil and Paraguay) and the touristic potential of the Iguassu Falls, considered as one of the natural wonders of the world. Furthermore, the development of Ciudad del Este as a low-tax commercial hub has attracted significant population flows into the region. This last city is expected to be among the ten fastest growing cities in Latin America by the year 2030, according to UN urbanisation prospects. Moreover, the region receives millions of tourists each year, seeking the local attractions.

Urban planning and investment in infrastructure have not been on par with population growth. Adequate urban planning has been absent, resulting in an uncontrolled urban sprawl. Irregular land occupation has led to the creation of slums, mainly along rivers and risk areas, which is an issue of concern given their high exposure to floods. The speed of investment in public and private infrastructure has not been enough, and the pressure is increased by the intense flow of tourists. Some basic city services, like sanitation (sewer and refuse), are not available to all the population. Investment in tourism infrastructure is also required to capitalise on the large flux of tourists, especially in Ciudad del Este. Moreover, high deforestation rates represent a threat to the region’s forests and biodiversity. Other problems related to the expansion of the cities include unemployment, illegal and clandestine practices, as well as issues involving traditional communities, such as violence and land appropriation.

Past climate trends

Historical trends suggest that climate patterns have changed in the triangle-city region during the last 5 decades. Results show that the annual amount of precipitation has increased over the years. Annual maximum daily precipitation and the number of extreme precipitation events showed an increase, indicating that heavy precipitation events are becoming more intense and frequent. Moreover, daily maximum and minimum temperatures also presented a positive trend throughout the years, indicating a warmer climate. Furthermore, it is important to highlight that as the cities are located in an area prone to severe convective weather, it is likely that tornados can affect the cities in the future.

Extreme water-related weather events have caused the largest impacts in the triangle-city region. Heavy rainfall and flooding have been the most common events affecting the cities. Two types of floods were detected: river floods, caused by an increase in river levels, and urban floods, due to intense precipitation. Past episodes of droughts have affected the tourism sector, as well as the water drinking supply in Ciudad del Este. Moreover, we found that hailstorm events follow a pattern of low frequency and high impact. The most recent hailstorm event occurred in September 2015, generating severe material losses.

The meteorological monitoring system in the triangle-city region requires to be enhanced, while definitions of extreme weather events should be unified. These aspects are essential to enhance our understanding of weather and climate in the region. For instance, the different countries in the triangle-city area define heat-wave and cold-wave events in a different manner. This heterogeneity complicates their analysis. Furthermore, it is necessary to increase the number of reliable weather stations. This study found inconsistencies in meteorological data collected in different weather stations, which complicated the analysis and limited the amount of reliable information.

Future climate projections

Mean temperature is expected to increase in the triangle-city region by the end of the 21st century. Studies conducted for South America and Paraguay, which use different global and regional climate models and scenarios, show an increase in temperature for all time-frames (near- to long-term) and seasons (spring, summer, autumn, winter). However, the magnitude of this increase depends mainly on the climate model used to produce those projections.

Changes in mean precipitation in the region are difficult to determine, given contradicting projections. Existing studies have produced conflicting evidence for this variable, resulting in a range of results that vary according to the scenario, term, and season that are selected in the modelling process. However, the analysis of past trends has revealed that extreme precipitation events have increased, and it is expected that these trends will continue.

Extreme weather events are expected to increase, especially those related to high temperatures. Heat waves could become more common in the future across the triangle-city region. Positive trends were found in the number of summer days, tropical nights, and warm nights (see Chapter 4 for definitions of these terms). However, statistically significant trends were only obtained in relation to maximum and minimum temperatures. If this phenomena is combined with potential increases in precipitation, the triangle-city region could expect the occurrence of more severe extreme weather events.

Policy, legal and institutional settings for climate change adaptation

Climate change adaptation initiatives are still very incipient at the municipal level. The three countries have started to develop their plans for climate change adaptation. Brazil and Paraguay released their National Adaptation Plans (NAPs) in 2016, while Argentina has its plan currently under development. However, these efforts have not trickled down to local governments yet. Even when the NAPs mention the requirement for municipalities to develop their local plans, no specific planning instruments or strategies for climate change adaptation were identified in any of the cities. This constitutes an important gap that requires to be urgently addressed.

The cities possess emergency protocols and contingency plans, but prevention, preparedness and recovery measures are deficient. The cities have designed a course of action to help them respond to an unforeseen event, although some of these plans were not available for consultation. Response mechanisms rely basically on the municipalities through different organisations, like the fire departments, with the support of other institutions. In Puerto Iguazú and Ciudad del Este the fire brigades are organized by volunteers, whereas in Foz do Iguaçu they are formed by the military. In terms of preparedness measures, the existing early warning systems are not designed to provide timely and accessible information directly to citizens. Evidence on strategies for prevention were scarce. In relation to recovery and reconstruction actions, there seems to be no proper plans in place. These also represent important gaps that are waiting to be addressed.

Guidelines for local adaptation and the existing emergency settings in the three cities present similarities, providing an opportunity for joint planning and

acting. The three countries have produced guidelines for local adaptation focusing on common aspects, such as territorial management, land use, sanitation and infrastructure, as well as the incorporation of climate change elements in all instances of urban management and development. Although formal climate change adaptation strategies are still inexistent, this represents a good opportunity for the three cities to develop joint initiatives and institutionalise city-to-city cooperation. There is evidence that willingness to cooperate already exists on this matter, as shown in this report, although it happens on an informal basis.

There are established agreements and protocols that institutionalize cooperation among the three cities and countries, but these are not applied in practice. The Mercosur protocol for cooperation and assistance to environmental emergencies, as well as the complementary adjustment to the agreement between Brazil and Argentina for civil defence cooperation in boundary localities, provide guidelines for the exchange of information and assistance among parties in the face of emergency events. However, such protocols seem to be unknown or not used by local actors, while cooperation occurs on an informal basis, through the collaboration of individuals and organisations. Nonetheless, there are efforts to institutionalise cooperative actions, like a proposed agreement among the fire departments of the three cities.

Socio-economic vulnerabilities

Foz do Iguaçu shows a lower level of vulnerability to extreme weather evens compared to Ciudad del Este and Puerto Iguazú. Foz has relatively more green areas (45% of the municipal area), lower poverty indicators (less population living in poverty and in slums), better access to water, waste treatment, and education, a lower mortality rate, a larger public budget and a more dynamic and diversified economy. Foz also has higher levels of preparedness and recovery. The results also indicate that its institutions, in general, enjoy good reputations, specifically for emergency management and for allowing citizen participation in government decisions. Foz has a better disposition to adopt good practices from other cities and cooperate with them, since it has adopted and applied similar policies from other cities.

Ciudad Del Este and Puerto Iguazú display larger vulnerabilities, compared to Foz do Iguaçu. They have proportionally more population susceptible to impacts related to extreme events and a lower capacity to recover from them. These cities are highly-urbanised without sufficient green spaces. Their lack of urban planning has led to the occupation of risk areas. The level of public services is insufficient in the areas of health, water and sanitation. They also show low levels of preparedness and response, having limited resources for recovery. In addition, the results indicate lower reputational levels among their institutions for emergency response, as well as poor governance for the participation of the population in local government. This constitutes a barrier to build effective adaptation strategies in these cities.

Ciudad del Este is more sensitive to extreme events, like heavy rains and heat waves. This city is highly urbanised and has a lower proportion of green areas per person. This increases the heat island effect, which has consequences on human health. Given that the city has a larger proportion of vulnerable population (below 14 years of age and above 65), the risk to be affected increases. Moreover, insufficient green spaces elevate the probability of flooding, since runoff increases and water infiltration is reduced.

The cities have different levels of development, reflected in the quality and coverage of basic public services. Ciudad del Este is the city that suffers the most from insufficient coverage of public services. A large part of its population does not have access to drinking water and sanitation. Energy supply problems were identified in Puerto Iguazú, while solid waste management was pinpointed as a serious issue in Ciudad del Este and Foz. Other problems that were detected are low levels of education and increasing levels of insecurity. In addition, it was found that road infrastructure requires urgent maintenance, along with an increase of transport services to communicate the three cities, especially between Puerto Iguazú and Ciudad del Este. For instance, a bridge and more ferries are required to connect these two cities.

The region offers a good business environment, but economic diversity in the region is low. The economy of Foz do Iguaçu is more diversified, but still relies heavily on tourism, which is sensitive to climate impacts. The same is true for Puerto

Iguazú, where tourism is one of the main activities. The agricultural sector in Ciudad del Este accounts for almost a third of its gross domestic product (GDP), being an activity that is also sensitive to changes in climate. Regarding the business sector, the results show that Ciudad del Este possesses a large number of firms, but the majority are small and medium enterprises (SMEs), which are generally the most vulnerable in the private sector. Further diversifying the economies of the three cities would contribute to reduce their vulnerability.

Despite its lower levels of vulnerability, Foz do Iguaçu still needs to improve its public policies for land use and spend more on infrastructure to address constant problems of flooding. Irregular occupation of areas along riverbanks puts deprived populations at serious risk. Furthermore, poor infrastructure in terms of water drainage systems leads to flooding of public roads, some of them on a constant basis. The municipality, however, has limited resources, which hampers its capacity to prepare, respond and recover from extreme weather events. So far, Civil Defence has identified 35 critical points across the city, and has acknowledged that in order to solve these problems a vast amount of investment will be needed.

Irregular settlements in high risk areas represents a serious governance challenge in the three cities. A key problem is the relocation of population living along riverbanks. However, this has proven to be a complicated issue, since people tend to return to the same areas after being relocated. This is due to various reasons, but mainly because the affected persons do not want to leave the central region of the city, considering that new housing provided by the municipality is generally far from the city centre, away from their workplace, schools, and commercial areas. Despite most resettlement efforts have been ineffective, a successful case was registered in Foz do Iguaçu, which deserves to be studied more attentively to identify any important lessons that can be applied to other cases.

Civil Defence is the first entity to respond to an emergency and disaster situation in the cities. Actors in the region, interviewed for this study, consider that this institution constitutes the foundation of the cities' capacity to respond to unforeseen events. It includes the fire brigades, which are the first to provide assistance to affected population. The Red Cross in Ciudad del Este equally plays a relevant role in aid delivery efforts. However, these institutions are often underfunded and lack training and special equipment for some types of emergencies and disasters.

Cooperation

City-to-city cooperation to respond against extreme weather impacts does exist, but mainly at an informal level. Customarily, extreme weathers events are faced by each city independently. However, there are strong links and communication between certain institutions, like the fire brigades of the three cities. Although there are no formal protocols for cooperation, people show willingness to cooperate and manifest solidarity mainly due to personal and professional affinities. There are several accounts of cases where the cities have helped each other to face threats, like fire and dengue outbreaks. Cooperation between the three cities still needs to be formalised, and this could help to reduce their vulnerabilities to extreme weather events.

Local development councils represent an excellent mechanism to build cooperation between the cities. CODESPI (Puerto Iguazú), CODEFOZ (Foz do Iguaçu), and CODELESTE (Ciudad del Este) seek to promote long-term sustainable development in each city, while aligning and integrating the interests of society within government actions in a democratic manner. These entities have been successful in promoting policies and implementing improvements that have benefited the cities. They have also tried to strengthen the links between the three urban centres, opening new ways of cooperation and finding efficient communication channels in the region.

Cooperation among the cities is not balanced. Foz do Iguaçu acts as a node, linking the three cities. On the one hand, the Friendship Bridge connects the city to Ciudad del Este, while the Fraternity Bridge (Tancredo Neves) links it with Puerto Iguazú. On the other hand, Ciudad del Este and Foz do Iguaçu are strongly related through Itaipu Binacional, a joint partnership between Paraguay and Brazil, providing energy and a source of income to both countries. In turn, Foz do Iguaçu and Puerto Iguazú are joined by the Iguassu Falls, another source of income for these two cities. In this sense, Foz do Iguaçu has strong links with both its neighbours. However, the relationship between Puerto Iguazú and Ciudad del Este is weaker. No bridge connects these cities and they are only communicated by ferries.

A certain level of coordination exists regarding the sharing of climate information. Civil Defence institutions play an important role in this regard. For instance, individuals interviewed for this study informed that climate information collected by the meteorological radar in the neighbouring town of Cascavel (Brazil) is used in Puerto Iguazú. There are other examples of information sharing between the other cities. Civil Defence in Foz do Iguaçu also pretends to obtain better measuring instruments. The tasks undertaken by Civil Defence in these cities are thus valuable, since they generate co-benefits for the region and create a favourable terrain to foster stronger cooperation.

There are barriers to active cooperation between the three cities. Seeking to engage the three cities to undertake cooperative actions is not a simple task. There are numerous barriers, starting with language. Although a large proportion of the population understands and speaks Spanish and Portuguese, communication issues represent an issue. There are also cultural differences and divergent legal settings. Moreover, economic, political and security issues often hinder cooperation actions. The existence of historical constraints between countries also plays an important role.

What can the cities do to reduce their vulnerabilities?

Stakeholders from different sectors of the three participating municipalities were brought together to discuss possible solutions to increase the climate resilience of cities, given the identified vulnerabilities. These solutions can be classified into four types.

Planning. Adequate urban and land-use planning are paramount for advancing on the development and resilience of the municipalities. An effective plan to organise the urban environment is essential to control the sprawl and correct any irregularities, like the inappropriate occupation of riverbanks and other risk areas. Effective city planning, however, is a process that involves technical and political elements. It also implicates the creation of policies and regulations which must be monitored and enforced.

Structural. As has been said, insufficient investment in infrastructure has led to various problems, such as a deficient level of public services. The need to invest in basic sanitation is essential. The cities do not provide full coverage of domestic sewage collection, especially in districts farthest from the central regions. Investment in efficient drainage systems is also urgent, contributing to reduce urban flooding. Other structural solutions are related to the improvement of solid waste management systems, strengthening the resistance of housing in deprived areas, and the creation of more green spaces.

Non-structural. An important issue identified in this study is the lack of reliable data, from climatic to socio-economic. Building the capacity of the municipalities to collect, process and disseminate quality data is vital to foster climate resilient development, as it is necessary to better understand the situation and monitor progress. Other measures are aimed at providing training to municipal officials regarding climate change and adaptation actions. Improving environmental education and developing awareness among the population is also essential, in order to influence people’s behaviour and make them aware of the risks faced by the region and the importance of keeping the cities and rivers free of pollution and waste.

Cooperation. The triangle-city region offers good opportunities to foster strong city-to-city cooperation. The creation of a Tri-National Civil Defence Council has been mentioned by various actors, which would allow a better coordination of preparedness and response actions, pooling financial and human resources from the three cities. Similarly, the establishment of a tri-national chamber formed by the three local development councils could help to address common problems and design a future vision for the region. Other solutions relate to the creation of joint early warning systems, as well as setting more spaces for discussion and programmes for cooperative actions.

Conclusions

1. **Given the expected population growth and climate projections that indicate the likelihood of more frequent and severe extreme weather events, the triangle-city region must urgently implement disaster risk reduction measures**

and increase its climate resilience. It is essential for the cities to revise and improve their contingency plans and make them publicly available. Efforts have to be made to develop strategies aimed at prevention, preparedness and recovery actions. Furthermore, municipalities require to start developing their local climate change adaptation plans in accordance with national-level guidelines, designing courses of action to deal with an uncertain climate in the future.

2. **The three cities face the opportunity to develop joint local initiatives and plans to deal with future climate effects.** Given that the cities have not yet incorporated climate change as an essential factor in their work programmes and are yet to start developing adaptation strategies, it is an appropriate moment to create these in a cooperative manner. It is important that the cities understand that their future is intertwined and that unilateral actions might not be as efficient and effective than when these are implemented in a cooperative manner.

3. **The cities should adopt a medium and long-term vision to successfully adapt to a changing climate.** The existent early warning systems and the exchange of information between Civil Defence institutions are mainly oriented to deal with short-term issues. However, a longer term perspective is absent in the three cities. Future climate information is not used in the triangle-city region. It is required to investigate what type of information is required by different economic sectors (e.g. energy, tourism, agriculture, commerce) to undertake their adaptation actions.

4. **The three cities share socio-economic vulnerabilities.** Even though the analysis presented in this study treats the vulnerability of each city independently, this vulnerability is actually shared. In essence, the three cities form a single and cosmopolitan urban centre. People constantly crosses the borders in their daily lives to work, do shopping or for recreational issues. In this sense, any problem affecting one city would have immediate consequences on the rest. Addressing vulnerabilities or implementing solutions from an individual perspective thus makes little sense. In order to successfully build climate resilient development, cooperation must be an integral element in any climate change adaptation strategy.

5. **Cooperation needs to be formalised and better balanced.** The level of cooperation that exists today to face extreme events is to a large extent informal. Formalising and institutionalising city-to-city cooperation would strengthen links between the municipalities and generate an atmosphere of certainty, security and trust. The proposed solutions to create a tri-national civil defence council and a tri-national chamber formed by the three local development councils is an important step toward this goal. However, the involvement of the municipalities is indispensable. Further efforts are required to engage them, as well as state and national authorities, in the process. Moreover, cooperation must be better balanced to ensure that links are strengthened between Ciudad del Este and Puerto Iguazú. Building a bridge between these two cities would contribute to boost their relationship.

6. **The triangle-city region embodies an excellent opportunity for successful city-to-city cooperation.** The region brings together more than 80 ethnic groups which, along with the presence of traditional peoples and an intense flow of visitors from all around the world, makes it a melting pot of cultures and ideas. Diversity and exchange are part of the local reality. This makes a favourable scenario for transboundary cooperation. The lessons learned from this region could be extremely helpful for other regions of the planet. The opportunity to build a more cooperative and resilient future is available today.

Introduction
Introdução
Introducción

2. INTRODUCTION

Cities have occupied a central stage as essential actors in the combat against climate change. Several initiatives have been created over recent years to engage major cities around the world to strengthen their efforts to become greener and more environmentally friendly and, at the same time, more resilient to extreme weather phenomena, while improving the living standards of their populations. This focus on cities is significantly relevant as it is expected that the majority of people in the planet will live in cities by mid-century. In the case of South America, the UN (2016) expects that around 80% of its population will be urban by 2050. Concurrently, cities are expected to increasingly face climate effects in the form of more intense and frequent extreme weather events over the years, putting at risk millions of people, especially those that are more vulnerable. Existing studies (IPCC, 2014) have shown that Latin America is particularly exposed to weather-related events and displays numerous vulnerabilities (e.g. poverty, economic and political instability, lack of resources and infrastructure, etc.). Based on a number of climate projections for the region developed by various teams of researchers (IPCC 2014), which show increasing trends in extreme climate variability, it is essential for Latin American countries to undertake actions to reduce their vulnerability and foster climate-resilient development.

The ratification of the Sendai Framework for Disaster Risk Reduction approved by UN member states in 2015 represents an important step towards reducing disaster risk and building resilience. In particular, the Declaration of Asuncion (2016), which involved ministers and authorities from Latin American countries, recognised the need to strengthen local actions and address vulnerabilities.[1]

The majority of climate change vulnerability studies have focused on large cities, often the big and renowned megacities, while smaller cities have been overlooked. However, it is in medium and small-sized cities where the fastest population growth rates are being registered. They are also the ones that generally present the highest vulnerabilities, such as lack of resources, infrastructure, human capital, among others. Nevertheless, it is also this type of cities that offer the largest opportunities, since in

[1] http://eird.org/ran-sendai-2016/docs/declaracion-sendai-americas.pdf

many cases they are still not locked-in by existing technology and infrastructure, and show a greater potential for sustainable urban planning and land-use management, among other aspects.

The present study emerges from the need to understand the climate change vulnerability of medium- and small-sized cities, in order to protect their development process against adverse climate impacts and make them more resilient. Addressing vulnerability is essential, as it has been recognised that efforts to enhance resilience are more effective when vulnerability is low ((Hernandez Montes de Oca, 2013). As stated, small and medium cities are generally 'lesser equipped' than larger ones to face extreme weather impacts and some can exhibit greater vulnerabilities (e.g. poor infrastructure, weak finance, lack of skills, etc.). It is then vital to address vulnerabilities to effectively advance urban climate resilience.

This assessment focuses on the cities of Ciudad del Este (Paraguay), Foz do Iguaçu (Brazil) and Puerto Iguazú (Argentina), which share borders at the confluence of the Parana and Iguazú rivers, forming the so-called triple-border zone. Specifically, Ciudad del Este is expected to be the fourth fastest growing city in Latin America by 2030 in terms of population growth according to UN urbanisation prospects (UN, 2015). The rapid expansion of the cities has been mostly fuelled by an increasing economic activity in commerce and tourism. Lack of planning, however, has generated problems related to infrastructure and provision of public services. Accelerated growth has put pressure on the environment in the form of pollution and deforestation. The latter has intensified the risk of flooding, to which the triple-border zone is highly exposed because of its geographical location. In recent years the area has suffered severe floods, aggravated by El Niño, causing heavy economic and social costs. Adequate risk reduction strategies are currently hindered by poor transboundary cooperation, in turn affected by political incongruity, weak institutional capacities and different legal settings. This challenge adds to other existing problems, such as poverty, corruption, insecurity, smuggling and drug trafficking.

The triple-border zone represents an interesting case study, as it represents an opportunity to understand how cities cooperate in a transboundary context. Around 116 million people in South America live in transboundary basins. However, transboundary issues are rarely addressed in national climate change adaptation plans, while adverse effects of climate change and rapid growth can have a great impact in the cities within those basins. Moreover, there is a lack of understanding about the cooperation opportunities that arise at a city scale which can deliver greater co-benefits.

From the best of our knowledge, the present assessment represents the first attempt to analyse the vulnerability of the three cities to climate related events. Furthermore, this represents a novel effort to examine vulnerability as a phenomenon shared by the three urban centres, whereby cooperation is paramount to face the climate change challenge of the triple-border region.

This assessment involved the participation of numerous actors from the three cities who shared their knowledge, experiences and ideas about how to make the cities more resilient to climate change under a cooperation framework. In a similar way, the assessment required large amounts of data, which were collected from different sources in various ways. Our Steering Committee was key in granting us access to data, and we want to take this opportunity to thank all of its members.

This assessment provides valuable findings that explain the vulnerability of the three cities and highlight the gaps and areas of action that need attention. We believe that this report is valuable as an initial approach to the climate vulnerability of the cities and opens various avenues for future research. It can be considered as a stepping stone, providing valuable insights into the challenges ahead.

This assessment is valuable for policy-makers, practitioners, academics, and many other persons and organisations that are not only interested in understanding the vulnerability of the triple-border region, but who are also concerned about how to improve the well-being of its inhabitants and promote a more inclusive, sustainable and resilient development.

The report is structured in the following way. Chapter two provides the research context, providing a general background of the characteristics and socio-economic structure of the cities. The following two chapters describe past climate trends that have affected the region, and present future climate projections. Moreover, these chapters present the challenge that the triangle-city region has ahead in terms of temperature, precipitation, and extreme weather events. Chapter five addresses the political legal and institutional settings for climate change adaptation in the triangle-city region and presents some gaps that the cities need to fulfil. The socio-economic vulnerabilities are presented in chapter six, where the framework for assessing the vulnerability of the triangle-city to extreme weather events is provided, followed by a detailed description of the research approach to construct the Urban Vulnerability Index, where the different indicators are identified. Then, it empirically explores the dimensions of vulnerability, which allowed the identification of the most/least vulnerable of the three cities. In the same chapter and to examine deeper the current situation of the triangle-city region, the qualitative analysis is presented. It focuses on which are the current problems in relation of extreme weather events that different stakeholders perceive are happening in the triangle-region. The chapter also presents the strategies that the cities have adopted in the short-term to react and face the impact of extreme weather events. Moreover, it portrays the plans that the cities are undertaking to face future climate-related impacts. The chapter finishes with an examination of the cooperation between these 3 cities. This is followed by a presentation of different preliminary solutions proposed by different stakeholders. It highlights important needs, in terms of planning, implementing structural and non-structural measures, and specific aspects where cooperation can be improved. Finally, conclusions are drawn in Chapter eight, which offers a summary of the main findings and offers some policy recommendations.

This study was supported by the Climate Resilient Cities in Latin America initiative, formed by the Climate and Development Knowledge Network (CDKN), the International Development Research Centre (IDRC) and Fundación Futuro Latinoamericano (FFLA).

Background review of the cities

Revisão histórica das cidades

Revisión histórica de las ciudades

3. BACKGROUND OF THE TRIANGLE-CITY REGION

The triangle-city region is situated on the Parana Basin at the confluence of two large water courses. The Parana River sets the border between Ciudad del Este (Paraguay) and Foz do Iguaçu (Brazil), while the Iguazú River limits the latter with Puerto Iguazú (Argentina). This last river shelters the world’s largest set of waterfalls in terms of volume of water, the famous Iguazú Falls. Given its natural and geopolitical characteristics, the region is currently an important touristic, industrial and commercial pole for the three countries. As Kleinschmitt, Azevedo and Cardin (2013) point out, one peculiarity of this triple border is that it is essentially urban, intensely transited and very populous, although inserted in the context of large rural areas. From a cultural standpoint, it is also a cosmopolitan place, home to about 80 ethnic groups, which receives millions of visitors each year (PMFI, no date; IPEC, 2015).

Historically, the region was inhabited by the the indigenous Tupi-Guarani as the European colonization began in sixteenth century. The arrival of settlers and the subsequent formation of Jesuit missions led to a mixture of cultures that remains present, as can be seen today in Paraguay, where both Spanish and Guaraní are official languages. Later, by the end of the nineteenth century and throughout the twentieth, the region received population flows from diverse backgrounds. As from the 1960's, population registered rapid growth, in parallel to infrastructure expansion, such as the construction of Ponte da Amizade, the bridge linking Foz do Iguaçu and Ciudad del Este, inaugurated in 1965; the BR-277 highway, connecting Foz do Iguaçu to the Brazilian coast, in 1969; and the Tancredo Neves International Bridge, linking Puerto Iguazú and Foz do Iguaçu, in 1985 (PMFI, no date b; Kleinschmitt, Azevedo and Cardin, 2013; IPEC, 2015).

Moreover, the construction of power generation plants in the region significantly contributed to this scenario. Emphasis should be placed on the Binational Hydroelectric Plant of Itaipu, the second largest hydroelectric plant in the world and the biggest provider of hydroelectricity in terms of annual accumulated production (Itaipu Binacional, no date). Its edification, which started in 1972, involved up to 40,000 workers, engendering waves of migration to the area (PMFI, no date b).

Commerce also attracted population flows to the region, especially in the

Paraguayan border. As from 1991, commercial flows between the three countries were intensified with the creation of the Southern Common Market (Mercosur), for which the tri-border region constitutes an important trade corridor, as it links the Pacific to Atlantic coasts and provides land-locked Paraguay with access to ocean ports.

3.1. Foz do Iguaçu

Situated on the westernmost point of the Brazilian state of Paraná, Foz do Iguaçu is formally the oldest city of the triangle region. The municipality was founded in 1914, but only received its current name four years later. In 1939, tourism started to gain importance for the local economy, with the foundation of the Iguaçu National Park, which hosts the Iguazú Falls. During the 1970's, the construction of Itaipu dam led to a new growth cycle in the city, consolidating the industrial sector and generating a big population increase (PMFI, no date b).

In 1970, the number of local inhabitants was 33,966, reaching 136,352 after only ten years. Along the following decades, the population continued to grow, reaching around 256,088 inhabitants in 2010[2]. Since then, growth rates have slowed down, being estimated that the population in 2016 reached 263,915 inhabitants (IBGE, no date). While in 1980 three fourths of the population were urban (74.47%), nowadays almost all is urban (99.17%).

In economic terms, the services sector holds the largest share of the Gross Domestic Product (GDP) of the municipality, followed by the industrial and agricultural sectors (IBGE, no date; IPARDES, 2017).

[2] It's worth to note that, according to another research conducted between the two last national census, Foz do Iguaçu's population achieved 311.336 inhabitants in 2007 (IBGE, no date). The decrease in the number of inhabitants might be associated, among other factors, to the strengthening of fiscalisation in the Brazilian frontier, which affects contraband activities (Cardin, 2012).

Table 1. Gross value added at basic prices according to main activities – 2014

ACTIVITIES	VALUE (R$ 1.000,00)
Agriculture and livestock	52.992
Industry	3.984.866
Services	3.145.911
Public administration	1.011.056
Total	8.194.825

Source: Caderno Estatístico do Município de Foz do Iguaçu (IPARDES, 2017, p. 23).

Tourism plays a major role in the city. In the year 2000, Foz do Iguaçu received 800,000 visitors. In 2012, that amount had more than doubled, reaching about 2 million (Secretaria Municipal de Turismo, 2017). Foz do Iguaçu is the third Brazilian municipality most visited by foreigners (Ministério do Turismo, 2016) and stands among the 20 most desired destinations by Brazilian tourists (Ministério do Turismo, 2012).

3.2. Puerto Iguazú

Puerto Iguazú is located in the province of Misiones, Argentina. Although logging and mate herb exploitation were relevant in the occupation of the province, the foundation of Puerto Iguazú was, itself, related to tourism. The first town settlements initiated in 1901, but it was not until 1951 when it became a municipality. Currently, the city is one of the most important of Misiones, in which tourism is a main economic activity. Just in 2010, the Iguazú National Park, the town's major attraction, received almost 1.2 million visitors. The services sector accounted for 51.2% of the province's GDP (91.4 billion pesos) in 2012, followed by industry, with 37.4%, and the primary sector, with 11.4% (IPEC, 2015).

In addition to the intense flow of tourists, the municipality has also presented a population increase over the last decades. According to the 2010 National Census, Puerto Iguazú was one of the municipalities that had the largest population rise in relation to 2001. Its growth rate of 33.7% contrasts with the provincial and national averages of 14.1% and 10.6%, respectively (IPEC, 2015). In that year, the municipality's population was of 42,849 inhabitants[3]. As in Foz do Iguaçu, almost all of this population is urban (96%) (IPEC, no date). The population projection of Puerto Iguazú for 2020 is 58,760 inhabitants (IPEC, no date b).

3.3. Ciudad del Este

As the youngest municipality of the triangle region, Ciudad del Este was founded in 1957, adopting its current name in 1989. It is the capital of the Alto Paraná department. The city developed mainly through commerce, receiving a boost from the construction of Ponte da Amizade (DAP, 2014) and the establishment of low and tax-free trade regimens, which attracted population contingents from Paraguay and abroad, including a big number of immigrants from China and the Middle East (Rabossi 2004). The city quickly became a pole of international trade, with emphasis on the commerce of asiatic technological products. In that sense, shopping tourism is a main driver of the local economy. It's commercial flow has been pointed out as the third biggest in the world, after Miami and Hong Kong (Dreyfus 2005; Rabossi 2004)[4].

Ciudad del Este is currently the second most populous city in Paraguay, only behind the national capital, Asunción. It is also the most populous of the triple border, having kept high rates of population growth during the last decades. The municipality had 281,422 inhabitants in 2012, almost 24% more than in 2000 (DGEEC, 2015). It is expected that this number will exceed 300,000 before 2020. The United Nations (UN) projects that Ciudad del Este will be among the ten fastest growing cities in Latin America by 2030 (UN, 2015).

Therefore, it's worth to note the interrelationships that these three cities have developed, conforming a particular frontier dynamic that transpose national limits (Kleinschmitt, Azevedo and Cardin, 2013). As it will be discussed in section 5, although each city has its own institutional settings, several agreements have encouraged cooperation among them over time. However, regulations and laws at a national level

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[3] It's important to point out that the data provided by local actors interviewed by the project indicate higher population numbers than the official ones registered in the census.

[4] Rabossi (2004), however, problematizes this information: although it is found in various works about the region, he indicates the lack of precise data about the city's economy numbers.

influence how situations are managed at a local level either in favour of cooperation, as in Mercosur, or against it, such as in regulations of frontier fluxes, given legal and security issues, as described in the sequence.

3.4. Present challenges faced in the triangle region

Despite its economic relevance, the fast and intense growth of the triangle region has also generated problems, adding up to existing ones. Job creation, for instance, has not been enough to keep up with the pace of population growth, causing unemployment. As reported by the Municipality of Foz do Iguaçu, this has given rise to a large informal economy, as well as sprawling slums. More pressure has also been exerted on key sectors, such as health, education and public safety (PMFI, no date b).

Regarding security and rule of law, illegal and clandestine practices, such as contraband and drug and gun trafficking, have become common in the border region between Foz do Iguaçu and Ciudad del Este (Cardin, 2012). Moreover, there have been suspicions of terrorist-related activities in the area (Rabossi, 2004; Dreyfus, 2005).

The unplanned urban growth has also led to infrastructure problems, intensified by the large flow of tourists. Massukado and Teixeira (2006) indicate the need for investments in tourism infrastructure in Foz do Iguaçu. Gandara, Souza and Lacay (2011) point out that, although the city's great potential for tourism, there is no organizational incentive to develop other local attractions, which could contribute to the region's development.

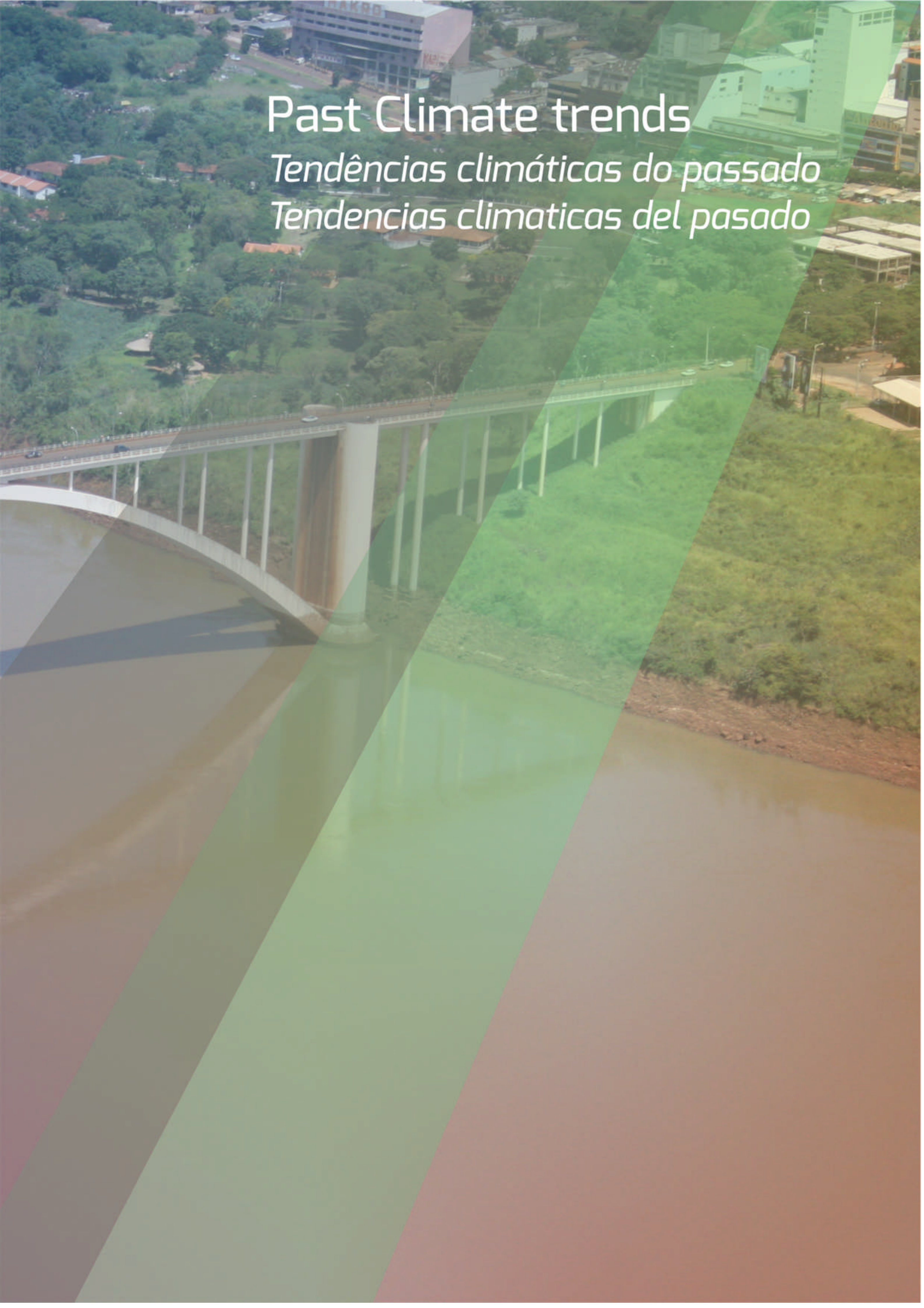
On the other hand, threats to the region's main touristic attraction, the Iguazú Falls, have been reported. Both national parks that host the falls in Argentina and Brazil are recognized by Unesco as World Heritage Sites since 1984 and 1986, respectively. However, the area has been subject to land pressure, putting at risk the biological collection it shelters (Ortiz et al., 2000). Agriculture expansion is pointed as the main cause of forest fragmentation and degradation in the Upper Paraná Atlantic Forest, engendering the largest threat to the ecoregion's biodiversity. Other causes include the construction of infrastructure, such as dams and roads, illegal hunting, unsustainable forest exploitation and squatting by landless people (Di Bitetti et al., 2003).

The advance of agriculture alongside environmental and land issues has also been reported among indigenous communities. In Paraguay, the National Census of Population and Housing for Indigenous Peoples (DGEEC, 2015b) indicates tenure problems in the region of Ciudad del Este, including land appropriation by agro-entrepreneurs or cattle ranchers. Other problems pointed out by the communities are violence and difficulties related to natural resources, such as the reduction of wild animals, fumigation with agrochemicals and contamination of watercourses.

Past Climate trends

Tendências climáticas do passado

Tendencias climaticas del pasado



4. PAST CLIMATE TRENDS

4.1. Extreme weather and climate events in the triple-border region

This chapter is about analysing the occurrence and past climate trends of extreme weather and climate events in the triple-border region. The extreme weather and climate events analysed in this chapter are: (i) intense or extreme precipitation, (ii) strong winds, (iii) hail storms, (iv) heat waves, (v) cold waves, (vi) floods, (vii) and droughts.

Some of the major sources of risk for human society are extreme weather and climate events (Stephenson 2008). Climate change thus represents a significant challenge as it leads to variations in the frequency, intensity, spatial extent, duration and timing of these extreme events (Seneviratne et al. 2012). Furthermore, rapid and unplanned population growth in urban areas, plus inadequate infrastructure, have made us potentially more vulnerable to these events than we were in the past (Stephenson 2008).

The Intergovernmental Panel on Climate Change (IPCC) defines a weather or climate extreme event as “the occurrence of a value of a meteorological variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable” (Allan Lavell et al. 2012). Nevertheless, some climate extremes, like droughts and floods, which can affect human activities, may be the result of an ensemble of weather or climate events that may be not extreme themselves. As well, there are some weather or climate events that can lead to extreme conditions or disasters even if they are not extremes in a statistical sense (Seneviratne et al. 2012). However, extreme events are often but not always associated with disasters. The association depends on the exposure and vulnerability of the area of occurrence of the event (Allan Lavell et al. 2012).

In order to analyse extreme weather events in the triple-border region, data from two weather stations located in the region were used. These stations are: (1) “Ciudad del Este Weather Station” located in Ciudad del Este, Paraguay (Figure A 1 and Table A 1), and (2) “Iguazú Aero Weather Station” located in Puerto Iguazú, Argentina (Figure

A 2 and Table A 2).

Regarding meteorological data from Foz do Iguaçu, we have analysed all the data available in the HidroWeb Platform of the National Water Agency of Brazil. We have found a few historical data of precipitation and only one short period of temperature data. Comparing these data between each other and between the data available in Paraguay and Argentina we found no correlation and lots of missing points. For these reasons, we have chosen not to use data from this city as they have low quality.

4.2. Past Weather and Climate Extreme Events

4.2.1. Intense rainfall

The occurrence of heavy precipitation events has often led to urban and river floods in the triple-border region. These flood events affect people's quality of live or may cause loss of human lives and often cause huge economic impacts. Since there are large variations in precipitation patterns throughout the world, it is not possible to provide a single definition of heavy precipitation that is suitable for all regions (TT-DEWCE 2016).

The American Meteorological Society in its Meteorology Glossary defines heavy rain as: *"rain with a rate of accumulation exceeding a specific value that is geographically dependent*" (American Meteorological Society 2012). Furthermore, when a precipitation event is considered to be extreme it relates to one of the following two approaches: (1) a precipitation event is considered to be extreme when certain threshold that has certain associated impact is exceeded, or (2) a precipitation event is considered to be extreme due to its infrequency. In this case, percentiles are usually used, and extreme precipitation events are commonly considered to be above the 90th, 95th, and 99th percentiles (TT-DEWCE 2016).

The approach adopted in this study to define extreme precipitation events over the triple border region is the 90th percentile in terms of daily precipitation. Furthermore, the occurrence of annual maximum precipitation events was also analysed and, in order to determinate the period of occurrence, a seasonal analysis was conducted. In this analysis, meteorological seasons were used, i.e. spring: September, October and November; summer: December, January and February; autumn: March, April and May;

and winter: June, July and August.

4.2.2. Ciudad del Este Weather Station

To define extreme precipitation events the historical record of daily precipitation of this weather station was used. These data were provided by the Meteorology and Hydrology Directorate of the National Civil Aeronautics Directorate of Paraguay (DMH/DINAC). The analysis period covered 41 years of data, between 1966 and 2006. The annual amount of precipitation throughout the years was analysed, and during this period the mean annual precipitation was 1,795mm/year. Moreover, a positive trend of annual precipitation was estimated, indicating that the amount of precipitation is increasing over the years (Figure 1).

Figure 1 and Figure 2 show the annual amount of precipitation in Ciudad del Este Weather Station (1966-2006) and in Aeropuerto Guarani Weather Station located in the neighbouring city of Minga Guazú (1998-2015). This latest weather station was used to observe the recent trends as it has data up to 2015.

Years with a low the amount of precipitation coincide with droughts events i.e. 1967-1968, 1978-1979, 2000, and 2008. In contrast, years with an increase in precipitation coincide with floods events i.e. 1983, 1990, 1998, and 2014.

The annual maximum daily precipitation throughout the years can be observed in Figure 3. Likewise, a positive trend in the intensity of annual maximum daily precipitation was detected. The highest amount of precipitation registered is 213.80mm on May 20, 1997. Historically, these events have occurred mainly in summer, followed by autumn, spring and winter (Figure A 3).

In order to define extreme precipitation events, the 90th percentile of the historical record was determined. This percentile is 41.98mm/d and, in this sense, 475 extreme events were detected. Moreover, a positive trend in the number of daily extreme events through years was also observed, indicating that these events are becoming more frequent (Figure A 4). Historically, these events have occurred mainly in spring, followed by summer, autumn and winter (Figure A 5).

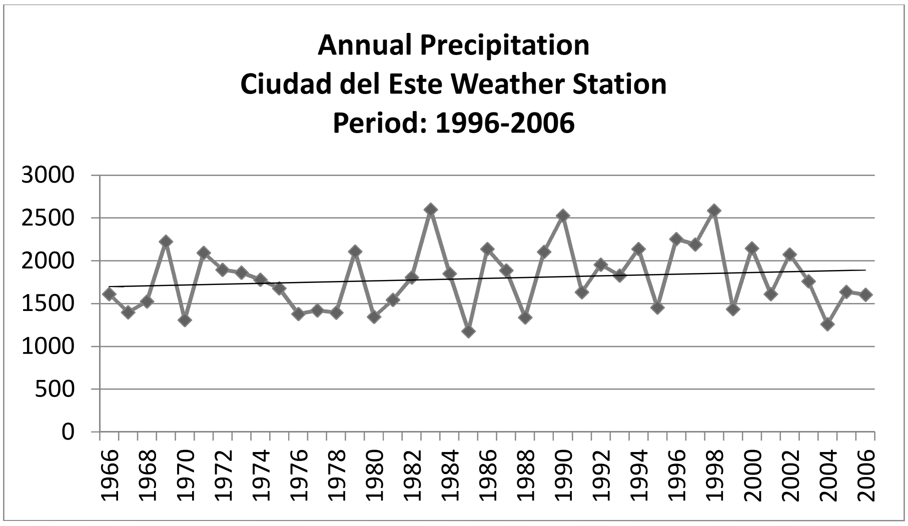


Figure 1. Annual precipitation. Ciudad del Este Weather Station.

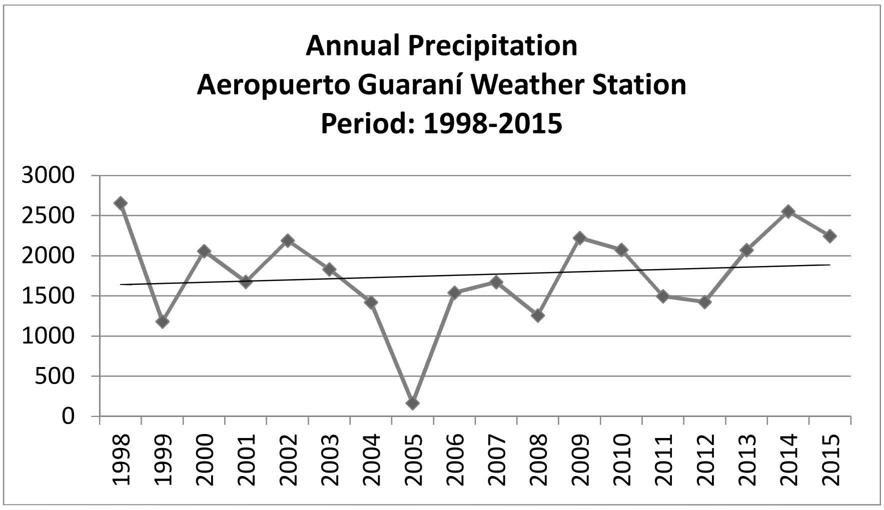


Figure 2. Annual precipitation. Aeropuerto Guaraní Weather Station. Minga Guazú.

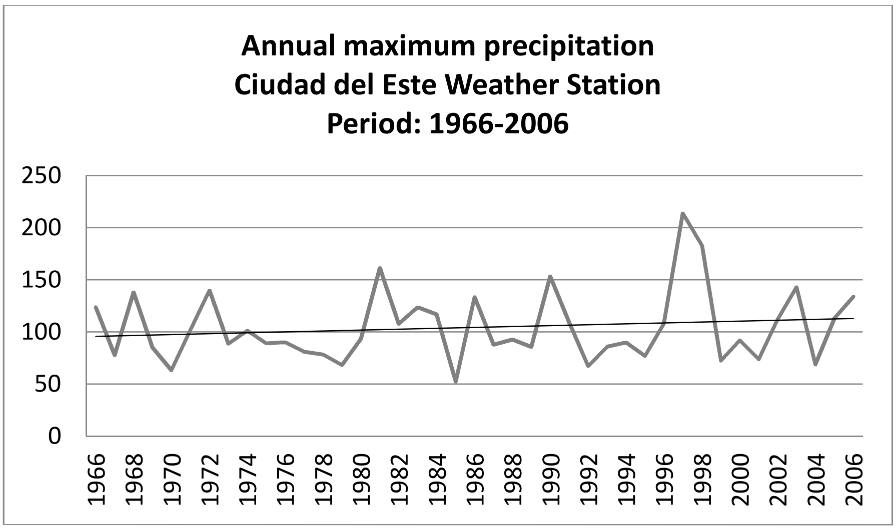


Figure 3. Annual maximum daily precipitation data. Ciudad del Este weather station.

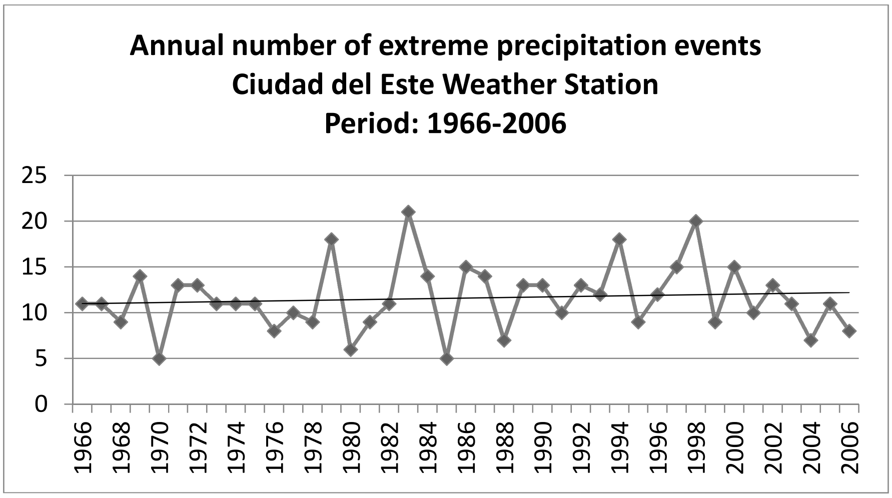


Figure 4. Annual number of extreme precipitation events. Ciudad del Este Weather Station.

4.2.3. Iguazú Aero Weather Station

In order to analyse precipitation events in the triple-border region, daily precipitation data from this weather station was also used. These data were provided by the Regional Climate Centre for Southern South America (CRC-SAS). The analysis period covered 48 years, between 1969 and 2016. During this period, the mean annual precipitation was 1,892mm/year. In addition, a positive trend in the annual precipitation was detected, indicating an increase in the amount of rainfall over the years (Figure 5).

Analysing the maximum daily precipitation in each year, a positive trend was also perceived (Figure 6). The highest amount of precipitation registered was 188mm on April 30, 2014, few days before of the most rapid increase in the streamflow in the Iguazú River. Historically, these events have occurred mainly in autumn, followed by summer, winter and spring (Figure A 4).

*The 90th percentile of the historical record in this station corresponds to 44mm/d, yielding 517 extreme events over 48 years. As well as in Ciudad del Este Weather Station, a positive trend in the number of daily extreme events is observed (Figure 7). Historically, these events have occurred mainly in spring, followed by the summer, autumn and winter (*Figure A 6*).*

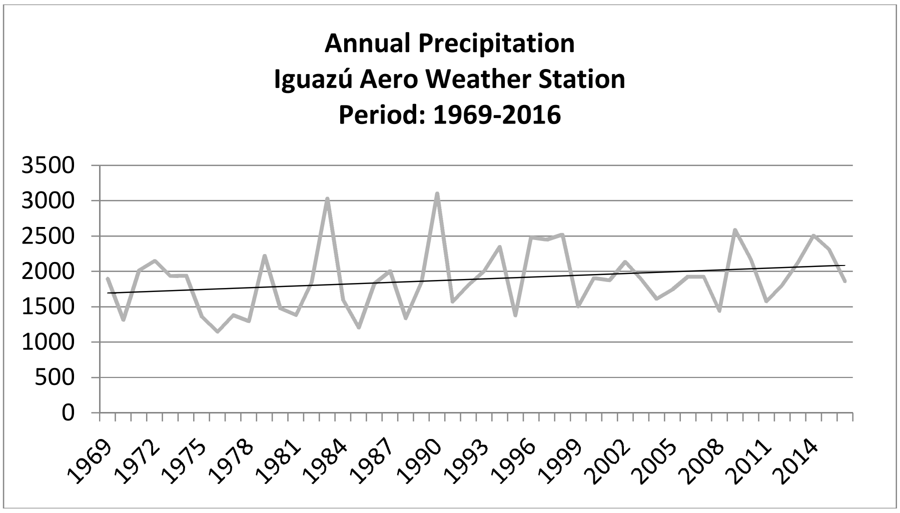


Figure 5. Annual precipitation. Iguazú Aero Weather Station.

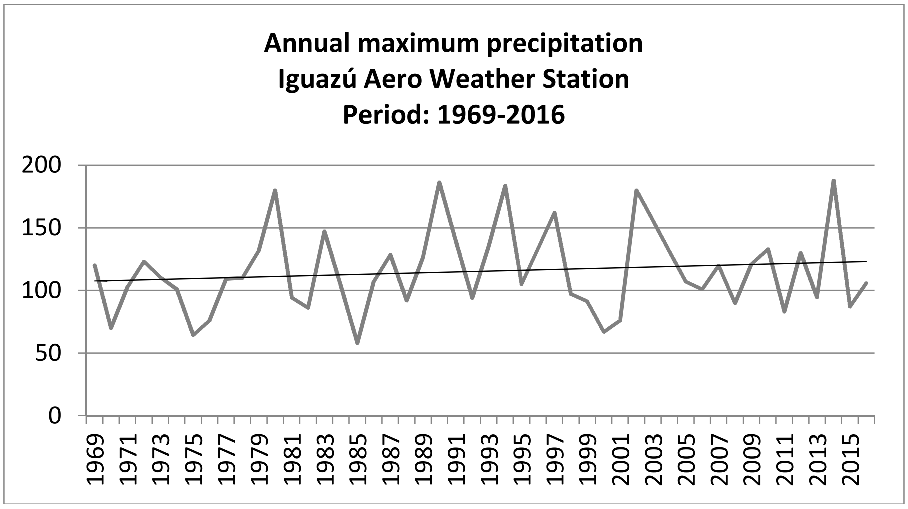


Figure 6. Annual maximum precipitation over the years. Iguazú Aero Weather Station.

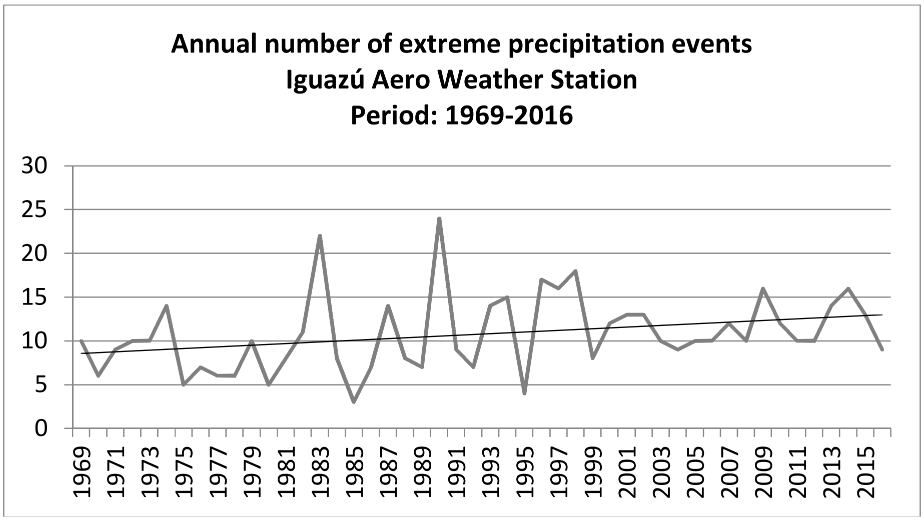


Figure 7. Annual number of extreme precipitation events over Puerto Iguazú. Iguazú Cataratas Weather Station.

4.2.4. Summary of results

Given the results obtained in both weather stations, it can be concluded that the annual amount of precipitation over the triple border region is increasing over the years. Moreover, the annual maximum daily precipitation is also increasing indicating that precipitation events are becoming more intense.

Finally, an extreme daily precipitation event over the triple-border region corresponds to a level of daily precipitation (24 hours) above 41.98mm (Table 2). Around 500 extreme events were detected in each weather station during the study period. Furthermore, the annual number of these events is increasing over the years, showing an increase in the frequency of heavy precipitation events over this region.

Table 2. Summary of results of precipitation data analysis.

Intensive Rainfall				
Weather Station	**90th Percentile (mm/day)**	**# of extreme events**	**Historical maximum (mm/day)**	**Annual mean precipitation (mm/year)**
Ciudad del Este (1966-2006)	41.98	476	213.80	1,795
Iguazú Aero (1969-2016)	44.00	517	188.00	1,892

4.2.5. Strong winds

Strong winds have affected the triple-border region throughout the years, mainly causing damage to fragile infrastructure and, consequently losses of human lives and economic impacts. Moreover, usually these strong winds cause trees to fall affecting human livelihoods and energy provision systems.

It is important to highlight that the triple-border region is located within an area that has been recognized as prone to severe thunderstorms, including large hail, damaging winds and also the occurrence of tornados (Brooks, et al., 2003; Nascimento & Doswell III, 2005; Silva Dias, 2011). In addition, La Plata basin, within which the triple-border region is encompassed, is characterized by potential F3 (158-206m/h) tornados or F4 (207-260m/h) tornados in the Fujita Scale (Fujita 1973). Tornado events in the South of Brazil have occurred mainly in spring and summer (Silva Dias 2011), so it is essential to pay special attention in these seasons to future possible events.

Moreover, an increase in the number of tornado reports in southern Brazil was reported since the twentieth century. One of the possible causes of this rise since 1970 could be an abrupt change in rainfall patterns that occurred in this region at that time, as a result of global warming (Silva Dias 2011).

4.2.6. Hail Storms

There are no meteorological instruments to measure hail events in the triple-border region, so in order to determinate the occurrence of these events, information available in various newspapers and websites for each country were used. Particularly, reports from voluntary observers available in the Argentinian Meteorological Service website were used to determine the number of hail storms over Puerto Iguazú. Likewise, to determine these events in Foz do Iguaçu the Information System of the Civil Defense of the Parana State Government was used.

Hail storms events do not occur with high frequency over the triple-border region, but when they occur they usually cause a lot of damages, mainly because of fragile infrastructure that characterizes some neighbourhoods in the region. Typically, these events last only a few minutes (between 5 and 15 minutes) and the diameter of hails can vary approximately between 1 and 5 cm.

A hail storm event that caused major damages in the triple-border region occurred on September 7, 2015 (Table 3). This event started around 7pm in Ciudad del Este and only lasted approximately 15 minutes, but it was enough to destroy cars and dwellings. San Rafael, Fátima, Obrero and the San Roque neighbourhoods were the most damaged ones. About 6,000 homes were damaged because of the thunderstorm, mainly by hail, across Alto Parana and the Canindeyú department in Paraguay. Likewise, this event left thousands of victims in Foz de Iguaçu. The Porto Meira neighbourhood was the most damaged, where 95% of houses affected. After this event, an emergency state was declared by the “Prefeitura de Foz do Iguaçu”, because at least 60,000 people were affected. Similarly, in Puerto Iguazú, the event lasted around 6 minutes and destroyed numerous houses and cars.

Table 3. Hail storms over the tri-border region.

Events	Data of occurrence	City affected	Reference
Event N°1	19/June/1994	Foz do Iguaçu	Parana State Government – Civil Defense.
Event N°2	20/November/2000	Foz do Iguaçu	Parana State Government – Civil Defense.
Event N°3	07/August/2008	Foz do Iguaçu	Parana State Government – Civil Defense.
Event N°4	11/September/2008	Foz do Iguaçu	Parana State Government – Civil Defense.
Event N°5	29/August/2011	Foz do Iguaçu	Parana State Government – Civil Defense.
Event N°6	29/October/2011	Puerto Iguazú	Voluntary Observer Platform – Argentinian Meteorological Service
Event N°7	29/August/2012	Puerto Iguazú	Voluntary Observer Platform – Argentinian Meteorological Service
Event N°8	07/November/2014	Puerto Iguazú	Newspapers.
Event N°9	20/November/2014	Ciudad del Este	Newspapers.
Event N°10	07/September/2015	Foz do Iguaçu Puerto Iguazú Ciudad del Este	Parana State Government – Civil Defense. Voluntary Observer Platform – Argentinian Meteorological Service
Event N°11	19/September/2015	Ciudad del Este	Newspapers.
Event N°12	15/October/2015	Foz do Iguaçu Puerto Iguazú	Newspapers.
Event N°13	10/November/2015	Puerto Iguazú	Voluntary Observer Platform – Argentinian Meteorological Service
Event N°14	19/August/2016	Puerto Iguazú	Voluntary Observer Platform – Argentinian Meteorological Service

Based on: (Parana State Government - Civil Defense, n.d.; Platform of the Argentinian Meteorological Service, n.d.; and various newspapers)

4.2.7. Heat waves

A Heat Wave can be defined as an extended period of temperatures above the normal in a specific geographical area. Thus, there is no universally accepted definition establishing thresholds for temperatures and time periods (Yagüe et al. 2006). According to the WMO's Meteoterm vocabulary, a heat wave is an extreme weather event with marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks (TT-DEWCE 2016). Additionally, in the IPCC glossary, a heat wave is defined as a period of abnormally hot weather (IPCC 2012).

The Task Team on Definitions of Extreme Weather and Climate Events of the World Meteorological Organization recommends using a practical and qualitatively oriented definition of a heat wave. Thus, a heat wave is defined as unusual hot weather (max, min and daily average) over a region persisting at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds (TT-DEWCE 2016). It is important to mention that daily maximum and minimum temperatures are of concern since prolonged periods with high minimum temperatures can be devastating as people can get no relief. By the same token, there is a vast literature that looks into the relationship of heat waves and health which considers other climate variables such as wind speed, radiation, humidity, among others (World Meteorological Organization and World Health Organization, 2015).

Regarding the triple-border region, the Meteorology and Hydrology Directorate of the National Civil Aeronautic Directorate of Paraguay (DMH/DINAC) defines a heat wave as a period of at least 3 consecutive days without rainfall, with maximum temperatures above the 95th percentile of maximum temperatures and minimum temperatures above certain thresholds depending of the locality (UNDP Paraguay 2017).

The National Meteorological Service of Argentina (SMN) defines a heat wave as an extended period of excessively warm temperatures, in which maximum and minimum values are above certain thresholds defined for each location for at least 3 days. The thresholds used by the SMN are the 90th percentile of maximum and minimum temperatures between October and March each year (Argentinian Meteorological Service n.d.).

Furthermore, in order to define heat waves events the SMN conducted an analysis in Argentina. They only define heat waves in the Center and Northeast zone of this country using the 90th percentile of the maximum and minimum temperatures between October and March of 1961-2010. Specifically, in Puerto Iguazú, the 90th percentile of minimum temperatures was 22°C, and the maximum temperature was 34°C. The heat wave events detected in this study occurred mainly in February and they regularly lasted 3 days (Argentinian Meteorological Service n.d.).

In contrast, there is no specific definition of heat waves in Brazil. The National Institute of Meteorology of this country defines a heat wave as an unpleasant and extremely warm time period which can last days or weeks (Brazilian Meteorological Institute (INMET) n.d.). Moreover, in the Brazilian Classification and Codification of Disasters (COBADRE), a heat wave is defined as an unpleasant and excessively warm extended time period, where temperatures are above a normal value for a specific region in a specific time of the year. Usually, a period of at least three days with temperatures above 5°C of the mean maximum values is adopted (Superintendence of Protection and Civil Defense of Brazil n.d.). The Government of Parana State defines a heat wave as a time period with maximum temperatures above the usual mean for a specific place and time (Parana State Government n.d.).

In order to define heat wave events over the triple-border region, data from the same weather stations that we used in the evaluation of heavy precipitation events were used. Furthermore, these data were assessed using the approaches proposed by DMH/DINAC and SMN to compare and contrast their results.

4.2.8. Ciudad del Este Weather Station

To define heat wave events over the triple-border region, daily maximum and minimum temperatures data from the Ciudad del Este Weather Station were used (Figure A 1 and Table A 1). The historical record of daily maximum temperature available in this weather station includes 14,975 days, since January 01, 1966 until December 31, 2006, and there are only 2 missing data points.

In Table 4 the maximum annual value of maximum temperatures over the years can be observed. The highest value recorded was 40.2°C on December 9, 1985. In addition, the highest values of maximum temperatures recorded for each year show an increasing trend over time (Figure 8).

These annual maximum temperatures have happened between September and March, covering spring and summer (Figure A 7 and Figure A 9). In 1974, 1981 and 1991 the highest values of maximum temperature were recorded more than once in different months. In 1974, the highest annual values were recorded in November and

December; in 1981, in February and March and, in 1991, in January and November.

Table 4. Maximum daily temperatures through the years. Ciudad del Este Weather Station.

Year	Daily Maximum Temperature (°C)	Year	Daily Maximum Temperature (°C)	Year	Daily Maximum Temperature (°C)
1966	37	1980	37	1994	37
1967	38.4	1981	36	1995	37.2
1968	37.5	1982	36	1996	35.6
1969	37.4	1983	35.2	1997	37
1970	37.4	1984	36	1998	36.8
1971	37.6	1985	40.2	1999	38
1972	36.8	1986	37.4	2000	36.6
1973	38.6	1987	36.4	2001	36.5
1974	35.4	1988	38	2002	37.4
1975	37	1989	35.6	2003	38.4
1976	36	1990	37	2004	39
1977	38	1991	36.5	2005	39.6
1978	38	1992	36.5	2006	38
1979	38.8	1993	37.8		

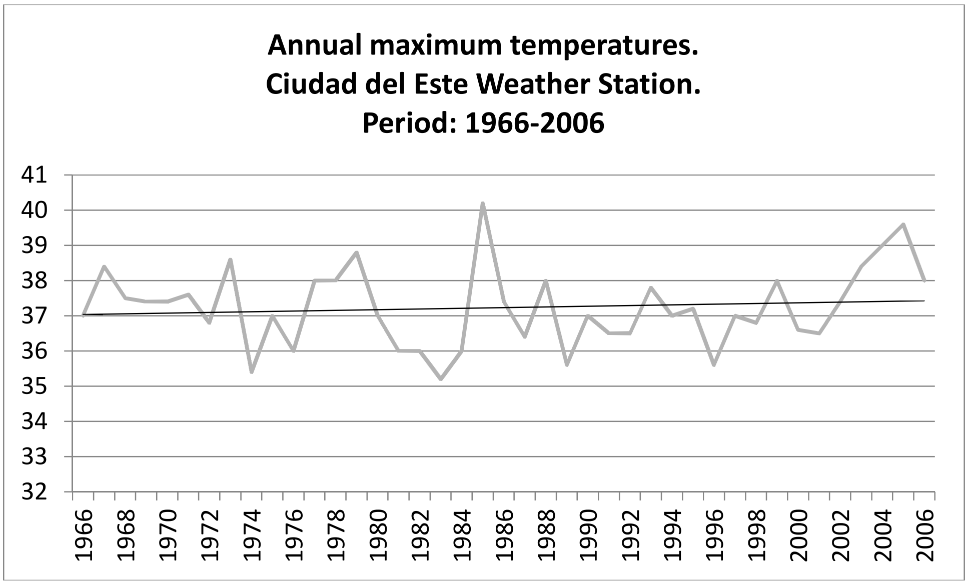


Figure 8. Annual maximum temperatures. Ciudad del Este Weather Station.

4.2.9. Approach proposed by DMH/DINAC

Using the definition provided by DMH/DINAC, the first step consisted in selecting the time periods in which the threshold was surpassed for at least 3 consecutive days. This threshold is the 95th percentile, which is 34.8°C in this data set. In the second step, the occurrence of precipitation during these periods was studied. Finally, the time periods that lasted at least 3 consecutive days with no precipitation were considered as heat wave events and their minimum temperatures were analysed. It was estimated that there were 60 events registered between 1966 and 2006 (Table A 9).

4.2.10. Approach proposed by SMN

In order to determine heat wave events using the approach proposed by SMN, the 90th percentile of maximum and minimum temperatures were calculated using daily data between October and March of the historical record (1966-2006). The 90th percentile of maximum temperatures is 34.8°C and of minimum temperatures is 23.5°C. Time periods of at least 3 consecutive days that simultaneously exceeded these thresholds were considered as heat waves events. Finally, 21 heat waves events were detected over the study period (Table A 10).

4.2.11. Iguazú Aero Weather Station

In order to define heat wave events in the triple-border region the historical record of daily maximum and minimum temperatures available in the Iguazú Aero Weather Station was used (Figure A 2 and Table A 2). The time period include 17,533 days, since January 01, 1969 until December 31, 2016.

In Table 5, the maximum annual value of maximum temperatures over the years can be observed. Figure 9 shows a positive trend, which indicates an increase in the highest value of maximum temperatures recorded each year. In addition, the highest value recorded was 40°C on December 19, 1985.

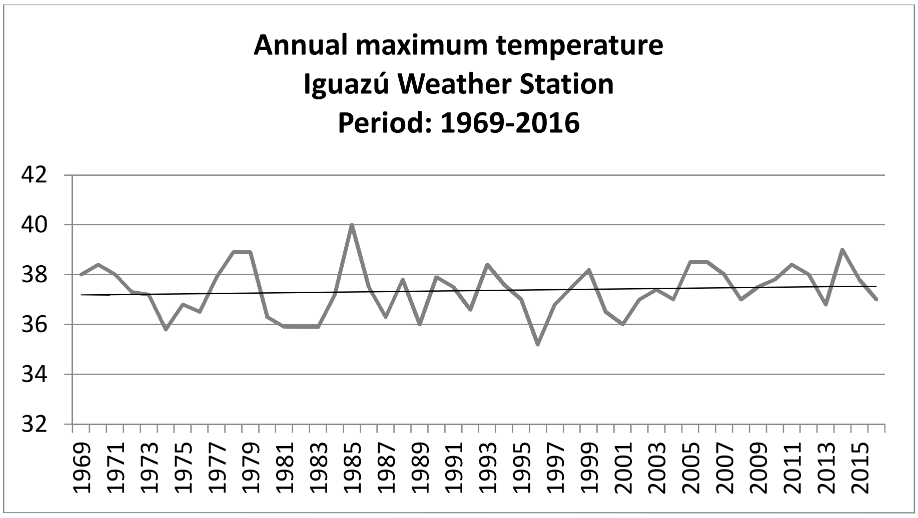


Figure 9. Annual maximum temperatures. Iguazú Aero Weather Station.

Table 5. Annual maximum temperature over Puerto Iguazú. Iguazú Aero Weather Station.

Year	Daily Maximum Temperature (°C)	Year	Daily Maximum Temperature (°C)	Year	Daily Maximum Temperature (°C)
1969	38	1985	40	2001	36
1970	38.4	1986	37.5	2002	37
1971	38	1987	36.3	2003	37.4
1972	37.3	1988	37.8	2004	37
1973	37.2	1989	36	2005	38.5
1974	35.8	1990	37.9	2006	38.5
1975	36.8	1991	37.5	2007	38
1976	36.5	1992	36.6	2008	37
1977	37.9	1993	38.4	2009	37.5
1978	38.9	1994	37.6	2010	37.8
1979	38.9	1995	37	2011	38.4
1980	36.3	1996	35.2	2012	38
1981	35.9	1997	36.8	2013	36.8
1982	35.9	1998	37.5	2014	39
1983	35.9	1999	38.2	2015	37.8
1984	37.2	2000	36.5	2016	37

Annual maximum temperatures events happened between September and March, covering mainly summer and spring (Figure A 8 and Figure A 10). In 1969, 1980, 1981, 1989, 2005 and 2016 the highest values of maximum temperature were recorded more than once. In 1969, the highest annual values were recorded twice in February. In 1980, they were recorded twice in October. In 1981, they were recorded once in February and another in March. In 1989, they were recorded four times in

December. In 2005, they were recorded once in February and again in March. In 2016, they were recorded once in January and in October.

4.2.12. Approach proposed by DMH/DINAC

Using the definition provided by DMH/DINAC, the first step consisted in selecting the time periods when the 95th percentile was surpassed for at least 3 consecutive days. The 95th percentile for this data set is 34.9°C. The second step consisted in determining the occurrence of precipitation during these periods and, subsequently, in analysing the minimum temperatures for periods that fulfilled those conditions. In this sense, 65 heat waves events were identified between 1969 and 2016 (Table A 6).

4.2.13. Approach proposed by SMN

In order to determine heat wave events using the approach proposed by SMN, the 90th percentile of maximum and minimum temperatures was calculated using daily data between October and March of the historical record (1969-2016). The 90th percentile of maximum temperatures is 34.72°C, and of minimum temperatures is 21.9°C. Time periods of at least 3 consecutive days that simultaneously exceeded these thresholds were considered as heat wave events, resulting in 18 events (Table A 8).

4.2.14. Summary of results

As can be seen in Table 6, the maximum value recorded in the triple-border region is around 40°C, and the 95th percentile using the entire historical record is almost the same as the 90th percentile using the historical record between October and March. If the methodology to define heat wave of SMN does not include the “minimum temperatures”, probably the number of heat wave events will be the same as using the DMH/DINAC approach. Nevertheless, the number of heat wave events is similar in each approach using data of both weather stations.

Table 6. Summary of heat waves events.

Heat waves						
Weather Station	**Historial maximum**	**Max. Temp. 95th PCTL[1]**	**# events**	**Max. Temp. 90th PCTL[2]**	**Min. Temp. 90th PCTL[2]**	**# events**
Ciudad del Este (1966-2006)	40.2°C	34.8°C	60	34.8°C	23.5°C	21
Iguazú Aero (1969-2016)	40°C	34.9°C	75	34.72°C	21.9°C	18

[1]Historical record. [2]October to March.

4.2.15. Cold waves

A cold wave is a meteorological event generally characterized by a severe drop of air temperature near the surface leading to extremely low values. It often causes severe impacts on human health, agriculture and generates high heating costs. In extreme cases, it can lead to human mortality, as well as livestock (TT-DEWCE 2016).

According to WMO's Meteoterm vocabulary, a cold wave is defined as a marked cooling of the air, or the invasion of very cold air, over a large area (TT-DEWCE 2016). Moreover, the U.S. National Weather Service defines a cold wave as a rapid fall in temperature within a 24-hour period, requiring increased protection to agriculture, industry, commerce and social activities (American Meteorological Society n.d.).

In the Guidelines on the Definition and Monitoring of Extreme Weather and Climate Events of the WMO, a cold wave is defined in general terms as marked and unusual cold weather characterized by a sharp and significant drop of air temperatures near the surface (max, min and daily average) over a large area and persisting below certain thresholds for at least two consecutive days during the cold season (TT-DEWCE 2016).

Regarding the definitions of these events at regional levels, the DMH/DINAC of Paraguay defines a cold wave as a period of at least 5 consecutive days with minimum temperatures below the 10th percentile of minimum temperatures of the historical record in a specific location (UNDP Paraguay 2017).

The SMN of Argentina defines a cold wave as an excessively cold period during which minimum and maximum temperatures are below certain thresholds that are defined for each location for at least 3 consecutive days. The threshold used by the SMN is the 10th percentile of minimum and maximum temperatures between April and September of each year (Argentinian Meteorological Service n.d.).

The SMN conducted a study in order to analyse cold wave events in Argentina. Due to Argentina's climate characteristics, the SMN has not analysed cold wave events across the extreme Northeast of the country, which includes the provinces of Misiones, Formosa, Corrientes and Chaco. The SMN claims that the minimum temperatures are not low enough compared to the temperatures registered in other more southern areas. Nevertheless, they define a similar type of extreme event related to low temperatures called "time periods with extremely low temperatures" (Argentinian Meteorological Service n.d.).

A time period with extremely low temperatures implies minimum and maximum temperatures that lie below certain thresholds defined by each location which last for at least 3 consecutive days. The threshold used by the SMN is the 10th percentile of minimum and maximum temperatures defined by the historical data between April and September (Argentinian Meteorological Service n.d.). In addition, the SMN conducted an analysis of this type of events using temperature data from Puerto Iguazú between 1961 and 2012. As a result, the monthly distribution and duration were identified. These events have occurred mainly in July, corresponding to winter season and, the average duration of these events is 3 days (Argentinian Meteorological Service n.d.).

There is no specific definition of cold waves in Brazil. The country's National Institute of Meteorology uses the same definition as the U.S. National Weather Service, without specific thresholds and time periods (Brazilian Meteorological Institute (INMET), n.d.). According to the Brazilian Classification and Codification of Disasters (COBADRE), a cold wave is divided into two subtypes, (i) *Friagem* and (ii) Frost. *Friagem* is defined as a period of time of at least 3 or 4 days during which the values of minimum temperatures are below the normal values for one specific area and time period. This definition is similar to the definitions proposed by DMH/DINAC and SMN. On the other hand, frost is defined as the formation of a layer of ice crystals on the surface or on exposed foliage (Superintendence of Protection and Civil Defense of Brazil n.d.).

In order to define cold waves events in the triple-border region an assessment of temperature data recorded by Ciudad del Este Weather Station and Iguazú Aero Weather Station were used. In the analysis we adopted both approaches proposed by DMH/DINAC and SMN to identify any differences. It is important to stress that efforts should be undertaken to homogenize definitions in the future in the triple-border region.

4.2.16. Ciudad del Este Weather Station

The historical record of daily minimum temperatures available in Ciudad del Este Weather Station (Figure A 1 and Table A 1) was used. The time period includes 14,975 days, from January 01, 1966 until December 31, 2006, while there are only 5 missing data points.

Table 7 shows the minimum annual values for minimum daily temperatures. The lowest value recorded was -3°C on July 18, 1975. Furthermore, a positive trend of annual minimum temperatures was detected (Figure 10). Thus, there is an increase in the minimum temperatures recorded each year.

These annual minimum temperatures happened between May and September, covering mainly the winter season (Figure A 11 and Figure A 13). In 1977, 1978, 1979, and 1981 the lowest value for minimum temperatures were recorded more than once. In 1977, the lowest annual values were recorded twice, in May and in June. In 1978, two events were recorded in June. In 1979, these were recorded once in May and another one in June. In 1981, events were recorded twice in June.

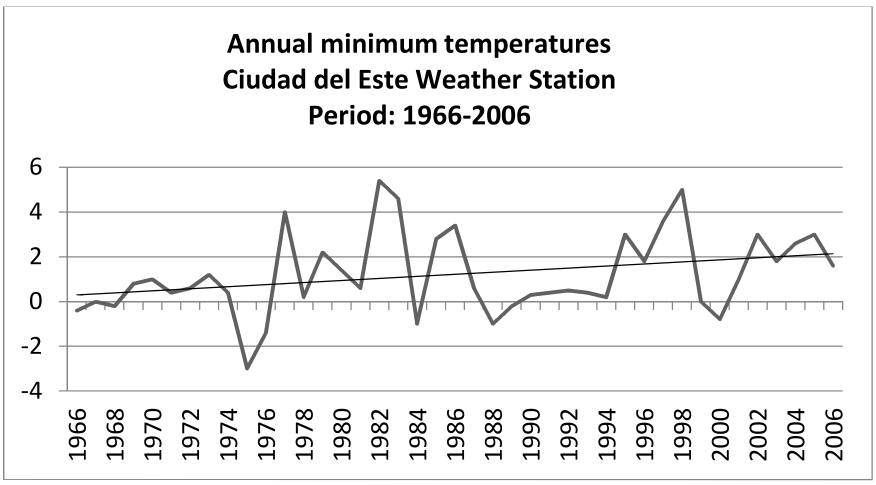


Figure 10. Annual minimum temperatures over the years. Ciudad del Este Weather Station.

Table 7. Annual minimum temperatures. Ciudad del Este Weather Station.

Years	Daily minimum temperature (°C)	Years	Daily minimum temperature (°C)	Years	Daily minimum temperature (°C)
1966	-0.4	1980	1.4	1994	0.2
1967	0	1981	0.6	1995	3
1968	-0.2	1982	5.4	1996	1.8
1969	0.8	1983	4.6	1997	3.6
1970	1	1984	-1	1998	5
1971	0.4	1985	2.8	1999	0
1972	0.6	1986	3.4	2000	-0.8
1973	1.2	1987	0.6	2001	1
1974	0.4	1988	-1	2002	3
1975	-3	1989	-0.2	2003	1.8
1976	-1.4	1990	0.3	2004	2.6
1977	4	1991	0.4	2005	3
1978	0.2	1992	0.5	2006	1.6
1979	2.2	1993	0.4		

4.2.17. Approach proposed by DMH/DINAC

To define cold waves using the definition provided by DMH/DINAC, all periods of at least 5 consecutive days with minimum temperatures below the 10th percentile were selected. The 10th percentile of this dataset is 9.2°C, resulting in 79 cold wave events using the historical record in this weather station (Table A 9).

4.2.18. Approach proposed by SMN

In order to determine cold wave events using the approach proposed by SMN, the 10th percentile of maximum and minimum temperatures were calculated using daily historical data between April and September. The 10th percentile of maximum temperatures is 18°C and of minimum temperatures is 7°C, resulting in 22 cold wave events (Table A 11).

4.2.19. Iguazú Aero Weather Station

To analyze extreme events of minimum temperatures, data from the Iguazú Aero Weather Station (Figure A 2 and Table A 2) were used. The historical record of daily minimum and maximum temperatures was used. The time period includes 17,532 days, since January 01, 1969 until December 31, 2016.

Table 8 shows the minimum annual value for minimum daily temperatures over the years. The lowest value recorded is -4°C, being recorded twice, on July 18, 1975 and on July 12, 1988. In addition, in Figure 11 a positive trend of annual minimum temperatures was determined, indicating that the lowest value of minimum temperature recorded each year is increasing over time.

These annual minimum temperatures happened between May and September, covering mainly the winter season (Figure A 12 and Figure A 14). In 1972, 1980, 1981, 2000, and 2007, the lowest values of minimum temperatures were recorded more than once. In 1972, the lowest annual value was recorded twice in September. In 1980, it was recorded in June and July. In 1981 and in 2000, it was recorded twice in July and, in 2007, it was recorded once in May and another time in July.

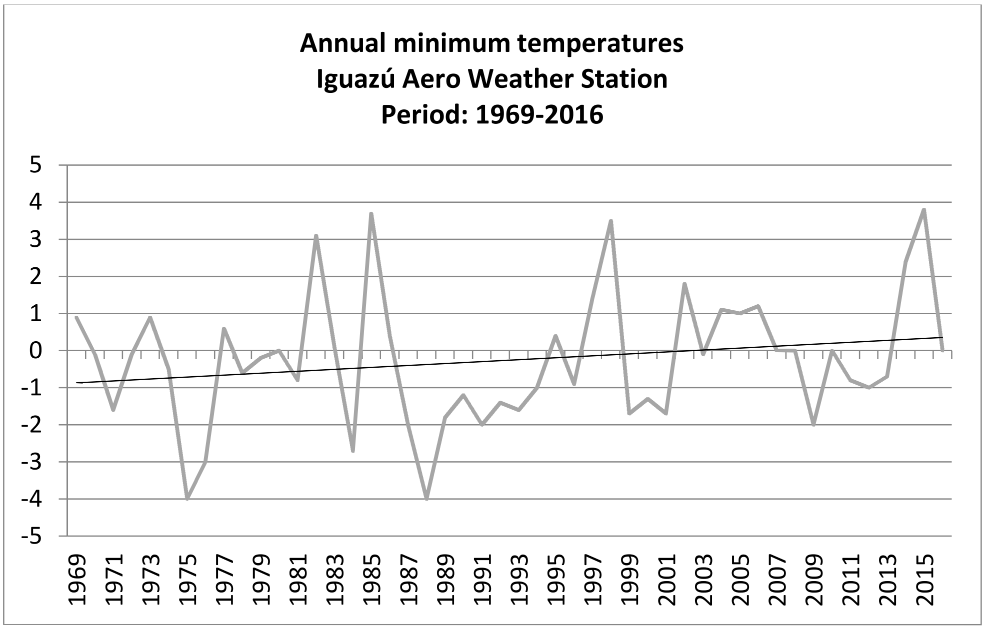


Figure 11. Annual minimum temperatures. Iguazú Areo Weather Station.

Table 8. Annual minimum temperatures. Iguazú Areo Weather Station.

Years	Daily minimum temperature (°C)	Years	Daily minimum temperature (°C)	Years	Daily minimum temperature (°C)
1969	0.9	1985	3.7	2001	-1.7
1970	-0.1	1986	0.4	2002	1.8
1971	-1.6	1987	-2	2003	-0.1
1972	-0.1	1988	-4	2004	1.1
1973	0.9	1989	-1.8	2005	1
1974	-0.5	1990	-1.2	2006	1.2
1975	-4	1991	-2	2007	0
1976	-3	1992	-1.4	2008	0
1977	0.6	1993	-1.6	2009	-2
1978	-0.6	1994	-1	2010	0
1979	-0.2	1995	0.4	2011	-0.8
1980	0	1996	-0.9	2012	-1
1981	-0.8	1997	1.4	2013	-0.7
1982	3.1	1998	3.5	2014	2.4
1983	0.1	1999	-1.7	2015	3.8
1984	-2.7	2000	-1.3	2016	0

4.2.20. Approach proposed by DMH/DINAC

To determine cold wave events using the approach proposed by DMH/DINAC, the 10th percentile of the daily minimum temperatures was calculated, which is 8.7°C. Time periods of at least 5 consecutive days with temperature below this percentile were selected and defined as cold waves, resulting in 84 events over the study period (Table A 10).

4.2.21. Approach proposed by SMN

In order to determine cold wave events using the approach proposed by SMN, the 10th percentile of maximum and minimum temperatures was calculated using daily data between April and September of the historical record. The 10th percentile of maximum temperatures is 17.5°C and of minimum temperatures is 6°C. Hence, time periods of at least 3 consecutive days during which minimum and maximum temperatures were registered simultaneously below these thresholds were considered as cold wave events. This resulted in 30 events over the study period (Table A 12).

4.2.22. Summary of results

As can be seen in Table 9 the minimum temperatures recorded in the triple-border region are around -4°C. In contrast to heat wave events, there is a significant variance in the 10th percentile using the entire historical record as compared to the 10th percentile using the historical record between April to September. Thus, it is important to unify the methodology to define cold wave events over the triangle region.

Table 9. Summary of cold wave events.

Cold waves						
Weather Station	**Minimum historical**	**Min. Temp. 10th PCTL[1]**	**# Events**	**Max. Temp. 10th PCTL[2]**	**Min. Temp. 10th PCTL[2]**	**# Events**
Ciudad del Este (1966-2006)	-3°C	9.2°C	79	18°C	7°C	22
Iguazú Aero (1969-2016)	-4°C	8.7°C	84	17.5°C	6°C	30

[1]Historial Record. [2]April to September.

4.2.23. Floods

In the triple-border region, two types of floods are usually registered: (i) river floods, due increase in river levels, and (ii) urban flooding due to intense precipitation events and changes in land-use caused by rapid and unplanned population growth.

River floods occur mainly due to natural processes that involve water run-off over major river beds. When people occupy these beds, considered as risk areas, impacts due to flooding are frequent. These impacts include material and human losses, an increase in water-borne diseases (e.g. cholera, leptospirosis), disruption of economic activities, and water contamination with toxics substances in certain areas (Tucci 2002).

The expansion of urban areas increases water run-off due to an increase of impermeable surfaces. In addition, high rainfall intensity causes flooding when drainage systems do not have the necessary capacity to handle the amount of rain. The impacts of urban flooding include an increase in sediments, and the contamination of superficial water-flows and groundwater (Tucci, 2002; Cozer et al., 2013). Furthermore, urban flooding often affects houses, causing material damage and roadblocks, which can temporarily interrupt economic activities.

In Ciudad del Este, flood events caused by rising levels in the Paraná River affect people located at floodplains in Remansito and the San Miguel neighborhoods. The Acaraymí stream affects a number of neighborhoods, including San Rafael, San Antonio and San Agustín (Figure 12). Water from the Parana River flows into the Acarymí due to differences in volume, increasing the level of the stream. When the Acarymí stream increases its levels, the neighborhood of Che La Reina is also affected. On the other hand, urban flooding is a common trait in Ciudad del Este, due to intense precipitation events and to an inadequate drainage system. This is worsened by an accumulation of rubbish thrown into the roads, or well due to people taking advantage of the run-off generated by the rainfall to eliminate garbage and other types of waste. It is important to highlight that there have been cases of people having drowned during these urban floods.

In Foz do Iguaçu, major flood events are caused by a rise of the Iguazú and Paraná rivers, mainly affecting the southern neighborhood of Porto Meira, which borders both rivers. In addition, intense precipitation causes an overflow of the M'Boicy River and the Ouro Verde stream. This can trigger flood events affecting houses and blocking roads (Figure 13). Similarly to Ciudad del Este, the combination of an inadequate storm drainage system and rubbish accumulation worsens the situation.

In Puerto Iguazú, flood events associated with major impacts are caused by a rise of the Tacuara and Panambi streams. These problems have been partially solved due to the construction of canals and drainage systems. However, the increase of the level of the Iguazú River affects tourism due to the closing of some trails in the Iguassu Falls Park.

A summary of flood events in the triple-border region is shown in Table 10. In addition, the problematic surface water resources are presented.

Table 10. Summary of problematic surface water resources and main areas affected over the triple-border region.

City	Problematic Superficial Water Resources	Neighborhood Affected
Ciudad del Este	Acarymí Stream.	San Rafael San Antonio San Agustín Che La Reina
Ciudad del Este	Parana River	Remansito. San Miguel.
Foz de Iguaçu	M'Boicy River (rapid response river)	Neighborhoods in the center.
Foz do Iguaçu	Ouro Verde Stream (rapid response stream)	Jardim Morenitas (I and II). Ouro Verde.
Foz de Iguaçu	Iguaçu River.	Porto Meira floodplains.
Foz de Iguaçu	Parana River.	Porto Meira floodplains. Jardim Jupira.
Puerto Iguazú	Tacuara Stream.	People located at the border. San Francisco.
Puerto Iguazú	Panambi Stream.	People located at the border.

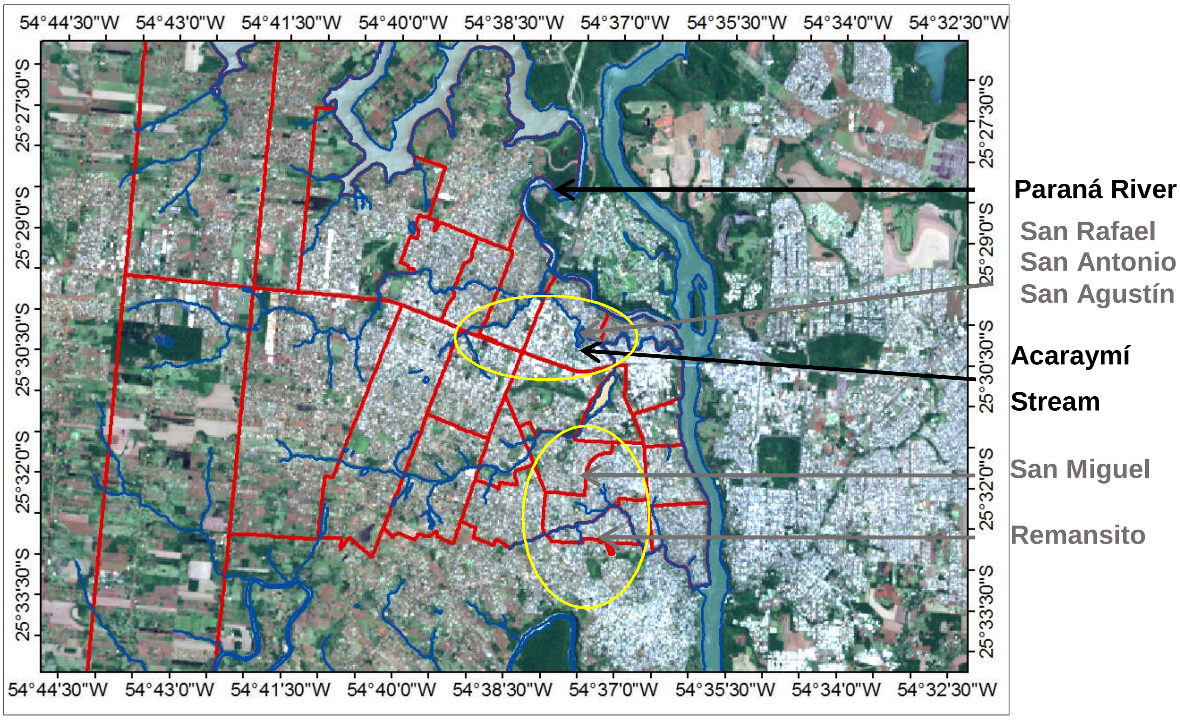


Figure 12. Ciudad del Este, superficial water resources and neighbourhoods. Blue lines: superficial water resources. Red lines: neighbourhood division.

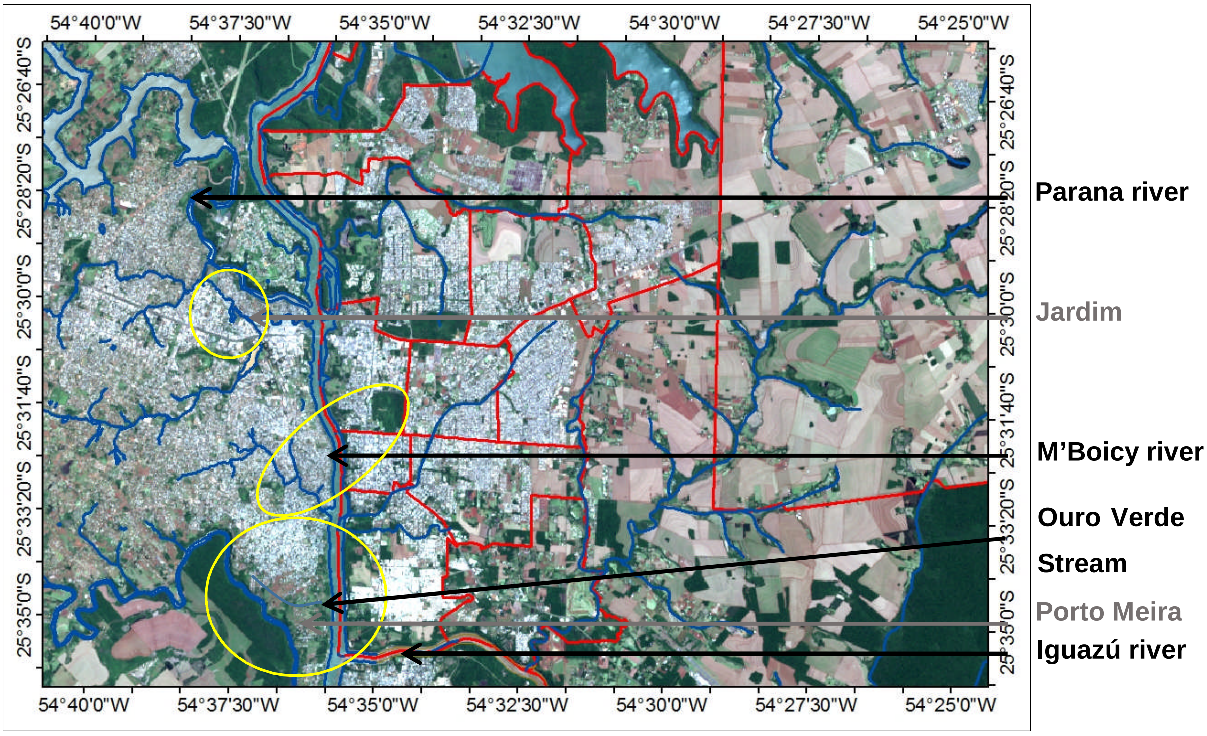


Figure 13. Foz do Iguazú, , superficial water resources and neighbourhoods.
Blue lines: superficial water resources. Red lines: neighbourhood division.

4.2.24. Parana and Iguazú rivers

The most important superficial water resources in the triple-border region are the Parana and Iguazú rivers. Their behavior determines major floods events in the region. The Paraná River has an extension of approximately 4,000km, and its width varies throughout its course. The river source is located in Brazil and its discharge is located at the La Plata River in Argentina. The water catchment approximately measures 1,510,000km^2 (Monte Domecq, et al., 2003) . The daily mean streamflow between 1983 and 2016 registered in Itaipu was 11,723m^3/s. The maximum daily streamflow was 39,790m^3/s (15/June/1983), and the minimum daily streamflow was 6,082m^3/s (10/September/2001) (ITAIPU, 2017).

The Iguazú River is one of the major tributaries of the Paraná, and its source is also located in Brazil. It has an extension of approximately 1,320km (Sarafian 2006). The mean daily streamflow between 1983 and 2016 was 1,925m^3/s, registered at the fluviometric station located at Capanema. The maximum daily streamflow was 28.799m^3/s (10/July/1983) and the minimum was 134m^3/s (12/October/1988) (ITAIPU

2017).

Increments in the level of the Parana River are due to precipitation that occurs during long periods of time. These increments result in a great water volume, although peaks are reached slowly. In contrast, increments in the Iguazú River are mainly due to intense precipitation events that occur in short periods of time, and peaks are reached very fast. The most critical situation takes place when overflows from the Parana River overlap with overflows from the Iguazú River (Monte Domecq et al. 2003).

Table 11 shows the twenty major floods of the Parana River between 01/12/1975 and 30/09/2009, registered in the fluviometric station located at the Friendship Bridge (Superintendência Regional do Paraná 2013). In addition, streamflow levels registered at the R11 fluviometric station, located just beyond the confluence of the Parana and Iguazú rivers, and at the fluviometric station in Salto Cataratas, are presented. Furthermore, an important increase in the level of the Iguazú River occurred in 2013, affecting a great quantity of people and the Iguassu Park was closed. In addition, in 2014, the most rapid hourly increment of the levels of the Iguazú River occurred with similar consequences.

Table 11. Twenty annual major floods between 1976 and 2009 observed in the fluviometric station located in the Friendship Bridge.

Pick data	Friendship bridge (Paraná River)	R11 (Confluence of the Parana River with the Iguazú River)	R11 (Confluence of the Parana River with the Iguazú River)	Salto Cataratas (Iguazú River)
	Level (m)	Level (m)	Flow (m3/s)	Flow (m3/s)
31-05-92	127.70	126.74	49,240	27,510
13-07-83	127.59	126.70	49,176	26,870
24-01-90	122.82	121.41	39,401	9,145
04-02-97	122.37	121.16	38,961	7,955
22-05-87	121.95	121.04	38,760	16,684
29-04-98	119.99	119.04	35,418	14,718
03-12-82	119.82	118.60	34,698	7,815
14-01-95	118.90	117.84	33,481	12,890
04-10-93	118.32	117.30	32,638	11,941
15-02-77	117.07	-	-	2,390
15-09-89	117.02	116.26	31,038	13,996
01-11-05	116.09	110.83	23,463	-
07-03-80	116.01	114.64	28,645	2,390
29-12-81	114.72	113.54	27,081	5,855
15-03-79	114.35	113.39	26,872	11,845
09-02-07	112.84	111.34	24,112	-
23-02-01	112.41	111.40	24,184	6,625
14-10-96	112.24	111.10	23,802	12,674
11-01-84	111.94	110.54	23,073	1,022
23-06-94	111.93	110.89	23,524	7,675

Based on: (Superintendência Regional do Paraná 2013)

4.2.25. M'Boicy River and Ouro Verde Stream

The M´Boicy River and Ouro Verde Stream are problematic surface water resources in Foz do Iguaçu due to rising water levels caused by intense precipitation that trigger flood events. The M'Boicy River is the major urban river that goes through almost the entire city of Foz do Iguaçu, and has its discharge at the Parana River. On the other hand, the basin of the Ouro Verde Stream is located in the southern neighborhood of Porto Meira. The stream starts close to the Horto Municipality (latitude

25°34’19.75’’S, longitude 54°33’39.22’’W), and its discharge is also located at the Parana River (latitude 25°33’42.75’’S, longitude 54°35’36.62’’) (Cozer et al. 2013).

4.2.26. Tacuara and Panambi Streams

The Tacuara and Panambi streams are problematic surface water resources in Puerto Iguazú. The Panambi stream begins at the Los Trabajadores neighborhood. From there, it goes through Santa Rita, Primavera, Unión, San Lucas and Santa Rosa neighborhoods, until it discharges at the Tacuara Stream. The Tacuara Stream starts in the center of Puerto Iguazú and discharges at the Paraná River (TVO Iguazú 2017). Currently, the problems caused by flood events associated with these water resources are partially resolved, as some sections of the Tacuara stream have been channeled. Currently, there is a project to funnel approximately 1,000m of the Panambi stream.

4.2.27. Droughts

A drought is a temporary climate phenomenon, which can differ greatly from other extreme events. Droughts usually develop slowly and steadily, making it difficult to determine the onset and end. Despite its development, droughts can end up being extremely devastating and costly, affecting society, the economy, natural habits, and ecosystems (TT-DEWCE 2016).

Droughts are usually categorized into four general types: (1) meteorological, (2) agricultural, (3) hydrological, (4) and socio-economic (Wilhite & Glantz, 1985; Valiente, 2001; TT-DEWCE, 2016). Meteorological drought is often defined exclusively on the basis of the degree of dryness and the duration of the dry period (Wilhite & Glantz 1985). Thus, it occurs when there is absence or a reduction of precipitation over a period of time in a certain area. This water deficit can lead to impacts to agriculture, resulting in agricultural drought. Hydrological drought occurs when stream-flows of surface or subsurface water supplies are inadequate to supply specific established demands. Moreover, socioeconomic drought is when water shortages negatively affect the economy of a region (Wilhite & Glantz, 1985; Valiente, 2001; TT-DEWCE, 2016).

In the Guideline on Definitions and Monitoring of Extreme Weather and Climate Events of the WMO, drought is defined in general terms as a marked unusual period of abnormally dry weather characterized by prolonged deficiency below a certain threshold of precipitation over a large area and persisting for timescale longer than a month (TT-DEWCE, 2016).

Droughts are critical to Paraguay, Brazil and Argentina because most of their electricity is derived from hydroelectric generation. In the triple-border region, droughts are especially important in Ciudad del Este. The drinking water supply system of this city mainly depends on a small lake called Lake Republic, which is sensible to a decline in precipitation (Figure 14). Furthermore, droughts are important also in Puerto Iguazú and Foz do Iguaçu, since they can have an impact on the Iguassu Falls and consequently on tourism.

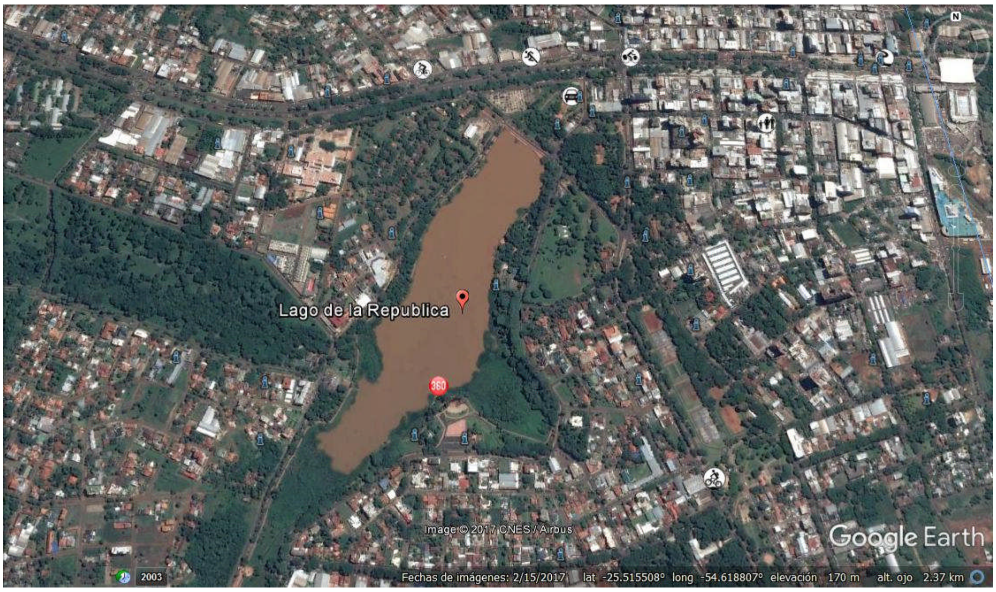


Figure 14. Republic Lake in Ciudad del Este.

In 2014, a study was conducted in order to determine drought events over Paraguay between 1964 and 2011 (Báez Benitez & Monte Domecq 2014). They defined three types of droughts events: (I) Agricultural (at least 3 months with deficit of rainfall), (II) Meteorological (at least 6 months), and (III) Hydrological (at least 12 months). For agricultural droughts, severe to extreme drought occurred in the years 1967, 1968, 1978, 1979, 1986, 1989, 1999, 2000, 2004, 2006, 2007 and 2009. For meteorological drought, severe droughts were encountered in 1967, 1968, 1978, 1988 and 2003. For hydrological drought, severe events were found in years of 1967, 1968, 1978, 1979, 2000 and 2008. Furthermore, the worst drought events occurred in 1967, 1968, 1978, 1979, 1999, 2000 and 2008 (Báez Benitez & Monte Domecq 2014). These results coincide with a study of droughts conducted in Argentina in which the drought event during 2008 was the most extreme recorded between 1960 and 2008 (Rivera & Penalba 2010). Likewise, the results of a study of drought events between 1995 and 2015 in South-eastern Brazil show that severe droughts occurred during this period. Once between October 1999 and August 2000 and, another between February 2014 and November 2014 (Melo et al. 2016). Moreover, a hydrological drought was detected between 2011 and 2012 in the South-eastern Brazil (Melo et al. 2016).

In fact, the early 2000s drought was responsible for a major energy crisis in Brazil, leading to energy-rationing programs (Melo et al. 2016). Moreover, the drought of 2008 generated a huge impact in Ciudad del Este as Lake Republic was dry and, in consequence, there was no drinking water available for the population. In this case, Foz do Iguaçu helped the population in Ciudad del Este, providing additional supply of drinking water. Furthermore, some episodes of drought events were triggered by a reduction in the levels of the Iguazú River. In 2012 and 2014, this decrease caused economic impacts due to a reduction in the number of tourists.

Future Climate Projections

Projeções climáticas futuras

Proyecciones climáticas futuras

5. Future climate projections

5.1. Introduction

Global Climate Models are the most advanced instruments currently available for simulating the response of the global climate system to increasing greenhouse gas (GHGs) concentrations. These models, mostly formed by a set of equations, attempt to represent atmospheric and oceanic physical processes. Thus, projections of the possible evolution of atmospheric and oceanic conditions can be made. It is important to mention that projections derived from these models contain a certain amount of uncertainty, and for this reason they should be regarded guiding tools (Argentinian Meterological Service n.d.).

Many of these future climate projections are underpinned, in turn, by different possible socio-economic scenarios, which imply different assumptions about the future evolution of economic and social variables (Argentinian Meterological Service n.d.). Climate change has become a core feature of many scenarios used in regional and global assessments of environmental and socioeconomic change (Jones, et al., 2014).

These climate models, in spite of being an extraordinary tool to assess the global climate evolution using some specific initial assumptions, should be taken with caution, as they do not necessarily depict a true representation of reality. In addition, the reliability of their results decreases when they are applied to smaller regions (Argentinian Meterological Service n.d.).

5.2. Future Global Climate Projections

5.2.1. Scenarios

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) describes four scenarios of future climate projections (Table 12). "*A* *scenario is a story or image that describes a potential future, developed to inform decision making under uncertainty"* (Jones, et al., 2014). The scenarios used in the AR5 are known as Representative Concentration Pathways (RCPs).

The RCPs are based on selected scenarios from four modeling teams/models, and are named according to their 2100 radiative forcing[5] level as reported by these teams. The radiative forcing estimates are based on the forcing of GHGs and other forcing agents, but do not include direct impacts from land-use change or the forcing of soil particles. Basically, total radiative forcing represents the cumulative human-induced emissions of GHGs from different sources expressed in Watts per square meter (Table 12) (van Vuuren et al. 2011).

The RCPs were used to drive climate model simulations as part of the World Climate Research Programme's Fifth Coupled Model Intercomparison Project (CMIP5) in order to: (I) evaluate how realistic the models are in simulating the recent past; (II) provide projections of future climate change on two time scales, near term (out to about 2035) and long term (out to 2100 and beyond); and (III) understand some of the factors responsible for differences in model projections (Taylor et al. 2012).

[5] Radiative Forcing is the measurement of the capacity of a gas or other forcing agents to affect that energy balance, thereby contributing to climate change (Stockholm Environment Institute n.d.).

Table 12. Summary of four scenarios used in the AR5.

Scenario	Description
RCP8.5	This scenario is characterized by increasing GHGs over time. The emission pathway is representative for scenarios in the literature leading to high GHGs concentration levels. In this scenario the expected average change of temperature is +4°C by the end of 21st century in comparison to the period of reference (1986-2005).
RCP6	It is a stabilization scenario where total radiative forcing is expected to peak after 2100 without overshoot by employment of a range of technologies and strategies for reducing GHGs emissions. It is characterized by a medium baseline of GHGs emissions and high mitigation actions. In this scenario the expected average change of temperature is +2.5°C by the end of 21st century in comparison to the period of reference (1986-2005).
RCP4.5	It is a stabilization scenario where total radiative forcing is expected to peak before 2100 by employment of a range of technologies and strategies for reduction of GHGs emissions. It is characterized by a very low baseline of GHGs emissions and medium-low mitigation actions. In this scenario the expected average change of temperature is +2°C by the end of 21st century in comparison to the period of reference (1986-2005).
RCP2.6	This scenario is characterized by a substantially reduction of GHGs emissions (and indirectly emissions of air pollutants) over time. The emission pathway is representative for scenarios in the literature leading to very low GHGs concentration levels. In this scenario the expected average change of temperature is approximately +1°C to the end of 21st century in comparison to the period of reference (1986-2005).

Based on: (Meinshausen et al., 2011; van Vuuren et al., 2011; Jones, et al., 2014; Alianza Clima y Desarrollo (CDKN), 2014)

5.3. Future Global Climate Change

5.3.1. Temperature

The mean global temperature is projected to increase in the near term (2016-2035) relative to the period of reference (1986-2005). This increase will likely (>66% probability) be in the range of 0.3°C to 0.7°C if no major changes are detected in the energy of the Earth's surface (Collins et al. 2013).

Furthermore, projections of changes in the global mean surface temperature in the mid-term (2046-2065) relative to the period of reference (1986-2005) will likely (>66%) be in a range of 0.4°C to 2.6°C considering all scenarios (Collins et al. 2013). Moreover, from around the mid-21st century, the rate of global warming begins to be more strongly dependent on the scenario. In addition, the projections of changes of the global mean surface temperature in the long term (2081-2100) relative to the period of reference (1986-2005) will likely (>66%) be in a range of 0.3°C to 4.8°C considering all scenarios (Table 13). This global surface warming will also continue beyond 2100 under all RCP scenarios (Collins et al. 2013).

Table 13. Projections of global mean surface temperature for the mid and late 21st century relative to the reference period of 1986-2005.

		2046-2065		2081-2100	
	Scenario	**Mean**	**Likely range**	**Mean**	**Likely range**
Global Mean Surface Temperature Change (°C)	RCP2.6	1.0±0.3	0.4 to 1.6	1.0±0.4	0.3 to 1.7
	RCP4.5	1.4±0.3	0.9 to 2.0	1.8±0.5	1.1 to 2.6
	RCP6.0	1.3±0.3	0.8 to 1.8	2.2±0.5	1.4 to 3.1
	RCP8.5	2.0±0.4	1.4 to 2.6	3.7±0.7	2.6 to 4.8

Based on: Collins et al., (2013)

5.3.2. Water Cycle

On a global scale, relative humidity is projected to remain constant, but specific humidity is projected to increase in a warming climate. In addition, it is virtually certain (>99%) that in the long term, global precipitation will increase along with a rise in global mean surface temperature. Furthermore, it is likely (>66%) that there will be more intense storms and fewer weak storms as temperatures increase (Collins et al. 2013).

Changes in mean precipitation in a warmer world will show significant spatial variations. Increasing and decreasing volumes of precipitation will be registered in different regions, whereas no important variations will be detected in other locations. In addition, contrasts in precipitation between wet and dry regions, and between wet and dry seasons will become more common across the globe as temperatures increase (Collins et al. 2013).

5.3.3. Changes in Climate Extremes

Regarding changes in temperature extremes at a global scale, model projections indicate a significant warming trend by the end of the 21st century. Consequently, increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes are expected. Moreover, the length, frequency, and/or intensity of heat waves will increase over most land areas (Seneviratne et al. 2012).

Furthermore, the frequency of heavy precipitation or the proportion of total rainfall from heavy precipitation will increase over tropical regions by the end of the 21st century (Seneviratne, et al., 2012). In addition, extreme precipitation events will become more intense and frequent as global mean surface temperature increases over mid-latitudes and wet tropical regions. These projected changes in temperature and precipitation imply possible changes in floods patterns. It is possible that projected increases in heavy rainfall will contribute to increase flood events in some regions (Seneviratne et al. 2012).

Finally, with regard to extreme winds events, it is difficult to make a reliable projection due to relatively few studies of projection of this meteorological variable, and also due to limitations in the simulations of these events (Seneviratne et al. 2012).

5.4. South American Climate Projections

5.4.1. Climate Phenomena and Regional Climate Change

Projected major changes in South America include a southward displacement of the South Atlantic Convergence Zone (SACZ)[6]. This displacement will increase the precipitation in the Southeast. In addition, there is a positive trend in the Southern Annular Mode (SAM)[7]. In a positive SAM, the extratropical storm moves through the

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[6] The South Atlantic Convergence Zone (SACZ) is a band of convection, which extends over South America to the South Atlantic Ocean with orientation NW/SE (Pezzi et al. 1998).

[7] The Southern Annular Mode (SAM), describes the north–south movement of the westerly wind belt that circles Antarctica, dominating the middle to higher latitudes of the southern hemisphere (Bureau of Meteorology of the

South, decreasing precipitation in central Chile and increasing it at southern South America (Collins et al. 2013).

Moreover, there is high confidence that the area of the South America monsoon will expand. In effect, it is very likely (>90%) that future increases in precipitation extremes will be due to monsoon systems. Finally, El Niño Southern Oscillation (ENSO)[8] will continue as the dominant mode of inter-annual variability in the tropical Pacific, with global effects in the 21st century. The regional variability of precipitation related to ENSO will likely intensity due to the increase in atmospheric humidity. However, there is little confidence in projections of this phenomenon for the 21st century (Collins et al. 2013).

5.4.2. Projections of changes in temperature and precipitation.

The fifth IPCC Assessment Report presents a summary of projected climatic changes over South America using scenarios from the fourth and fifth AR. Table 14 presents these projections derived from global and regional models for the region, indicating the projected change, emission scenarios, time spans, and references. In general, an increase in the amount of rainfall over the south-eastern part of South America can be observed, and also an increase of extreme precipitation events in terms of intensity and frequency. Moreover, an increase in runoff can be observed. This increase will probably be triggered by the increase of precipitation. Furthermore, an increase in temperature is also expected for the coming years, specifically an increase in the number of warm nights. Likewise, an increase in the number of consecutive dry days can be observed. In contrast, a reduction in the duration of droughts is expected, but an increase in its frequency and severity is projected in the near-term (2011-2040).

Australian Government n.d.).

[8]The El Niño-Southern Oscillation (ENSO) is a phenomenon that involves fluctuating ocean temperatures in the equatorial Pacific, causing global variations in temperatures and precipitation amounts (State Climate Office of North Carolina (US) n.d.).

Table 14. Regional projected changes in temperature, precipitation, and climate extremes in different sectors of South America (SA).

Southeastern South America		
Variable	***Projected changes***	***Reference***
Scenario characterized by a balance in the use of technologies that use fossil fuels and alternative sources of energy in a future world with a fast economic growth (A1B).		
Precipitation, runoff, and air temperature by 2100	Precipitation: +20% to +30% Runoff: +10% to +20% Air temperature: +2.5°C to +3.5°C	(Marengo et al., 2012)
Warm nights, Consecutive dry days (CDDs), and heavy precipitation by 2100	Warm nights: +10% to +30% CDDs: +1 to +5 days Heavy precipitation: +3% to +9%	*(Menéndez & Carril 2010)*
Air temperature and rainfall by 2100	Air temperature: +2°C to +4°C Rainfall: +20% to +30%	*(Giorgi & Diffenbaugh 2008)*
CDDs and heavy precipitation by 2099	CDDs: +5% to +10% Heavy precipitation: +2% to +8%	(Kamiguchi, et al., 2006)
Precipitation in southeastern SA by 2100	Precipitation: +0.5mm/d to 0.5mm/d	*(Sörensson et al. 2010)*
Scenario that describes a very heterogenic world. Economic growth per capita and technology change are different between one region and another (A2).		
Precipitation and temperature in the La Plata basin by 2050	Precipitation: +0.5mm/d to 1.5 mm/d Temperature: +1.5°C to 2.5°C	(Cabré, et al., 2016)
Precipitation during summer and spring, and in fall and winter by 2100	Precipitation: +0.4mm/d to +0.6mm/d Precipitation: -0.02mm/d to -0.04mm/d	(Seth, et al., 2010)
Warm nights, CDDs, and heavy precipitation by 2100	Warm nights: +6% to +12% CDDs: +5 to +20 days Heavy precipitation: +75days to +105days	(Marengo, et al., 2010) (Marengo, et al., 2009)
RCP4.5 and RCP8.5		
Drought frequency, intensity, and duration in SA south of 20°S for 2011-2040 relative to 1979-2008	Frequency: +10% to +20% Severity: +5% to 15% Duration: -10% to -30%	*(Penalba & Rivera 2013)*
RCP4.5		
Temperature for the late 21st century in relation to the baseline period 1986-2005.	Temperature: +0.6°C to 2°C	*(Magrin et al. 2014)*
RCP8.5		
Temperature for the late 21st century in relation to the baseline period 1986-2005.	Temperature: +2.2°C to +7°C (Approximately +4°C)	*(Magrin et al. 2014)*
Precipitation for the late 21st century in relation to the baseline period 1986-2005.	Precipitation: +15% to +20%	*(Magrin et al. 2014)*

Based on: Magrin et al., (2014)

5.5. Climate Projections for the Triple-Border Region

In order to determine climate change projections for the triple-border region, we use the results from an assessment for South America under RCP4.5 and RCP8.5 scenarios. This study was made by the National Institute for Space Research of Brazil. In general, to provide long-term simulations of climate change at a higher resolution, Regional Climate Models are nested in Global Climate Models. In this study, the Regional Climate Model, called ETA, was nested into two Global Climate Models, the HadGEM2-ES and the MIROC5. This analysis was focused on climate change projections for summer and winter. Moreover, future changes were shown in time-slices of 30 years, comprising the near-term (2011-2040), medium-term (2041-2070) and long-term (2071-2100). The period of reference is 1961-1990 (Chou et al. 2014).

An additional study was used to compare and contrast the results of climate future projections. This research is titled “A Climate Analysis using Coordinated Regional Climate Downscaling Experiment (CORDEX) simulations in a cooperation framework: the case of Paraguay”, and was conducted by the Euro-Mediterranean Center on Climate Change of Italy. In this study, the IPCC scenarios (RCP2.6, RCP4.5, and RCP8.5) of the AR5 were used in climate and environmental models from CORDEX to make climate projections over Paraguay. The future changes were shown for the same time periods of the research described above. Nonetheless, in this study the period of reference was 1971-2000, while all seasons were analyzed (Mercogliano, et al., 2017).

5.5.1. Temperature

Regarding changes in temperature, the simulations produced with ETA-HadGEM were more sensitive to an increase of GHGs in comparison to the Eta-MIROC5 simulations. Thus, results show greater values for projected temperatures in ETA-HadGEM in comparison to Eta-MIROC5 (Table 15). Furthermore, results of projections over Ciudad del Este also show increases in temperature for each period and season. In conclusion, all projections show that the temperature will increase over the triple-border region throughout the years (Table 16).

Table 15. Projected changes in temperature over the Triple Border Region.

Models	Time periods	Summer (December-January-February)		Winter (June-July-August)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
ETA-HadGEM	Near term	+2.5°C	+3.5°C	+2.5°C	+3°C
	Middle term	+3.5°C	+5°C	+3°C	+4°C
	Long term	+4.5°C	+9°C	+3°C	+6°C
ETA-MIROC5	Near term	+1°C	+1°C	+1°C	+1°C
	Middle term	+1.5°C	+2°C	+1°C	+2°C
	Long term	+1.5°C	+3°C	1.5°C	+3°C

Based on: (Chou et al. 2014)

Table 16. Projected changes in temperature over Ciudad del Este, PY

Time periods	Spring (September-October-November)			Summer (December-January–February)			Autumn (March-April-May)			Winter (June-July-August)		
	RCP			RCP			RCP			RCP		
	2.6	4.5	8.5	2.6	4.5	8.5	2.6	4.5	8.5	2.6	4.5	8.5
Near term	0.5°C	0.5°C	2°C	0.5°C	0.5°C	0.5°C	0.5°C	0.5°C	2°C	0.5°C	0.5°C	0.5°C
Middle Term	1°C	2.5°C	3°C	1.5°C	2.5°C	3°C	2°C	2.5°C	3.5°C	0.5°C	2°C	3°C
Long term	1.5°C	3°C	4.5°C	1.5°C	3°C	4°C	1.5°C	3°C	4.5°C	1°C	2.5°C	4.5°C

Based on: (Mercogliano, P. et al., 2017)

5.5.2. Precipitation

Regarding the amount of precipitation, simulations with Eta-HadGEM show lower levels of precipitation in comparison to the simulations from Eta-MIROC5. For summer, simulation with Eta-HadGEM shows a reduction of the amount of precipitation for all time periods and scenarios. In contrast, simulations with Eta-MIRO5 show no differences or increases in the amount of precipitation in every time period and scenario (Table 17).

For winter, simulations with Eta-HadGEM show no difference in the amount of precipitation in the near-term period under the RCP4.5 scenario and a reduction of precipitation under RCP8.5 scenario. No changes on the amount of precipitation are found in the medium-term. Moreover, an increase in the amount of precipitation is shown for the period 2071-2100 under both scenarios. In general, simulations with Eta-MIROC5 do not show significant changes on the amount of precipitation for all time periods and scenarios (Table 17).

Likewise, projections for Ciudad del Este show increases in the amount of precipitation under some scenarios and seasons, and decreases under other scenarios and seasons. In general, an increase in the quantity of precipitation is observed in spring for each term under all scenarios. Moreover, it can be observed a reduction in the amount of precipitation in summer in the long-term under each scenario. In autumn no significant changes can be detected, and in winter an increase in the amount of precipitation can be observed under RCP2.6 in near- to long- terms (Table 18).

In conclusion, it is difficult to determine the changes in mean precipitation in the triple-border region, given that these changes depend on the scenario, term, and season. However, it is important to recognize that this region is expected to experience changes in the amount of precipitation in each of terms analyzed. For this reason, water-related solutions must be implemented in order to reduce negative impacts in the future.

Table 17. Projected changes in precipitation over the Triple Border Region.

Models	Time periods	Summer (December-January-February)		Winter (June-July-August)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
ETA-HadGEM	Near term	-1mm/d	-1mm/d	=	-0.5mm/d
	Middle term	-0.5mm/d	-0.5mm/d	=	=
	Long term	-1mm/d	-1mm/d	+1mm/d	+1mm/d
ETA-MIROC5	Near term	=	=	+0.5mm/d	=
	Middle term	+0.5mm/d	+0.5mm/d	=	=
	Long term	+0.5mm/d	+1mm/d	=	=

Based on: (Chou et al. 2014)

Table 18. Projected changes in precipitation over Ciudad del Este, PY.

Time periods	Spring (September-October-November)			Summer (December-January–February)			Autumn (March-April-May)			Winter (June-July-August)		
	RCP			RCP			RCP			RCP		
	2.6	4.5	8.5	2.6	4.5	8.5	2.6	4.5	8.5	2.6	4.5	8.5
Near term	=	20%	20%	=	=	=	=	=	10%	10%	=	=
Middle Term	20%	20%	20%	10%	=	=	=	=	=	+20%	=	==
Long term	20%	10%	30%	10%	-10%	10%	10%	=	==	+20%	-10%	==

Based on: (Mercogliano, P. et al., 2017)

5.5.3. Climate Extreme Indicators

In the research carried out by the National Institute for Space Research of Brazil, four climate extreme indicators based on daily precipitation were calculated for downscaling projections: total annual precipitation (PRCPTOT), the amount of precipitation from days that exceeded the 95th percentile of daily precipitation (R95p), the annual maximum consecutive dry days (CDD), and the annual maximum consecutive wet days (CWD).

The results show no changes in CDD and CWD indicators. However, in Table 19 results of the PRCPTOT and R95P indicators for the triple-border region can be observed. It is important to notice that the amount of precipitation from days that exceeded the 95th percentile of daily precipitation is expected to increase over the years. This indicates that extreme daily precipitation events are going to be more intense across the region over the years.

Table 19. Climatic Extreme Indicators

	PRCTOT	R95P
Near term	-200mm to +150mm	-50mm to +50mm
Mid term	-100mm to +200mm	0mm to +100mm
Long term	-100mm to +500mm	+50mm to +100mm

Based on: Chou et al., (2014).

In order to detect changes in climate extremes, a set of indices defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) was obtained using the RClimdex package of the R programming language. In order to calculate these indicators meteorological data (daily precipitation, daily maximum temperature, and daily minimum temperature) from each city of the triple-border region were used. Moreover, a significance level of 5% was adopted in order to accept or reject observed trends.

Results show that there is a positive trend in the number of summer days (days in one year with maximum temperatures above 25°C), and in the number of tropical nights (days in one year with minimum temperatures higher than 20°C). Moreover, a positive trend was found in warm nights (percentage of days when minimum temperature is higher than 90th percentile). These results show an increase in the temperature throughout the years, and are consistent with the results found in indicators of low temperatures.

A negative trend in the number of frost days (number of day in a year with minimum temperature bellow 0°C) can be observed. Moreover, there is a positive trend in the minimum monthly records of minimum temperatures, indicating that minimum temperatures are rising (i.e. getting warmer) throughout the years. In addition, there is a negative trend in the number of cool days and cool nights. Likewise, there is a negative trend in the cold spell duration indicator.

Regarding the difference between maximum and minimum temperatures, as both temperatures are increasing over the years the difference between them is becoming smaller. Thus, there is a negative trend in the diurnal temperature range, and this is probably happening because of the increase of humidity in the atmosphere.

5.6. Final remarks

The analysis presented in this chapter shows the extent to which climate change is expected to occur over the planet and more specifically over South America and the Triple-Border Region in the forthcoming years. It is extremely important to provide decision makers with the necessary knowledge to make well informed choices, in order to achieve the main goal of making the triple-border region more resilient to the impacts of climate change.

The increase found in precipitation for the coming years, in combination with an increase in deforestation rates that cause a decrease in the evapotranspiration, will trigger changes in hydrologic-related conditions in South America. In fact, significant trends of increasing streamflow were found in the sub-basins of the La Plata River basin (Magrin et al. 2014). Each economic sector in the triple-border region must take into account these variations in their future projects in order to plan accordingly. For instance, companies and government agencies that use water as a resource to generate electric energy must adapt their facilities to those changes, and the tourist sector must analyze how this could affect the Iguassu Falls. In addition, it is likely that this increase in river flows will lead to major floods that will mainly affect people living on flood plains.

Water resource management is a major concern for many cities that need to provide both drinking water and sanitation (Henríquez Ruiz 2009). Particularly, water availability for human consumption, storm drainage systems and flooding are of great concern in the triple-border region. In this context, irregular settlements pose particular challenges to urban governance and risk management given their scale, lack of infrastructure, and socioeconomic vulnerability (Romero-Lankao, et al., 2012).

Regarding food production, it is important to know that climate variability could cause important damages to crops, and could also lead to changes in livestock in the future. Extreme precipitation events, as well as long periods without precipitation, will continue affecting agricultural production. In general, all aspects of food security (food access, utilization and price stability) are potentially affected by climate change (Magrin et al. 2014).

Furthermore, it is important to highlight the relationship between changes in extreme meteorological events and health. Weather extremes changes are affecting human health by increasing morbidity, mortality and disabilities, and through the emergence of diseases in previously non-endemic regions (Winchester & Szalachman, 2012; Rodríguez-Morales, 2011). For instance, weather and climate variability are associated with dengue fever and its hemorrhagic variant in southern South America (Costa, et al, 2010; Viana & Ignotti, 2013). In addition, there are studies that show that increases in temperature and rainfall lead to increases in the quantity of the dengue vector and, consequently, to increases in dengue fever (Gomes, et al., 2012; Viana & Ignotti, 2013) . Moreover, the incidence of viceral leishamaniasis has increased in Brazil, Argentina and Paraguay in association with El Niño and deforestation (Cascio, et al., 2011; Bern, et al, 2008; Ready, 2008).

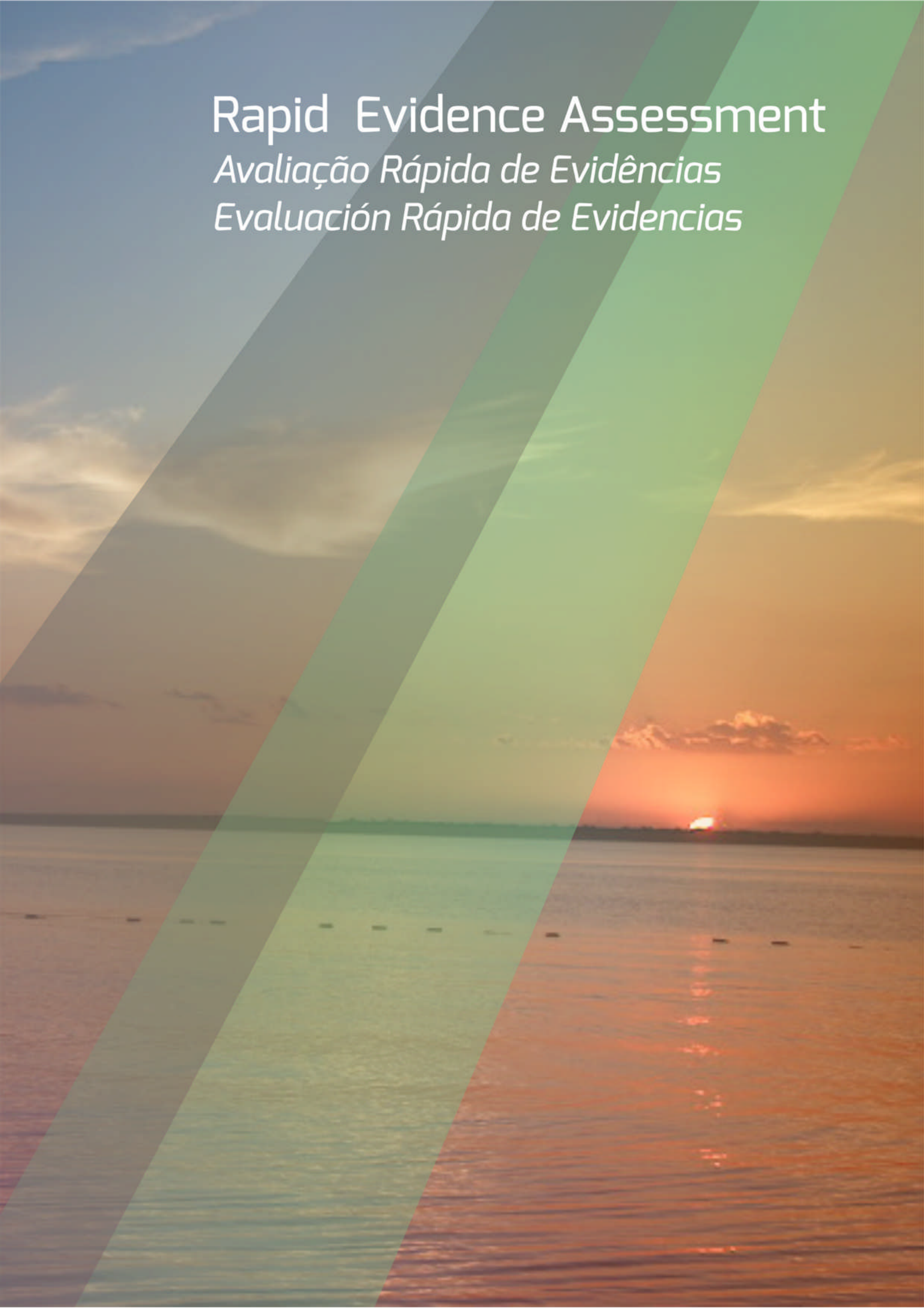
Air pollution and higher temperatures in urban areas are generating more chronic respiratory and cardiovascular diseases, and morbidity from asthma and rhinitis (Grass & Cane, 2008; D'Amato et al., 2013). In addition, heat waves and cold spells have increased urban mortality rates. Heat waves usually kill people by causing myocardial infarction, strokes, respiratory failure and heat stroke (McMichael & Lindgren 2011). On the other hand, in cold weather the human body can lose more energy and this can lead to hypothermia (core temperature below 35°C). Likewise, cold temperatures can cause the narrowing of veins and arteries and blood thickening, increasing cardiac workload and leading to many of the same cardiovascular problems as heatwaves produce (Seltenrich 2015).

In conclusion, the triple-border region is facing different types of problems that in the future can be intensified due to climate change. The first step toward adaptation to climate change is reducing the vulnerability of the cities (Magrin et al. 2014). For instance, health systems, water and sanitation services, waste collection, among many other measures, must be improved in order to make the region less vulnerable to climate change.

Rapid Evidence Assessment

Avaliação Rápida de Evidências

Evaluación Rápida de Evidencias



6. POLICY, LEGAL AND INSTITUTIONAL SETTINGS FOR CLIMATE CHANGE ADAPTATION IN THE TRIANGLE-CITY REGION

In order to identify the differences and gaps regarding policy, legal and institutional settings for climate change adaptation in the triangle-city region, a Rapid Evidence Assessment (REA)[9] was conducted. It considered existing policies, plans and strategies from the three cities, and/or from regional and national levels, when applicable, as well as international cooperation agreements and protocols. It is worth to note that Brazil, Paraguay and Argentina are signatories of the United Nations Framework Convention on Climate Change (UNFCCC) and of Sendai Framework for Disaster Risk Reduction (SFDRR). In that context, the three countries have been advancing on the development of strategies for adaptation and climate risk management, in parallel with climate change mitigation. While analysing such efforts, the REA also highlights the importance of fulfilling the existing gaps, as to achieve more effective adaptation planning and execution in the region as a whole.

6.1. Existing adaptation policies, plans and strategies

The first part of the assessment focuses on the local adaptation settings that exist in each of the three cities, alongside regional and national settings that orient or complement those. It should be noted that in some cases local data was not available, since formal strategies for climate adaptation are still relatively recent in the three countries, as is presented in the following sections.

In general, the risk management approaches identified at the local level regarding extreme weather events are mainly directed to emergency alert and

[9] Such methodology is used to provide a synthesis of evidence on a particular issue, which is more structured than a literature review but not as exhaustive as a systematic review. It can be used to obtain an overview of the density and quality of evidence on the regarding issue, as well as to provide evidence on key topics and to identify evidence gaps, in order to support programming decisions or the commissioning of further research (GDS, 2016).

response, including the identification and monitoring of risk areas. However, efforts towards prevention have also been identified, for instance, in the context of other urban managing instruments, such as infrastructure and drainage studies conducted to implement urbanization and sanitation plans.

6.1.1. Foz do Iguaçu

In Brazil, the guidelines for local adaptation measures are provided by the National Adaptation Plan for Climate Change. Launched in 2016, such plan was developed according to the National Policy for Climate Change and the National Plan for Climate Change, as well as sectoral plans for adaptation and mitigation and the commitments assumed by the country in the scope of UNFCCC. The strategies were divided into 11 themes or sectors, which include Cities and Natural Disasters (MMA, 2016).

The Cities Strategy points out that the vulnerabilities identified at the local level in Brazil regarding climate change vary in many aspects, and these should be taken into account to define adaptation approaches. For instance, cities with 100,000 to 500,000 inhabitants, which is the case of Foz do Iguaçu, tend to present vulnerabilities related to drainage and sanitation, and exposure to risks such as floods (especially in areas of irregular occupation), and spread of waterborne diseases. In that sense, one of the guidelines highlighted in the strategy is the development of a Municipal Risk Reduction Plan, which is foreseen in the City Statute (Federal Law nº 10.257/2001), along with other local planning instruments[10] (MMA, 2016b). In 2013, 90.6% of Brazilian cities didn't have such plan (IBGE, 2014). Up to the present day, as far as it could be investigated, that remains the case of Foz do Iguaçu, although other planning instruments address the subject, as it will be discussed ahead.

The Cities Strategy also recalls the importance of integrating and making the local planning instruments compatible, considering that "[…] all the sectoral plans related to the quality of life in the urbanization process are also instruments of

[10] Those include the Municipal Director Plan, the Hydrographic Basin Plan, the Municipal Environmental Plan, the Local Agenda 21, the Integrated Border Management Plan, the Municipal Solid Waste Management Plan, the Municipal Basic Sanitation Plan, the Mobility Plan and the Local Plan of Social Interest Housing.

environmental planning, which are essential to reduce the sensitivity of the municipalities to future impacts, besides of increasing their adaptive capacity" (MMA, 2016b, p. 73). In that sense, urban expansion, infrastructure, housing, land use and sanitation are also considered strategic points, whose addressment should take climate change aspects into account. In the case of Foz do Iguaçu, although the assessment identified that the city's Directive Plan was renewed in 2016 (PMFI, 2016), it was not possible to go through the document at the time of writing this report, in order to verify how advanced it is in terms of climate adaptation. According to project's informants, recently there have also been efforts to study the city's drainage issues, in order to integrate that in the next version of the Municipal Sanitation Plan, which is not yet concluded.

Likewise, the Disaster Risk Management Strategy indicates the need to strengthen risk reduction measures at the city level. It also presents the guidelines for disaster preparedness and response actions regarding extreme climate events. In Brazil, the institution responsible for implementing these actions is the Civil Defence, which is headed by a national secretary, and relies on organisations at state, regional and municipal levels. The structure is organized under the National System of Protection and Civil Defence (SINPDEC – Sistema Nacional de Proteção e Defesa Civil), which gathers public, private and nongovernmental entities (MMA, 2016b).

Foz do Iguaçu hosts the headquarters of the Regional Coordination for Civil Defence (CORPDEC – Coordenadoria Regional de Defesa Civil), which involves other nine municipalities and is coordinated by the state Fire Department. It's worth to note that in Brazil this is a military institution, although there are civil and voluntary fire brigades organized in different entities. Foz do Iguaçu also has its own Municipal Coordination for Protection and Civil Defence (COMPDEC – Coordenadoria Municipal de Defesa Civil), which is coordinated by the Municipal Secretary of Public Security and the Municipal Guard[11].

As expected in all Brazilian cities, Foz do Iguaçu has a local Contingency Plan of Protection and Civil Defence, which foresees the procedures to be taken in the case of emergencies or disasters related to storms, landslides, floods, overflows, hailstorms and windstorms. The plan identifies areas of attention for each of the events, describing

[11] http://www.geo.pr.gov.br/mapserver/defesacivil/coordenadores/geo.html

risk factors and possible damages at the locations. It presents the registered shelters and resources (vehicles, materials, human resources and voluntary institutions) available to attend any events, as well as the contacts and steps for the plan's activation and mobilization. Moreover, it provides the priorities and the organizational structure for the management of events, known as SCI (Incident Command System – Sistema de Comando de Incidentes). The plan is supposed to be simulated twice a year and revised accordingly. This revision should take into account the plan's compatibility with the ones adopted by other support organisms that might act jointly in the case of an occurrence (Defesa Civil do Paraná, 2017).

Another routine foreseen in the plan is the monitoring of risk factors, such as river levels, which is one of the possible causes to activate an emergency alert. The monitoring manager might as well check or receive alerts from other institutions, as mentioned in the plan, such as SIMEPAR (Sistema Meteorológico do Paraná), which integrates the Civil Defence system, and CENAD (Centro Nacional de Gerenciamento de Riscos e Desastres). Key informants consulted by this project also mentioned CEMADEN (Centro Nacional de Monitoramento e Alertas de Desastres Naturais), CPTEC/INPE (Centro de Previsão de Tempo e Estudos Climáticos/ Instituto Nacional de Pesquisas Espaciais), Itaipu Binacional (which also integrates the Civil Defence) and the radar from Asunción, in Paraguay, among others.

The issue of an alert and activation of the plan happens mainly through telephone and radio, but also through internet, specifically by e-mail and texting applications, such as WhatsApp. Key informants mentioned that an application is being developed and tested specifically for this matter, which might include public use in the future, and that the use of SMS messages is also being studied for that purpose. According to the plan, in case telephone and radio systems are affected in an occurrence, the State Emergency Radio Amateur Network (REED – Rede Estadual de Emergência de Radioamadores) must be contacted as fast as possible. In the SCI, mentioned above, there are also members assigned in communication and public information positions; however, the plan does not detail how the alerts are to be provided to the population.

The Civil Defence system also counts on instruments for registering events at the state and national levels. In fact, one of the guidelines provided by the Disaster Risk Management Strategy of the National Adaptation Plan is the integration of such kind of data banks (MMA, 2016b). In Paraná, the system additionally counts on the support of the University Centre for Disaster Study and Research (CEPED/PR – Centro Universitário de Estudos e Pesquisas sobre Desastres), inaugurated in 2013 in the municipality of Cascavel, 140 km distant from Foz do Iguaçu. One role of the centre is to provide information and education for disaster risk reduction to public and private institutions, as well as to the population in general[12]. According to informants interviewed by the project, the Foz do Iguaçu COMPDEC is trying to implement a CEPED in the municipality. Also, they mentioned a partnership that is under course with CEMADEN to install rain gauges in the municipal area, in order to produce specific meteorological information for the locality.

Moreover, other institutions in Foz do Iguaçu have their own emergency plans, such as the National Iguazú Park and Itaipu Binacional. The municipality is also participating in the United Nations Office for Disaster Risk Reduction (UNISDR) campaign titled Making Cities Resilient – My City's Getting Ready. The city appears on the campaign website, but there are no reports available. It was not possible to corroborate how advanced the city is in developing plans under this framework.

6.1.2. Ciudad del Este

Likewise, in Paraguay, the guidelines for adaptation at city level are provided by the National Adaptation Plan for Climate Change, launched in 2016, with basis on the National Adaptation Strategy for Climate Change[13] released in 2015. It was structured according to the National Policy for Climate Change, the National Development Plan, the National Policy for Risk Management and Reduction and the Environment Secretary Strategic Institutional Plan 2015-2018 (SEAM, 2016).

The document presents crosscutting actions to be conducted in multiple governmental instances, including municipalities, such as the incorporation of climate change aspects in territorial planning and management. It also determines that Paraguayan municipalities shall develop their Local Adaptation Plan for Climate

[12] http://www.ceped.pr.gov.br/modules/conteudo/conteudo.php?conteudo=1
[13] That corresponds to the second part of the National Plan for Climate Change, while the first part, released in 2014, regards the Mitigation Strategy.

Change, presenting the operational structure and the steps for its implementation, as well as the settings for its monitoring, evaluation and updating, which is to happen within periods of five years. Each city is supposed to elect a focal point to care for the plan's accomplishment, although its development must involve the Municipal Board and the Municipal Development Council, as well as key actors from the private sector and civil society, including those that possess local and ancestral knowledge. The priority criteria indicated for the implementation of adaptation measures are: vulnerability, urgency, synergy with mitigation measures, feasibility, flexibility, cost-benefit ratio and efficacy. In this sense, the plan highlights the importance of directing efforts to reduce risks related to climate and increase resilience (SEAM, 2016). However, as far as it could be investigated, Ciudad del Este does not have this specific plan yet. On the other hand, the municipality is working on the development of its urbanization plan, locally known as "Plan Taniguchi", referring to the name of the technical responsible for its elaboration. According to the project's informants, the plan contemplates much of what needs to be done in the city in terms of infrastructure, in every way. Such process started in 2014, but the plan is not yet being implemented.

In addition, the municipality has a local Council for Risk Reduction and Response, whose coordination was assigned to the city's Director of Social Development, Culture, Sports and Tourism. According to the project's informants, the creation of such council was guided by the premises of the Federal Law n. 2615/05, which establishes the National Secretary of Emergency (SEN – Secretaría de Emergencia Nacional) as the federal institution in charge of disaster risk management and reduction. Such law foresees that the immediate responsibility for emergency or disaster attention is of the district's organization, headed by the city Mayor[14]. Indeed, the Municipal Organic Law (n. 3966/10) establishes as a municipality's duty to prevent and care for emergency and disasters situations[15]. According to the project's informants, the council works together with the National Secretary of Emergency, the local organization of the Red Cross, the city's Fire Department and Itaipu Binacional, which is also a member of the Paraguayan National Commission on Climate Change, among other institutions that collaborate on a voluntary basis. Nevertheless, although

[14] http://www.ifrc.org/Docs/idrl/613ES.pdf
[15] http://www.mcde.gov.py/application/files/9014/7636/0617/Ley3966-10OrganicaMunicipal.pdf

the Municipality has a set of procedures on how to act in the case of emergencies, there was no official protocol available for consultation, as far as it could be investigated.

In terms of early warning systems, interviewed informants state that Itaipu Binacional has a key role, since it is supposed to provide notifications to the municipality about the dam levels and flow variations that might cause floods in the city. It was also reported that Itaipu is developing protocols for emergency warning and response, considering information from other points of the basin in agreement with the National Secretary of Emergency. The Fire Department also depends on information provided by the DMH/DINAC (Dirección de Meteorología e Hidrología/ Dirección Nacional de Aeronáutica Civil) that operates at the International Guaraní Airport, in the neighbouring city of Minga Guazú, which sends warnings to the corporation, but this seems to be an informal collaboration, mainly through WhatsApp messages. As in Foz do Iguaçu, telephone and internet texting applications seem to be the main channels used to activate emergency actions, though the Fire Department also uses radio communication. It is important to note that in Ciudad del Este, the firemen work on a voluntary and associative basis.

Paraguay is also investing on the expansion of its hydro-meteorological monitoring and alert network, which is headed by the DMH. In that scope, there are plans of implementing a Regional Meteorology Centre with a unit in Ciudad del Este (PNUD, 2016).

6.1.3. Puerto Iguazú

Argentina, in turn, has its National Adaptation Plan for Climate Change currently under development[16]. Expected for 2019, the document will provide the conceptual and institutional framework for implementing local adaptation plans, in a similar fashion as in Paraguay and Brazil. It is being developed in the scope of the National Cabinet for Climate Change, which was created in 2016, gathering 12 ministries under the

[16] Ludeña, Wilk and Quiroga (2012) mention, however, previous efforts already made in terms of climate adaptation planning in the country, such as the National Strategy for Climate Change, as well as a National Adaptation Program, which included the elaboration of Regional Plans for Adaptation.

coordination of the Ministry of Environment and Sustainable Development (MAyDS – Ministerio de Ambiente y Desarollo Sustentable), together with private, academic and non-governmental sectors. In 2015, a specific Adaptation Directorate was also created under MAyDS, which is conducting studies that will contribute for the structuring of adaptation policies and measures at national, sectoral and local levels (MAyDS, 2016).

However, a previous guide about vulnerability and climate change adaptation for local management and planning was released in 2015, in a joint effort including three institutions: the Sub-secretary of Territorial Planning of the Public Investment, the Sub-secretary of Development and Provincial Advancement and the Secretariat of Environment and Development (currently MAyDS). It points out the priority measures presented in the Second National Communication for Climate Change, which includes infrastructure and land use adaptation, and provides a methodology for incorporating the climate component into the local planning. This encompasses how to identify vulnerabilities, risks and potentials for adaptation in each location (SAyDS, 2015). Nevertheless, as far as it could be investigated, Puerto Iguazú doesn’t count on a specific management instrument for climate adaptation to present day.

In terms of emergency preparedness and response, the municipality rests on a local Civil Defence structure. That structure is headed by the Mayor and directed by a member of the Fire Department, which is, as in Ciudad del Este, a voluntary institution. A member of the brigade acts as Chief of Operations, and a member of the municipal hospital holds the position of Community and Sanitary Emergencies Director. The army, the gendarmerie and other forces might also act jointly. The Civil Defence is responsible for identifying, analysing and mitigating possible risks, as well as for emergency action planning and conducting, as well as for the rehabilitation of the public services in the affected areas. The procedures to be taken for each kind of emergency are described in the local Contingency Plan, which foresees measures for floods, traffic accidents with multiple victims, occurrences with dangerous substances, fires, airport incidents and mass casualties (Benítez, 2010). In the case of a flood emergency, for instance, the fire brigade is responsible for safeguarding the affected population, while the Social Action department of the municipality provides safe shelters for people. Depending on the occasion, the local Civil Defence might ask for help from the provincial one who, in turn, might recur to the federal one.

The local Civil Defence also has an established communication protocol. It determines the daily collection of data such as meteorological conditions, roads and public services situation, which can signal the need for action. The information should be verified, organized and archived, as well as exchanged with others organisms. The available communication channels are also supposed to be checked daily and repaired accordingly. In addition, the protocol presents the organogram for activating emergency procedures (Benítez, 2010).

Regarding early warning systems, interviewed informants report that the local Civil Defence might get alerts from its provincial counterpart, as well as from the National Meteorological Service (SMN – Servicio Meteorológico Nacional), the Puerto Iguazú International Airport and the radar of the Brazilian municipality of Cascavel, through radio communication and WhatsApp. It is worth to note that the province of Puerto Iguazú is the only one in Argentina that possesses an environment organism with ministerial rank: the Ministry of Ecology and Renewable Natural Resources of Misiones (Ministerio de Ecologia y Recursos Naturales Renovables de Misiones)**.** Among the measures that this institution has been developing towards climate change adaptation is the implementation of contingency plans and early warning systems[17].

6.2. International Cooperation Agreements and Protocols

The second part of the assessment is focused on the formal settings and instruments already developed in terms of cooperation among the three cities or countries, especially regarding alert and response systems towards disasters and emergency occurrences. It is worth noting that the spirit of cooperation in the triangle-region has been evoked by different initiatives over the years, such as the signature of an integration agreement known as Acta de Santa Maria del Iguazú in 1984. Although not frequently used (Kouwenhoven, 2014), the document aims to strengthen the bonds of good neighbourliness in the frontier, facilitating the commercial, touristic, cultural, educational, sanitary and social exchange, and promoting the wellbeing of the communities, among other issues.

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[17] http://www.ecologia.misiones.gov.ar/ecoweb/index.php/cambio-clima/acciones-de-adaptacion-y-mitigacion

Moreover, it is important to mention the Tripartite Agreement for Technical and Operational Cooperation among Itaipu and Corpus, which was signed by Paraguay, Brazil and Argentina in 1979. Such document establishes rules and principles for the exploitation of the water resources in the region. It highlights, among other points, the commitment to avoid damage and maintain the conditions of seaworthiness, ports operation and environment preservation, as well as the suitability of the use of successive watercourses to the non-causation of damages to any other State in the basin (SAE, 2013).

Another agreement signed in 2005 by Brazil and Argentina foresees cooperation measures for boundary localities such as the frontier between Foz do Iguaçu and Puerto Iguazú. That includes the elaboration of joint urban development plans, aimed not only to integrate infrastructure and services, but also regarding environmental conservation and recuperation, as well as to the strengthen common cultural identities[18]. In 2017, a complementary adjustment was added to the document, regarding the provision of emergency assistance services and cooperation on civil defence. Its functioning is based on the designation of focal points in each locality, with established rules about the circulation of assistance teams and vehicles on the other part of the territory. Each country should guarantee, for instance, that the professionals have all their rights, insurances and benefits safeguarded when acting on the foreign locality[19].

Another framework agreement on environment has been signed at national levels in the scope of Mercosur, in 2001, to which an additional protocol regarding cooperation and assistance to environmental emergencies was added in 2004. According to it, the cooperation should occur, for instance, through exchange of information and experiences, joint planning for risk reduction and response, provision of technical and logistical support between countries and training of human resources. Likewise, the protocol guides the designation of focal points in each country, and determines how the parties should establish compatible procedures in the case of environmental emergencies, describing the standards for notification and request for assistance among them[20].

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[18] http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/decreto/D8636.htm
[19] http://www.itamaraty.gov.br/pt-BR/component/tags/tag/1?start=570
[20]http://www.mre.gov.py/v1/Adjuntos/mercosur/Acuerdos/2004/espanol/71-

It is worth to note that, according to the project's informants, several cooperation measures already exist at local level, although not on a formal basis, as it will be further discussed in the next sections of the report. The firemen and other members of the Civil Defence from the three cities, for instance, are said to take joint training and collaborate with personnel and resources in the case of emergencies. Informants also stated they keep communication through radio and WhatsApp groups for alerts. Indeed, that seems to have been stimulated by the meetings held in the project, since local actors mentioned the need for more exchanging opportunities with their neighbouring counterparts. Nevertheless, there have been advances in order to institutionalize such cooperation, as in an existing partnership proposal among the three Fire Departments (SEAE, 2017).

6.3. Differences and gaps in institutional and legal settings

Since the specific settings for adaptation are relatively recent in the three countries, what can be noticed is that, at the local level, formal initiatives in such sense are still incipient. None of the cities in the triangle-region have, at present, managing or legal instruments regarding climate change adaptation itself. However, the development of those is foreseen in the three countries' national adaptation plans. Although Argentina is currently developing its plan, there have been efforts to guide local managing, as previously described. In the three countries, similar guidelines are offered for such purpose, focusing on the assessment of local vulnerabilities and risk reduction measures, especially related to territorial ordination, land use, sanitation and infrastructure. Another common guideline is the incorporation of climate change factors in all instances of urban managing and development. That offers an opportunity for joint adaptation planning among the cities, as recommended in existing cooperation agreements, which can raise the resilience capacity among all parties.

Regarding disaster prevention and response, on the other hand, the institutional settings in the three cities present several differences. The municipalities are the ones that coordinate the actions in all locations; however, the governmental instances in

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protocoloadicionalalacuerdomarcosobremedioambientedelmercosur-emergenciasambientales.pdf charge of these matters vary: in Foz do Iguaçu, they are in the sphere of control of the Public Security Secretariat and the Municipal Guard; in Ciudad del Este, of the Council for Risk Reduction and Response; and in Puerto Iguazú, of the Mayor and the firemen. Indeed, the Fire Department plays an important role in the three cities warning and response procedures, being organized distinctly in each of them. While in Foz do Iguaçu that is a military institution maintained by the state, in Ciudad del Este and Puerto Iguazú it relies on voluntary work. According to the project's informants, due to this issue, the brigade in Foz do Iguaçu possesses more resources and equipment than the two others. In addition, it was possible to identify formalized contingency plans only in Foz do Iguaçu and Puerto Iguazú.

Anyhow, the possible integration of the alert and emergency activation systems used by the three cities could raise effectiveness to all parties. It’s important to recall, however, that transboundary cooperation already exists in that sense, since the cities receive information from foreign radars such as the ones in Asunción and Cascavel, and cooperation initiatives among the fire brigades and the Civil Defence are also mentioned by the informants, although they do not recur to protocols already established at national levels, such as the Mercosur initiative. In fact, some of these protocols seem to be unknown by local actors. Another point that deserves attention is that such integration must include all possible communication channels, especially radio, as it is less likely to be affected by an occurrence.

Based on the assessment, it is possible to verify that the existing formal settings and cooperation agreements can be further explored to strengthen climate change adaptation in the triangle-city region. That represents a great opportunity, since one of the possible obstacles for cooperation can be institutional or legislation rigidity. In this case, on the contrary, there are established settings that favour integration and synergy for climate adaptation, which can potentiate and optimize actions towards the resilience of the region as a whole. Although there are cooperation measures that already work based on informal arrangements, their institutionalization would be important to guarantee that the same standards are followed independently of changes in government functions and structures. Thereby, specific agreements at the local level can represent an interesting pathway, such as the mentioned partnership that is under discussion among the Fire Departments of the three cities. In the scope of Mercosur, the recently created Work Subgroup 18, which regards frontier integration, may be another opportunity to develop that kind of setting, as pointed out by local actors.

Socio-economic vulnerabilities

Vulnerabilidades socio-econômicas

Vulnerabilidades socio-económicas

7. SOCIO-ECONOMIC VULNERABILITIES TO EXTREME WEATHER EVENTS IN THE TRIANGLE-CITY REGION

The complexity of today's problems, particularly in global environmental change, where natural and social sciences have a role to play in the understanding of the problem, calls for the use of multiple approaches. This study used a mixed-method approach to understand the vulnerability of the triangle-city to climate variations and extremes. By combining quantitative and qualitative viewpoints, thus valuing both objective and subjective knowledge, it is hoped to provide a better picture of the cities.

The first section of this chapter sets the ground for the assessment by offering some definitions so as to clarify what is aimed to be assessed: the vulnerability of the three cities Foz do Iguaçu (Foz), Ciudad del Este (CDE) and Puerto Iguazú (PI), to extreme weather events. Section 6.2 presents the quantitative analysis, and section 6.3 the qualitative analysis.

7.1. Conceptual framework

An assessment of the vulnerabilities to climate variations and extremes must start with a clear idea of what is it to be assessed. Vulnerability has a long tradition. A number of authors have followed its evolution and have suggested that it has been a powerful analytical tool along the years (see (Adger 2006; Eakin & Luers 2006; Füssel & Klein 2006; Janssen & Ostrom 2006; Cutter et al. 2003; Brooks et al. 2005; Brooks 2003; O'Brien et al. 2007; O'Brien, Eriksen, et al. 2004). Vulnerability is a contested term and no consensus has been achieved regarding a universally accepted definition (Carter et al. 2015). Vulnerability to climate change is broadly understood to be in direct and indirect relation to biophysical and socioeconomic aspects (O'Brien et al. 2007). The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report suggests a typology in which vulnerability is "*The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt*" (Scott et al. n.d.). Exposure, is "*The presence of people, livelihoods, species or ecosystems,* *environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected*". Adaptive capacity: "*The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*". And, coping capacity is "*The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term*". The definitions come from (Agard et al. 2014).

Different interpretations of vulnerability have implications on the assessment of the results and, consequently, on the recommendations for policy-makers (Kelly & Adger 2000; O'Brien, Sygna, et al. 2004)[21]. In essence, the understanding of these terms affects the type of adaptation that is promoted, influencing the decisions on how to operationalize the adaptation process (O'Brien et al. 2007). Therefore, to avoid misunderstandings and taking the IPCC 5AR, vulnerability is understood here as a phenomenon which encompasses the sensitivity of a city[22], i.e. the inherent social, economic and environmental characteristics of the city, which are exposed to a certain climate related event, to which the city reacts to (copes), and adjust to prevent future damages (adapts). In this manner, the level of vulnerability of a city will depend on its coping capacities (the current ability to respond to the short-term effects of an extreme climate-related event) and its adaptive capacities (the longer-term capacity to plan for preventing and/or managing the impacts of climate change).

Following (Hernandez-Montes-de-Oca 2013), this study makes a differentiation between coping and adaptive capacities, because by differentiating coping and adaptive capacities one can identify different needs and ways in which the cities can become resilient. Coping and adaptive capacities can be summarized as a greater

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[21] Similarly, different interpretations of resilience can lead to different pathways, thus is crucial to not neglect framing in climate change adaptation (Sakai & Dessai 2015)

[22] We are taking the starting point, or contextual, vulnerability defined by (O'Brien et al. 2007) in which vulnerability is a multidimensional and processual interaction between climate and society. Consequently, reducing vulnerability encompasses adjustments oriented to make individuals respond and adapt to the new conditions (O'Brien et al. 2007). Whereas there is another trend, that is to take vulnerability as end-point, or outcome: "Vulnerability as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, and concluding with biophysical impact studies and the identification of adaptive options. Any residual consequences that remain after adaptation has taken place define the levels of vulnerability (Kelly & Adger 2000; O'Brien et al. 2007)" (Agard et al. 2014). We believe that the starting point vulnerability provides a wider comprehension of the phenomenon as root causes can be unveiled.

capacity of action by a city to reduce its risk by decreasing their vulnerability. For this reason, a vulnerability assessment usually considers the capacities of cities to react and respond to climate events (e.g. are there plans to adapt to climate change in the city? How many resources for disaster prevention are allocated? Are there coordinated plans for the three cities? Is there technical and organizational capacity to reduce risks?).

There are various methods and frameworks to assess vulnerability, in Latin America for example, CDKN initiative has study vulnerability in many ways (Tehelen & Pacha 2017). The assessment of each component of vulnerability (sensitivity, exposure, coping and adaptive capacities) can be made by means of different methods, each of which has its own features. Interviews or focus groups tend to be more suitable for the assessment of adaptive capacity (Kuhlicke et al. 2011). On the other hand, scenario approaches or modelling have been suggested as being more applicable for the assessment of sensitivity (Tapia et al. 2015). Mapping vulnerability (Adger, 2006), mathematical model, taking into account the expected value of sensitivity (Luers *et al.* 2003). An indicator-based approach, has been widely used in vulnerability assessments. Despite the lack of consensus, one part of the vulnerability research community has claimed that the use of indicators is "*a theoretically sound and technically feasible way of assessing vulnerability*" (Moss *et al.*, 2001:63). An important aspect that needs to be taken into account is that quantitative indicators cannot describe all aspects of climate change vulnerability[23]. For that reason, this study also consider qualitative approaches to unveil aspects that quantitative indicators cannot reveal. The next section presents the quantitative analysis followed by the qualitative analysis of vulnerability of the triangle-city region.

7.2. Urban Vulnerability Index (UVI)

The objective of this section is to present a set of indicators, which allow the

[23] This issue is further complicated by limited data availability, especially when using the same indicators for cities from different countries. In many cases, indicators are not reported in the same units or formats, or they might simply be inexistent. These gaps can limit a comprehensive vulnerability assessment. For this reason, caution was exercised in the selection of specific indicators, ensuring whenever possible that they were available and consistent between different urban contexts.

assessment of the three cities in terms of their vulnerability and capacity to cope and adapt to climate related events. The development of such indicators serves as a useful exercise not only to understand the vulnerabilities at a city level, but also to provide a first indication of what actions are needed and where these have to be implemented. Moreover, these indicators offer a practical approach to compare and communicate the different situations of the three cities, and represent a starting point for further and more in-depth evaluations.

As mentioned above, an indicator-based approach is recommended for the assessment of exposure and vulnerability, and in relation to urban vulnerability indicators, the European Environmental Agency recommends that their development and communication require careful explanations as to what the indicator means and for which purposes it can or cannot be used *Jacobs et al. (2012)*. Swart *et al.* (2012) listed a number of benefits of using urban vulnerability indicators for supporting decision-making by a range of stakeholders at different levels, and as a basis for the adaptation-learning process. With caution, four of those can be applied to our case study: 1) Identifying specific developments in regards to lessons that can be learned (national level); 2) Offering input to policy-effectiveness assessments as a measuring and monitoring tool (national level); 3) Getting an indication on the reigning situation in each of the cities in the tri-border region (local level); 4) Encouraging further investigation of the situation with more detailed local data and knowledge (local level). In practice, all indicators have to be developed and interpreted carefully, as they could deliver an incomplete message.

7.2.1. Methodology

This research project, in this sense, has developed a set of indicators to operationalize our framework, i.e. the definitions presented in section 6.1. This framework was also designed so it can be applied for regular reporting, given that data is collected and provided in a timely and continuous manner. The framework focuses on specific climate change challenges, such as temperature, precipitation (including hail and wind), floods and droughts. Indictors for climate change vulnerabilities not specifically related to urban issues were not considered (e.g. crops sensitive to drought or hail).

The Urban Vulnerability Index (UVI) is based on the sequential implementation of a number of analytical steps shown in Figure 15. It starts with the characterisation of the different dimensions and sub-dimensions of vulnerability, which represent the most important themes to be measured based on an in-depth literature review. The next step in the sequence involves the development of a data model able capture the different elements of each dimension. A set of interviews were conducted to, among other purposes, collect qualitative data from strategical stakeholders when quantitative information was not readily available. The sequence then leads to the generation of a well-structured database. The data were subsequently classified and pre-processed. An internal consistency check was performed, based on measures of reliability. Once the data were revised, indicators were aggregated for each dimension. Then, all dimensions were later combined to create an index.

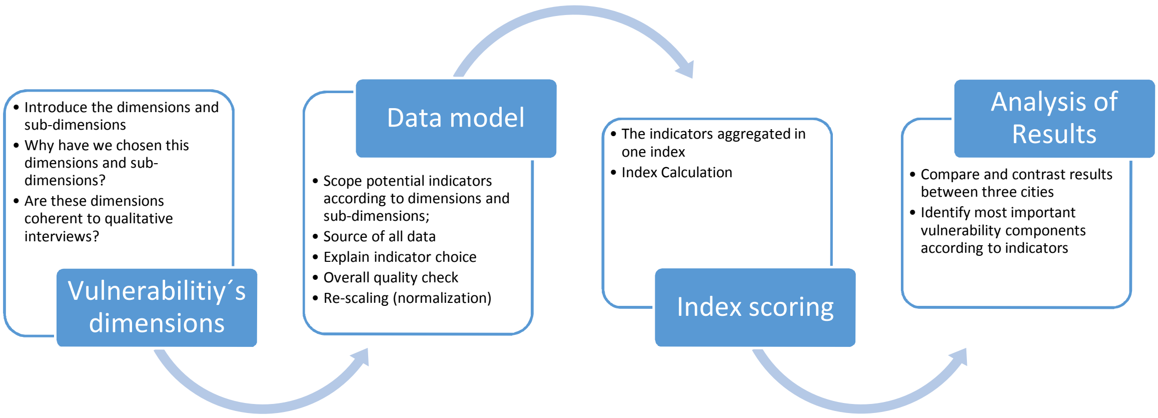

Figure 15. Analytical sequence followed

7.2.2. Vulnerability Dimensions

As mentioned above, applying the framework described in section 6.1, indicators for sensitivity, coping and adaptive capacity were developed. In practice, the study operationalises the definitions at a local level to help understand how different factors influence a city's vulnerability and provides a starting point for further in-depth studies.

In order to develop the UVI, we assumed that the cities' vulnerability is fundamentally associated with people, things and places, regardless of whether they experience a hazard that could cause damage (Carter et al. 2015). Thus, it is expected that systems would be affected, positively or negatively depending on their sensitivity, by climate change hazards given their exposure. It is assumed that the cities would properly respond to these changes if they have sufficient adaptive capacity to adjust. Therefore, the UVI integrates the sensitivity and adaptive capacity dimensions.

Measuring urban sensitivity encompasses, among others, a city's physical, social and economic factors (EEA 2012; Carter et al. 2015). In this research, the physical dimension consisted of the Land Use and Infrastructure factors (called sub-dimensions), based on the assumption that cities with better distribution of green and red spaces (i.e. built-up) within urban areas are less sensitive to the most important climate threats on the city (floods and high temperatures)[24] (Gábor & Jombach 2009; Klok et al. 2012; Swart et al. 2012). The quality of the strategical infrastructure sub-dimension was selected to provide indicators about built environment quality, focus on housing, emergency and transport infrastructure, considered as proxies for the city´s ability to maintain its crucial external public services after climate events. The main potential vulnerability of the built environment to climate change is from extreme events (Hunt & Watkiss 2011).

Social factors consisted of levels of human and social capital to support a better human development and the inherent sensitivity of the population. Human and social capital provide basic information on the capacity for communities in the city to engage in collective social activities and to support their well-being. Human and social capital were represented by access to the education and health systems, water availability, security, inequality and vulnerable population. Some population groups are more sensitive to climatic events (heat and flood) than others. For example, senior citizens aged 65 years and over are more sensitive to heat. There are also important physical factors that affect people with low incomes and young children, such as the quality of buildings, green structures and accessibility to public green and blue spaces. Some of the relationships between types of infrastructure and social sensitivity, however, were

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[24] We do not include other important land use features, such as urban population density, because there is not available information in the same format and unit for the three cities.

not examined in this study and we recommend that future research should be undertaken in this area (EEA 2012).

Economic factors involve economic diversification, public finances and characteristics of the business sector. The diversification of economic activities provides a proxy of the ability of a city to shift to other sources of income in reaction to adverse climatic conditions affecting its main activity. Public finance provides an indirect measure of the sensitivity of the city to any extra expenditure due to a climatic impact. Finally, the business sector is an indicator of the robustness of the economic aspects of a city.

The development of a comprehensive set of indicators that capture responses (and capacities to adapt to) to all possible types of events is neither completely feasible nor desirable. City-level data is often unavailable and the relationship between some of the existing indicators and the message they can provide sometimes is weak. Instead, we opted for more generic indicators, which are relevant for several climate hazards. In these sense, we were cautious to select indicators that were appropriate across at least two of the climatic threats mentioned by key informants during the fieldwork (e.g. heat and flooding).

To measure adaptive capacity, which is the ability of the urban areas to respond to climate change hazards, the sub-dimensions were divided into preparedness, response, recovery, networks, awareness and planning, capacity to change and cooperate. Together, these sub-dimensions represent a proxy for anticipatory adaptation, as well as the ability to respond to, cope with or recover from the climate hazards as they happen.

Direct measures of the dimension for coping and adaptive capacities are difficult to find, due to the relative novelty of the adaptation agenda in the region and, hence, there are few examples of adaptation measures that have been implemented. It has been acknowledged that coping capacity, which represents the potential for adaptation, rather than the actual long-term response, may be easier to measure (Adger et al. 2004). Nonetheless, although high coping capacity may not directly translate into efficient disaster management, measuring coping capacity helps to approximate how places are likely to deal with climate hazards. It is useful in comparing how different cities may face a changing climate (Swart et al. 2012).

7.2.3. Data model

A comprehensive literature review allowed the researchers to build a generic list of indicators that could be used within the assessment. *In total, 15 sub-dimensions and 73 different types of indicators were identified*. Table 20 summarises these findings:

Table 20 - Categories of indicators used in the study to assess city vulnerability to climate change

Dimension	Sub-dimension	Indicator
Physical Attributes (Sensitivity)	Land use (LUS)	Area of land devoted to urban sprawl and forest areas
	Strategical Infrastructure (IFR)	Type of materials mostly used for construction of average formal housing (roofs, structure, etc.) (e.g. concrete, wood, metal, etc.)
		Quality of existing main infrastructure in the city (bridges, roads, public buildings, water distribution, etc.) - (e.g. well maintained, fair, in need of repair, etc.)
		Number of public bus lines or other public transport services. Average price for one-way ticket, Motorization rate, Number of Public Transport Modes, Roads extension by urban area, Number of local TV and radio networks
Social Attributes (Sensitivity)	Demographic structure and dynamics (DEM)	Population, Population density, households, age composition, gender and labour force
	Poverty (POV)	Percentage of low income population, Percentage of the population living in slums
	Well-being (WBE)	Percentage of households with access to clean water supply, Percentage of households with access to waste water system, Percentage of households with access to waste disposal, Mortality rate, Childhood Mortality Rate, Childhood Mortality Rate – under 5 years, Percentage of illiterate people, percentage of children under age 17 in education, number of murders and crime rates, Gini inequality index
Economic Attributes (Sensitivity)	Size and diversification (SND)	Gross domestic product (GDP), GDP shares (%) of agriculture, industry, services and government
	Public Finances (FIN)	Public budget (spending), Municipal debt
	Business Sector (BUS)	Number of businesses, Business environment (simplicity to conduct business activities, legal settings, taxes, access to markets, etc.)
Coping Capacity (Capacity)	Preparedness (PRE)	Government budget targeting preparedness, Existence of official early warning systems, Existence of disaster risk reduction plans or strategies
	Response (RES)	Quality of medical services, quality of formal medical emergency services, quality of informal medical emergency

		services, number of emergency response services
	Recovery (REC)	Existence of Recovery funds, Existence of insurance systems, Insurance dissemination, Existence of financing mechanisms to recover
Adaptive Capacity (Capacity)	Networks (NET)	Number and quality of main (more important) formal institutions (public and private) that exist in the city (e.g. fire department, civil defence, police, etc.)
	Awareness and planning (ANP)	Existence of Climate Change adaptation plan
	Capacity to change (C2C)	Simplicity/Difficulty to implement policies, willingness to learn from other cities (existence of policy copied from other cities)
	Cooperation (COO)	Number of cooperation agreements with other cities

The vulnerability indicators in Table 20 illustrate the characteristics of potential receptors of extreme climate events in terms of their sensitivity to disruption and their capacity to resist, cope or adapt to them. The vulnerability indicators were categorised into two groups that influence vulnerability in opposite directions, namely ‘sensitivity’ and ‘capacity’. Indicators that are based on the same background variables and characterise contradictory or mutually exclusive socioeconomic, environmental or social trends have been included only once in the data model, either within sensitivity or within the adaptive capacity category. It is a general criterion to avoid redundancy. For example, the share of soil sealed area and share of total green area are mutually exclusive indicators. Thus, we decided to choose the indicator of green areas, represented by forested areas.

The main selection criteria were data coverage and comparability, rather than precision and accuracy. In order to increase data coverage, a flexible approach was adopted with regard to temporal and geographical harmonisation as far as possible. In practice, this implied that the indicators were collected for the last available year over the period from 2002 to 2016. In the absence of a city level dataset, geographical harmonization implies the use of transformations of regional values into city-level values.

Social and economic indicators of vulnerability rely heavily on existing datasets, many from the countries’ census databases. These databases provide official and good comparable sets of indicators, despite they present some slight differences in temporal and geographical units. In some cases, we transformed their scales using other available indicators that show correlation between the regional and municipality levels. For example, the Gross Domestic Product (GDP) of Ciudad del Este is not reported neither by the municipality, the state-level authorities nor the national office for statistics, but we did find the value for the Department of Alto Parana. We thus scaled down the provincial value to the municipality level according to GDP per capita, which is a common assumption.

An important limitation in this indicator-based vulnerability comparison has been the scarcity of comparable data needed to characterise cities along some specific dimensions of vulnerability, which has been acknowledged in several other studies (Vinchon et al. 2011; Swart et al. 2012; Tapia et al. 2015). In this case, it represented a complex matter, given that the comparison involved three cities in three different countries.

In particular, there is a lack of comparable data to assess the degree to which cities are aware and are already taking specific steps towards climate change adaptation (coping and adaptive capacity). As a result, some proxy indicators were used to provide relevant information on this dimension. A city's commitment to adapt, for example, was verified through the existence of on-going direct or indirect adaptation measures.

When quantitative data were unavailable, qualitative information collected through interviews had to be used, taking advantage of a broad identification of stakeholders. Some of these strategical stakeholders were personally interviewed using a semi-structured format or were invited to answer an online survey with open- and closed-ended questions.

In total, 73 indicators were collected or constructed and included in the data model. These indicators were selected following quality-based criteria on relevance and interpretability (in accordance to the literature), coverage, and reduced redundancy (i.e. avoiding indicators that measure similar trends). A summary of each indicator in the data model and its correspondent threat and source are provided in the Appendix A (Table A 1 and Table A 2).

Data preparation was carried out on all dimensions: sensitivity, coping and adaptive capacity indicators based on a three-step sequence:

- Quality check: indicators were visually checked for atypical values. Any inconsistent value (e.g. values expressed in the incorrect scale) were removed;

- Imputation of missing values: missing values were imputed through Single Imputation (median substitution), as a simple operational way of reducing bias;
- Re-scaling of variables: For simplicity, variables were further re-scaled to a new scale ranging from 1 to 10, based on the minimum and maximum values.
- In the case of qualitative variables, most of them belonging to coping and adaptive capacity, the minimum value used corresponded to the answer that leads to the most vulnerable situation. For instance, the answer to the indicator “existence of recovery funds” that leads to the most vulnerable situation is “No”, so the value of 1 was assigned.

Table B 1 (Appendix B) summarizes the maximum and minimum values for all variables, and presents the re-scaling formula used for each indicator:

7.2.4. Index scoring

The UVI aims to show the features of each municipality in terms of their sensitivity to climate impacts and their ability to resist, confront or adapt to them. The UVI permits inter-city comparisons creating a scale of priorities for adaptation action. The index comprises a set of indicators divided into three sensitivity dimensions and two adaptive capacity dimensions. Each municipality has its own UVI_m, which is calculated by the average of the Sensitivity Index (SI_m) and the Capacity Index (CI_m) (Appendix C - Equation 1). Different from other studies that use complex calculations (Tapia et al. 2015), a simple approach was opted for reasons of simplicity and to easily communicate relationships between sensitivity, adaptive capacity and vulnerability. The UVI_m ranges from 1 (lowest vulnerability grade) up to 10 (highest vulnerability grade).

The SI_m comprises a linear aggregation of eight sub-indices, one for each sub-dimension: Land Use, Strategical Infrastructure, Population, Poverty, Well-being, Size and Diversification, Public Finances and Business Sector (Appendix B - Table B 1). The SI_m is calculated by arithmetic mean of re-scaled indicators ranging from 1 (lowest sensitivity grade) up to 10 (highest sensitivity level) (Appendix C -Equation 2). The CI_m comprises a linear aggregation of seven sub-indices for each sub-dimension: Preparedness, Response, Recovery, Networks, Awareness and Planning, Capacity to Change and Cooperation (Appendix B - Table B 2). The CI_m is also calculated as the arithmetic mean of re-scaled indicators varying from 1 (highest adaptive capacity grade) up to 10 (lowest adaptive capacity grade) (Appendix C - Equation 3).

7.2.5. Analysis of Results

The UVI was applied to the three municipalities under study. The results can be seen in Table 21. Foz do Iguaçu has the lowest value (3.64), indicating a lower level of vulnerability. Both the Sensitivity (2.92) and Capacity (4.35) dimensions show low values, compared to the other cities. Higher UVI values were found for Ciudad del Este (7.51) and Puerto Iguazú (7.49). A closer examination shows that their vulnerabilities is explained by high values for certain factors. Both cities present high Sensitivity (6.91 and 6.34) and levels of Capacity that are lower than Foz (8.11 and 8.65). Results for Puerto Iguazú indicate that more factors explain its high sensitivity and the existence of features that might potentially decrease its Coping and Adaptive Capacities.

Table 21 – Results of the Urban Vulnerability Index (UVI) and its compounds for Foz do Iguaçu (BR), Ciudad del Este (PAR) and Puerto Iguazú (AR)

	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Urban Vulnerability Index	**3.64**	**7.51**	**7.49**
Sensitivity Index (SI)	**2.92**	**6.91**	**6.34**
Capacity Index (AC)	**4.35**	**8.11**	**8.65**

Dimension	Sub-dimension	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Physical attributes (Sensitivity)	**Land Use**	1.86	10.00	2.05
	Strategical Infrastructure	3.70	5.14	6.57
	Physical Index	**2.78**	**7.57**	**4.31**
Social attributes (Sensitivity)	**Population**	5.69	9.16	3.20
	Poverty	1.00	6.03	9.23
	Well-being	2.34	6.05	6.50
	Social Index	**3.01**	**7.08**	**6.31**
Economic attributes (Sensitivity)	**Size and diversification**	1.86	4.98	10.00
	Public finances	1.00	10.00	9.72
	Business sector	6.07	3.25	5.50
	Economic Index	**2.98**	**6.08**	**8.41**
Coping Capacity (Capacity)	**Preparedness**	4.00	10.00	10.00
	Response	6.00	7.00	10.00
	Recovery	4.00	7.00	7.00
	Coping Capacity Index	**4.67**	**8.00**	**9.00**
Adaptive Capacity (Capacity)	**Networks**	1.91	2.91	3.18
	Awareness and planning	10.00	10.00	10.00
	Capacity to change	3.25	10.00	10.00
	Cooperation	1.00	10.00	10.00
	Adaptive Index	**4.04**	**8.23**	**8.30**

The UVI is not exhaustive, in the sense that it does not include all potential aspects that can influence the vulnerability of municipalities. There are several features that were not addressed in this work. For example, vulnerabilities depend on the exposure of a given system and the intensity of hazards. Depending on these aspects, any system can be vulnerable. The UVI does not capture these because there is no assessment of hazard, exposure, and vulnerability. In addition, the index shows a static condition, ignoring the temporal evolution of each indicator. Thus, the analysis presented here represents an initial approach and can be useful as benchmark for future comparisons. Further more thorough initiatives are welcome. We describe in the next section the results obtained for each municipality and the main factors that influence their vulnerability.

7.2.6. Sensitivity

The **Physical Attributes** indicates that CDE presents a larger sensitivity than PI and Foz. The index is 7.57 for CDE, 2.78 for Foz and 4.31 for PI. Land Use is the most important factor for CDE, followed by "built environment" (Appendix D – Table D 1).

Table 22 – Physical Attributes Index Scoring

Sub-dimension	Factor	Indicator	Foz	CDE	PI
Land Use	Land Use	% of Urban Areas	31%	98,30%	15%
		% of Forest Areas	45%	1,2%	35%
Strategic Infrastructure	Built environment (type and quality)	Material	Masonry with concrete foundation	Masonry with concrete foundation	Masonry with concrete foundation
		Structure	Wood	Wood	Wood
		Roof Design	Box Gable	Box Gable	Box Gable
		Roof Material	Fibrocement	Clay roof tiles	Metal tiles
	Quality of infrastructure	Bridges	Median Good	Median Good	Median Good
		Roads	Median Bad	Median Good	Median Good
		Fire Departments	Good	Median Good	Good
		Police Station	Median Good	Median Good	Good
		Public Schools	Median Good	Median Good	Median Good
		Hospital	Median Good	Median Good	Median Good
		Civil Defence	Median Bad	Median Good	Median Good
		Waste	Median Good	Median Bad	Median Bad
		Water	Median Good	Median Bad	Median Bad
		Energy	Median Good	Good	Median Bad

Diversity and affordability of transport networks	Number of public bus lines	44	6	8
	Average price for one-way ticket*	1.06	0.45	0.94
	Motorization rate **	399.73	143.62	147.70
	Number of Public transport Modes	3	3	4
Communications local TV and radio stations	(Number of local TV and radio networks)	11	7	5

* Current US$

** (cars/people)*1,000

The **Land Use** indicators for Foz and PI depict substantial green areas (45% and 35%, respectively), which lie beyond the urban areas and belong to three national parks (Parque Nacional Iguazú, Parque Provincial Puerto Peninsula, Reserva Nacional Iguazú). Despite these massive forest clusters, there are few green areas inside the urban zones. On the other hand, CDE does not have any significant green areas (1.2% of the municipal territory).

Highly-urbanized areas without sufficient green spaces are important factors for the so-called 'Urban Heat Island'[25] (UHI) effect, which involves topography, high building mass, presence of impervious cover, and structures that hinder ventilation. The analysis considers the total forest area as a proxy for its distribution, since the cities' sensitivity to heat depends not only on the share of green areas, but also on their distribution throughout urban areas. This provides a reasonable initial estimate for sensitivity at the city level and can also provide an overview on potential hotspots.

Even relatively small towns, such as Foz and CDE, can experience a considerable UHI (Steeneveld et al. 2011). Urbanisation and human activities essentially alter the balance between the energy from the sun absorbed by the surface, then stored in the building mass and later released to the surrounding air (IPCC 2014). Most notably, the cooling effect of vegetated surfaces is replaced by the storage of

[25] 'Urban Heat Island' (UHI) describes the increased temperature of the urban air compared to its rural surroundings. The temperature difference can be up to 10 °C or more (Steeneveld et al. 2011).

heat in surfaces such as concrete, asphalt and stone. In this sense, cities can show sensitivity to impacts associated with high temperatures, depending on a number of factors.

The proportion of urbanized areas was used as a proxy for sensitivity to floods. In this respect, CDE and Foz were considered to be more sensitive. Low-lying human settlements in flood-prone areas increases the potential damage derived from extreme precipitations. Although human activities are very diverse in the three cities, the occupation of -flood prone areas close to rivers and large urban areas with surface sealing tend to aggravate flood hazards by accentuating flood peaks.

The sensitivity of **strategical infrastructure** to climate extreme events comprises determining factors that may vary by city and region, such as age, material composition and design (Boyle 2013). These determining factors were considered in the analysis in the form of qualitative indicators for the built environment (households) and general public views on the general condition (and level of maintenance) of infrastructure. The affordability and diversity of public transport and communications were also determined based on a quantitative assessment. The results indicate that Foz and CDE are similarly sensitive, while PI registers lower levels.

In regards to “built environment”, answers for “type and quality of houses” were similar in the three cities. Masonry-built houses with superficial foundation are predominant in the three cities, which confers resistance to climatic events. On the other hand, the interviews indicated that wood structured roofing is the most common type of roof in the three cities, which is less sensitive to extreme winds. According to the interviews, the predominant type of tiles in the cities of Foz (fibre cement), PI (Zinc) and CDE (Ceramics) offer protection to winds and heavy rains (Figure 16). However, during the hail storm of 2015 these tiles showed low resistance to hail, especially those made with fibre cement and ceramic.

Zinc tiles in Puerto Iguazú, Foz do Iguaçu

Regular Masonry Construction with Gable Roof and fibrocement tiles, Foz do Iguaçu.

Figure 16. Picture of common roof in Foz do Iguaçu and Puerto Iguazú

The quality of strategical infrastructure was deemed as being predominantly ‘median good’ in the three cities, according to interviews. The maintenance of road infrastructure (streets, avenues and bridges) was considered ‘median good’ as well, although in Foz the condition of streets was considered to be ‘median bad’ (Figure 17 shows some examples of strategical infrastructure in Foz do Iguaçu). The inadequate maintenance of roads and bridges increases the sensitivity to extreme climate events, such as winds and floods. Furthermore, maintenance of infrastructure (Table 23) was considered to be ‘median good’, which is not enough to indicate that they are not sensitive to extreme climate events. Finally, the structure of waste collection and disposal, and water supply in CDE and PI, and the energy supply infrastructure in PI are precarious according to the interviews, which indicates that these services can be significantly sensitive under climate emergencies. Figure 17 shows pictures of the general condition of representative infrastructure.

The cities’ public transportation services also presented some differences in quality, despite the different city scales. The three cities has the same public transportation modes: bus (predominant) and boat (occasionally and informal). Despite the greater coverage of public system transport networks in Foz (44 routes available, while CDE has 6 and PI has 8), their ability to effectively meet demand was not evaluated. Information on numbers of people that use the public system was not available either. On the other hand, the one-way price ticket is more expensive in Foz, which might influence the affordability of the system. Foz has a higher motorization rate (399 cars by every 1000 people) which, combined to expensive public transport system, can encourage a greater use of private cars for daily commutes, which influences the sensitivity of a city.

Social attributes indicate that CDE and PI share similar sensitivities. The Social Aggregated Index is 7.08 for CDE, 6.31 for PI and 3.01 for Foz (Appendix D – Table D 2). Population and Poverty indices are the most vital sensitivity factor for CDE and PI. Access to water and sanitation, and the health indicators are crucial to both cities, indicating an unbalanced public service supply between the cities.

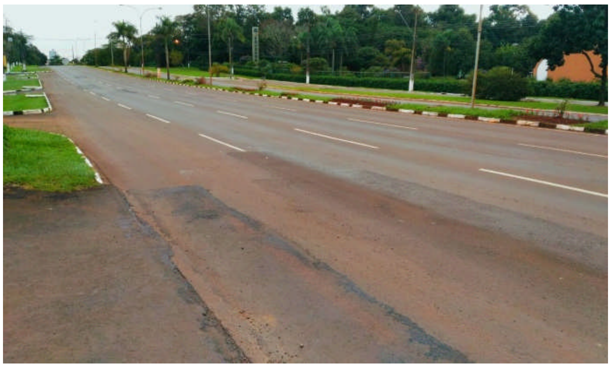
Table 23. Number of Strategic Infrastructure by city

Strategical Infrastructure	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Bridges	15	n.a.*	9
Highways	3	n.a.	(50 km)
Fire Department	4	5	7
Police Station	5	n.a.	5
Public Schools	75	n.a.	40
Health Infrastructure	50	40	5
Civil Defence	1	n.a.	1
Sewage Treatment Plant	10	0	1
Water Pump Station	10	1	3
Energy Site Substation	4	2	2

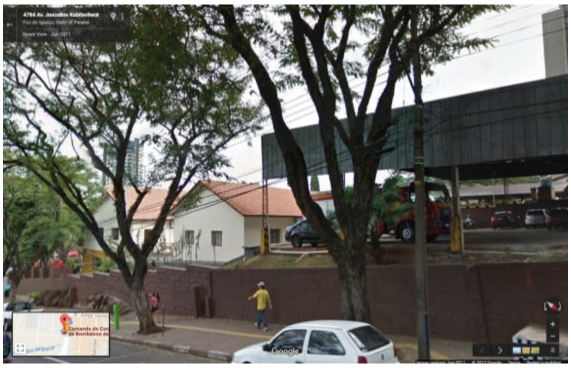
* No answer (n.a.)

(a) Rio M´Boicy Brigde, Foz do Iguaçu.

(b) Rio M´Boicy Brigde, Foz do Iguaçu.



(c) Av. Cataratas, Foz do Iguaçu.



(d) Fire Department, JK, Foz do Iguaçu.

(e) Public School, Foz do Iguaçu.

(f) Foz's Health Infrastructure.

(g) Sewage Treatment Plant, Foz do Iguaçu.

(h) Energy Site Substation, Foz do Iguaçu.

Figure 17. Examples of Foz do Iguaçu´s strategical infrastructures

Table 24. Social Attributes Indicators

Sub-dimension	Factor	Indicator	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Population	Population	Number of people	256,088	296,597	42,849
	Population density	Population density (pop/km²)	415	2,852	1,128
	Households	Number of households	79,161	47,536	11,386
	Sensitive groups	% of people with more than 65 and from 0-14	30.5%	35.6%	35.3%
	Labour Force	Number of people	133,547	166,223	28,230
Poverty	-	% of low income population	7.4%	9.2%	23.0%
		% of the population living in slums	2.5%	25.7%	22.0%
Well-being	Water	% of households with access to clean water supply	99.6%	30.0%	69.0%
		% of households with access to waste water system	99.9%	30.4%	21.0%
		% of households with access to waste disposal	99.1%	52.2%	90.0%
	Health	Mortality rate (by thousand people)	5.80	11.87	6.00
		Childhood mortality rate (by thousand new borns)	15.48	46.24	10.40
		Childhood mortality rate – under 5 years old (by thousand new borns)	17.10	15.70	12.60
	Education	% of illiterate people	5.1%	5.8%	23.0%
		% of children under 17 years old in school	85.6%	85.0%	83.0%
	Security and rule of law	Crime rate	1,227	114	3,995
		Murder rate	14.8	25.89	5.9
	Inequality	Gini Index	0.545	0.506	0.415

CDE's large population, high population density, and a large group of people older than 65 and children (aged 0-14) are important factors that explain its sensitivity (Table 24). Despite PI's smaller population, it has an important proportion of sensitive population, which confers it a higher vulnerability. This group can be particularly affected by water scarcity, droughts and increased temperatures. In the case of heat waves, senior citizens (over 65 year old) can be more sensitive to heat because of their intrinsic changes in their thermo-regulatory system and because of the use of drugs that can interfere with normal homeostasis. Children and babies also have on average a limited ability to thermo-regulate and are also more at risk of dehydration than adults.

When water availability is associated with affordability, low-income households constitute another sensitive group. Especially after extreme-weather impacts, low-income groups spend a considerable amount of their income on securing water and on recovering their homes. CDE and PI have important portions of their populations living in slums (25.7% and 22.0% respectively, while Foz has 2.5%), which usually are exposed to floods and other hazards. Proportionally, PI has a larger poor population among the three cities (23% of all population) (Table 24).

The set of well-being indicators illustrates important factors that influence PI and CDE's vulnerability to extreme climatic events. CDE's population has low access to essential services, such as water (30% of the population has access), health (11.87 mortality rate and 46.24 infant mortality), education system (5.80% of illiterate people), insecurity and income inequality (Gini income inequality index of 0.506) (Table 24). Likewise, PI presents the same challenges combined with poor access to sewage treatment (only 21% of households have access to this service). The lower performance for the set of indicators of well-being indicates that these cities already display a series of sensitivities to several threats, not being restricted to the climatic ones. Therefore, any new threats can put their population at risk, making them more sensitive to an uncertain climate change.

Climate events affect not only households. They quite often also have severe impacts on businesses and entire industries. The impact usually takes place on three different levels. The first one relates to the immediate physical impact on business premises (e.g. factory, office, etc.), including building structures, interiors and equipment. For instance, after a storm, businesses cannot operate until flood waters have receded and their premises are restored to a functioning level. This results in a second level of impacts, such as losses in production. A car company, for instance, will no longer be able to produce cars (outputs) and will face monetary losses. This might lead to a third and more indirect level of impacts due to a productivity decline throughout the entire supply chain, as suppliers might no longer be able to produce outputs on which other industries depend. Small cities with poor economic diversification, with small budgets for a fast response and without a strong business sector, can be more sensitive to climatic threats.

The economic attributes indicated, in general, low economic diversification and low public investment, although they suggest there is a good business environment. The aggregated index is 8.41 for PI, 6.08 for CDE and 2.98 for Foz (Appendix D – Table D 3). PI´s larger number may seem to indicate that its greater sensitivity is due to its size (its GDP is 14 times smaller than Foz's), and to the fact that it is fundamentally based on tourism (70% of the GDP). PI has a low public budget and a small business sector. All these factors suggest that PI's economic vulnerability is more significant compared to the other cities (Table 25). On the other hand, Foz's indicators show evidence of a more robust and diversified economy (stronger industry and services sectors) that may support its capacity to withstand climate disturbances. Foz's public budget, greater than the sum of CDE's and PI's, also indicates a lower sensitivity to economic disturbances, since the city has more resources to respond to climatic stress.

Table 25. Economic Attributes Indicators

Sub-dimension	Factor	Indicator	Foz	CDE	PI
Size and diversification	Economic size	Gross domestic product (GDP 2014 – current US$* 1,000)	2,675,248	730,815	172,567
	Economic diversification	Agriculture	0,65%	31.00%	2.00%
		Industry	48.63%	15.00%	25.00%
		Services	38.39%	49.00%	70.00%
		Public	12.34%	6.00%	1,00%
Public finances	Public accounts	Municipal budget (current US$ 1,000)	204,118	7,829	13,942
Business sector	Business vitality	Number of businesses	6,999	15,000	2.245
	Business environment	Simplicity to conduct business activities	Median	median	low

* Current US$ used to covert local currency: 1 USD = R$ 3.26 = 15.98 Pesos = 5,595.97 Guaraníes
**GDP for CDE was scaled-down using Alto Parana's GDP 2010 based on GDP per capita.

The indicators show that the relative importance of tourism in the economies of Foz and PI can explain their potential economic sensitivity to extreme climate events that affect tourist activities, such as floods or severe droughts. Foz's more diversified economy, however, does not limit potential damages. The presence of the Itaipu Hydroelectric Plant, on the other hand, is an important source of business diversification and financial resources for the municipal government.

Economic indicators also show that PI has a more sensitive economic structure.

The droughts registered in May and June of 2006, for example, drastically reduced the water flow in the Iguaçu River and created restrictions to tourism in the Iguassu Falls National Park. In this sense, long periods of climate anomalies represent a threat to the economic structure of both cities. On the other hand, CDE is based heavily on commerce and is sensitive to extreme events that impact its dense commercial activities or its access to other regions.

7.2.7. Capacities

7.2.7.1. Coping Capacity

The results derived from the qualitative indicators related to Coping Capacity suggest, in general terms, low levels of preparedness, response and recovery. Specifically, PI and CDE were considered to have a lower coping capacity. There are indications of insufficient levels of preparedness to reduce damages associated with climatic events, and these are related to the lack of government budgets for preparedness measures, no early warning systems and no Disaster Risk Reduction (DRR) plans or strategies. The absence of these three factors suggests an insufficient capacity to prepare against extreme climatic events, since this does not allow the complete disaster management[26] cycle (A. Lavell et al. 2012). Regarding response factors, emergency medical services were also considered inadequate in PI and CDE. The indicators show that the quality of formal and informal medical emergency, and response services is inadequate. The results suggest that health and emergency systems are already facing other external pressures and that extreme events might add extra burden to an already vulnerable system.

Although Foz seems to be comparatively better off in terms of preparedness and response factors, the lack of early warning systems and a low municipal budget for preparedness measures indicate an inadequate capacity to respond against extreme climatic events. The results derived from the qualitative indicators related to Coping Capacity suggest, in general terms, low levels of preparedness, response and

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[26] Disaster Management is “the body of policy and administrative decisions and operational activities which pertain to the various stages of a disaster at all levels.” (A. Lavell et al. 2012)

recovery Table 26.

Table 26. Economic Attributes Indicators

Sub-dimension	Indicator	Foz	CDE	PI
Preparedness	Existence of government budget targeting preparedness	Yes	No	No
	Existence of official early warning systems	No	No	No
	Existence of disaster risk reduction plans or strategies	Yes	No	No
Response	Quality of Medical Services	Good	Bad	Very bad
	Quality of formal medical emergency services	Good	Bad	Very bad
	Quality of informal medical emergency services	Very bad	Bad	Very bad
Recovery	Existence of recovery funds	Yes	No	No
	Existence of insurance systems	Yes	Yes	Yes
	Insurance dissemination	Low	Low	Low
	Existence of Financing mechanisms to recover	Yes	No	No

Foz has an institutional structure that allows the use of direct financial resources from the Municipal Treasury to be used as financing mechanisms for post-disaster recovery. In addition, our interviews and survey responses mentioned the existence of an insurance scheme which covers both households and businesses in the case of extreme weather events. However, this scheme is not well known and disseminated.

It is important to mention, on the other hand, that this set of features did not include an evaluation of the quality and promptness of the post-disaster reconstruction process. It is understood that the repair and reconstruction of public buildings are activities that might take some time to be implemented after an extreme event. However, when this time is significant, it can create problems. A pertinent example is the hail storm of September 7th, 2015, which caused damages to the roofs of several public schools in the Porto Meira region (Figure 18). The reconstruction of roofs in many schools was finalised until two months later, which demonstrates inadequate access to emergency resources and a low capacity to recover. This example aligns well to the results of the qualitative indicators. On the other hand, the lack of reconstruction funds and a low dissemination of insurance schemes in PI and CDE indicate low capacities for post-disaster performance, compared to Foz.

Figure 18. Examples of Damages and recovery measures, Porto Meira, Foz do Iguaçu.

7.2.7.2. Adaptive Capacity

Effective institutional networks rely on strong and reliable institutions, operative participation channels, and mechanisms for engaging civil society in government decisions. The results for Foz indicate that its institutions, in general, enjoy good reputations, specifically for emergency management and for allowing citizen participation in government decisions. This represents a necessary basis for the existence of efficient stakeholder networks that enhance the city's adaptive capacity. On the other hand, the results for CDE and PI indicate lower reputational levels among their institutions for emergency response, as well as poor governance for the participation of the population in local government. This constitutes a barrier to build effective adaptation strategies in CDE and PI.

The results for Foz indicate that its institutions, in general, enjoy good reputations, specifically for emergency management and for allowing citizen participation in government decisions (Table 27).

Table 27. Adaptive Capacity Indicators

Sub-dimension	Factor	Indicator	Foz	CDE	PI
Networks	Institutional Infrastructure Reputation	Fire Department	Good	Median Good	Median Good
		Civil Defence (Province)	Good	Bad	Bad
		Civil Defence (Municipality)	Median Good	Bad	Bad
		Police (Civil)	Median Good	Good	Bad
		Military Police	Median Good	Median Bad	n/a
		Federal Police	Median Good	Median Bad	Median Bad
		City Hall	Median Bad	Median Bad	Median Bad
		Army	Median Good	Median Bad	Median Bad
		NGOs	Median Good	Median Good	Median Good
		Health Department	Median Good	Median Bad	Median Bad
		Education Department	Median Good	Median Bad	Median Bad
	Governance structure and presence of networks (local governments, private sector, civil society)	Existing formal stakeholder networks and organisation	Yes	Yes	Yes
	Mechanisms for citizens to engage with government	Existence of effective participation networks	Yes	Yes	Yes
Awareness and Planning	Presence of adaptation and mitigation programs	Existence of Climate Change plan	No	No	No
Capacity to Change	-	Simplicity to implement policies	Median	Low	Low
		Existence of policy inspired from other cities	Yes	No	No
Cooperation	-	Existence of cooperation agreements with other cities	Yes	No	No

The results in general indicate significant inertia to promote new public policies in the municipalities. Some interviewees indicated that the introduction of new policies usually takes a long time. From conception to execution, public policies in Foz do

Iguaçu can take up to 2 years. Meanwhile, the results suggest that CDE and PI have even greater difficulties to develop and adopt new policies. Foz, on the other hand, has a better disposition to adopt good practices from other cities and cooperate with them, since it has adopted and applied similar policies from other cities, while this was not mentioned in the case of PI and CDE. We cannot, however, conclude from the answers that there is no predisposition to change and cooperate in these cities. Verifying this would require further research on the public management of PI and CDE. Finally, the qualitative evaluation suggested that despite the willingness of stakeholders to deepen cooperation between the three cities, federal government bureaucracy represents a great barrier for cooperation.

It is worth noting that there is a lack of climate change mitigation and adaptation plans or strategies in the three cities. This shows that climate change is still waiting to be integrated into public policy, which highlights the urgency to reduce adverse climate impacts and promote effective climate-resilient development in the region.

7.3. Qualitative analysis of the vulnerabilities in triangle-city region

7.3.1. Introduction

This chapter presents the findings derived from the analysis of responses and views expressed by key actors in the three cities, including government authorities, business representatives, members from NGOs and civil society, academics, etc. They were contacted between February and April and asked to participate in semi-structured interviews and focus groups (see Table E 1 for more details). This component of the analysis was undertaken with the aim of obtaining a more in-depth knowledge regarding the factors that can influence the vulnerability of the triangle-city to climate variations and extremes. Four themes were explored. 1) Which are the main climate-related events that the cities have experienced and how they have affected them? (i.e. exposure and sensitivity, following our framework). 2) Which are the actions that the cities undertake when they face climate events? 3) Which actions are the cities implementing to protect from future climate events? 4) How are the cities cooperating to jointly manage climate events? These four issues provide a reading of the current context regarding the vulnerability of the cities to climate change effects.

As will be explained, the three cities have suffered similar climate-related events and have experienced similar problems, especially related to urban flooding. In the face of this, it is thus imperative to engage the cities with actions that can build resilience. According to the views of those who participated in this research, the region has the potential to prevent the effects of extreme climate events, although this requires coordinated actions between the various actors in different sectors within each city and stronger cooperation among all the cities that form the triple-border.

7.3.2. Foz do Iguaçu

7.3.2.1. Exposure and Sensitivity

As has been explained, the vulnerability of the cities depends on their level of exposure to extreme events and their degree of sensitivity these events, which is determined, in turn, by their physical, social and economic attributes, as explained earlier in the chapter. The findings in Foz do Iguaçu indicate that hailstorms are perceived as one of the main extreme weather events that have produced the highest damages. This type of event became imprinted in the social memory on September 7th, 2015 when a hailstorm affected more than 60,000 people in Porto Meira, the southern region of the municipality. It affected about twenty thousand residences in a deprived neighbourhood, including an irregularly-occupied area (Figure 19) known as the Bubas[27].

[27] The Bubas are believed to be the largest informal settlements in Parana, originated by illegal settlements in private lands.

Figure 19. Aerial view of Bubas´s Invasion in Porto Meira

The Municipal Government decreed a ‘State of Emergency’ in order to receive financial aid from the federal government to support response and recovery activities[28]. Public assets were severely affected, with damages registered in day-care centres, schools and public buildings. Resources were also received to support government services. In addition, there was the need to bring teams from Curitiba, the state capital, to help the local Civil Defence.

Many respondents reported material damages to cars that were hit by hail, as well as numerous affected houses. Roofs were destroyed, leaving the furniture exposed to rain. According to some of the residents, the official teams seemed to be unprepared, as the magnitude of the event surpassed their coping thresholds. Local commerce was also not prepared to meet such a large demand for plastic canvas or roofing tiles. Many families demanded canvasses to cover their homes or to protect themselves from rain during the time they spent on shelters (Figure 20). Several interviewees also mentioned that the debris generated by the storm remained for months on the streets of the Porto Meira region, even though it is a public health risk to leave asbestos so openly exposed (Figure 20).

[28] To receive financial resources, losses due to damages in public assets must be greater than 2.7% of the Net Current Income of the municipality and 7.3% in relation to private property

Figure 20. Residences affected in Porto Meira and abandoned asbestos

The city also registers heavy rains, gales, lightning storms[29] and drastic changes in temperature. Temperature can vary during the year from minus 3°C to 54°C, but the most worrisome matter perceived by interviewees seems to be rain and storms. As one of them mentioned: "*Now it is possible to have the volume of three months of rain in a single day*" (R9_F)[30]. Strong winds can also accompany storms, occurring 3 times per year on average, and causing damages due to the falling of trees and power cables, affecting various properties. It was mentioned that in 1994 a strong gale '*even knocked down a very tall television tower of the Naipi TV, in addition to many trees*' (R5_F).

According to Civil Defence, about 80% of the problems associated with flooding on public roads are due to the precarious or inexistent infrastructure to drain excess water. This problem affects the M´Boicy stream, which crosses the city and often causes flooding problems to families living in precarious conditions, mostly in irregular areas. The Monjolo stream is another problematic urban stream surrounded by luxury condominiums and other types of commercial properties, including a university.

The most affected population lives along the river banks along the urban perimeter. According to governmental officials interviewed, during the last 5 to 8 years there have been efforts by the Municipality to relocate this people from those risk areas. The Municipality has constructed, according to the interviewees, thousands of houses for those families, but the problem remains unchanged. When they are resettled to new areas, many of these families end up selling their new homes and return to their old

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[29] INPE. Foz do Iguaçu is one of the cities in Paraná with the highest incidence of lightning storms. <http://www.inpe.br/webelat/homepage/menu/noticias/infografico.-.densidade.de.raios.no.brasil.php>.

[30] This is the code of the interviewee. It means "respondent number nine from Foz do Iguaçu".

grounds. This is due to various reasons, but mainly because these persons do not want to leave the central region of the city, considering that the houses built by the municipality are generally far from the city centre, away from their workplace, schools, hospitals, and commercial areas. This causes critical social and environmental impacts, because these sites present high risk and do not possess basic sanitation. The margins of these rivers often display a high concentration of household waste representing serious health risks. Further efforts are needed to prevent these families from becoming even more susceptible to new floods, and to protect their material assets. For this to happen, a stronger integration between different government bodies (namely the Secretariats of Security and Environment) would be desirable.

Despite resettlement seems to be a complex and difficult problem, the city has witnessed a successful case. At least 40 houses in the irregular settlement of Spring Garden, located next to the banks of the M´Boicy River, were regularly affected by flooding. These families were moved to another area, representing a case that deserves to be studied more deeply to identify any important lessons that can be applied to other cases.

Currently, Civil Defence is conducting research on which districts need more urgent intervention, paying special attention to risk areas on the margins of rivers and public roads. So far, Civil Defence has identified 35 critical points across the city, and has acknowledged that in order to solve these problems a vast amount of financial investment will be needed. Among the main urban flooding risk points identified are: JK Avenue (Panorama shopping area) (Figure 21), Av. José Maria de Brito, Av. das Cataratas (in front of Monaliza Hotel), Porto Meira, Vila C, Três Lagoas, Jardim São Paulo, Jardim Lancaster, Jardim Canada and Favela das Batallas, which also suffers from occasional landslides.

Figure 21. Urban Flooding in JK Avenue

Whenever intense precipitation is registered at the source of the Paraná River, the Itaipu Binacional Hydroelectric Plant opens its floodgates. This does not necessarily create a situation of risk for families living on the slopes of the Paraná River. Often the spillways are open for several days and the river level reaches about 7 to 8 meters above normal. However, when the river level rises up to approximately 20 meters, there is a possibility that families living on the banks might be affected, including restaurants and fishing clubs. According to Civil Defence, Itaipu Binacional sends them a daily bulletin informing about the levels registered downstream and upstream with respect to the dam location, as well as the volume of water being discharged through the turbines. Water can increae quickly. As expressed by an interviewee: *´Twice a year, in the region's rainy season, the Paraná River rises an average of 1.5 meters per hour and people need to leave very quickly, usually between July and August´* (R7_F). However, in case of any greater risks, Civil Defence, having been duly informed, takes the necessary measures.

This kind of exposure, characterised by long periods of rain, affect families living in risk areas. However, during long periods of drought, the energy sector suffers too, as the hydroelectric plant requires water to keep generating electricity.

Some economic sectors are more sensitive to climate-related events than others. First of all, it was learned that the representatives of the different sectors who were interviewed did not have formal information on the monetary losses derived from extreme weather events. Nonetheless, they recognised that the sector most affected by these events is trade. Businesses usually suffer structural damage (furniture, for example) and losses in inventory. The more days a business has to remain closed due to an extreme event, the greater losses it experiences. If the enterprise provides services, the damages may be lower, depending on the type of service. However, the service industry is mainly linked to tourism, and this is a highly sensitive sector.

The Iguassu Falls, the main tourist attraction in the city, is highly sensitive to climatic factors, which can alter the ecology of the National Park. Each time flood occurs, the whole river ecosystem is affected, causing destruction of fauna. Nesting places, hiding places and burrows are damaged, sometimes irreversibly. This affects the flow of visitors. For example, in 2006 a great drought was registered, seriously affecting the flow of the Iguazú River (Figure 22). Conversely, the fastest river flooding recorded in the Iguazú took place in 2014 (Figure 22). Whenever these impacts occur, the number of tourists decreases significantly.

Figure 22. Iguassu Falls 2006 and 2014

Other sectors are also affected by climate change in the region, especially family-based farms focused on the production of fruit and vegetables, and large scale grain production. The Municipal Department of Agriculture has registered approximately 1660 rural producers, and most of them are already feeling the effects of climate change due to weather variability (i.e. unusual long periods of rain/droughts).

The public sector is also affected whenever there are extreme weather events, mainly by having to invest money in actions that were not foreseen in its annual budget. Besides physical damages, the public health system requires handling the pressure derived from illnesses during these types of events, especially after urban flooding. Several illnesses are common during these periods, like leptospirosis and parasitosis, especially in children, due to contaminated water and the lack of sewage treatment. Besides, dengue[31] becomes a serious problem, especially in areas close to garbage

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[31] A disease transmitted by the mosquito *Aedes aegypti*

dumps, where refuse is not collected by city authorities.

After the hailstorm of 2015, the Municipality spent USD$ 848,151,[32] to purchase construction materials (e.g. lining, roofing tiles, glass) and pay for labour services to repair public offices and municipal schools where roofs had been destroyed. Plastic canvas were also purchased for affected families. Specialized vehicles were rented to collect debris, which had been piled up by the residents and volunteers at the edge of sidewalks on the streets of Porto Meira.

7.3.2.2. Coping capacities to face climate related events

The interviews also explored how the city has reacted when impacted by an extreme weather event in the city how it has responded to recover from the disaster. The analysis shows that the city relies on key organizations which provide immediate support. Most interviewees consider Civil Defence as an essential organization, representing the first line of defence during extreme weather events. As previously described, Civil Defence is the first to arrive to bring help according to its contingency plan. One of its first actions is to carry out a survey to find out what is needed to minimize the effects of the disaster.

Itaipu Binacional was highlighted by interviewees as another key actor during disasters. Itaipu, as mentioned in this report, is a member of the Civil Defence Council and contributes significantly by donating equipment, technology and financial resources, besides offering its expertise. Apart from Itaipu, other institutions that stand out are the Rotary Club, PTI, and diverse religious institutions. For instance, soon after the hailstorm in 2015, religious groups supported people and provided logistics in shelters. Civil society and some entrepreneurs also provided financial support and assistance, especially for the purchase of plastic canvas or roofing tiles. Overall, many people showed their solidarity and made donations. Politicians were present at the site, as well as the Army, Sanitary Surveillance, Federal Police, Military Police, Municipal Guard and Civil Defence. Even people from other municipalities sent help of engaged in various activities.

In general, local government bodies have an active role during disasters and

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[32] Observatório Social de Foz do Iguaçu. <http://www.osfi.org.br/>

shortly thereafter. However, their role in post-event prevention or reconstruction appears to be much weaker. Interviews reveal that there are gaps to be fulfilled in terms of how the city of Foz do Iguaçu is able to react in an efficient manner. For instance, it is still necessary to articulate better the aid that is provided to victims. As expressed by an interviewee, *'in this process some families receive a lot of help while others do not get any*' (R9_F). In many cases, there is a high amount of donations, but these are not efficiently and effectively distributed.

After the 2015 hailstorm, a registry of the poorest families was made in order to distribute plastic canvasses (Figure 23). However, it took a long time for the government to deliver this support, having to rely on volunteers. "*If it had not been for the donations and the efforts of the population itself, the impact on these [affected] persons would have been much greater*" (R17_F).

Figure 23. Affected families receiving plastic canvas donation by Army.

The analysis also reveals that other important factors influence the city's recovery. Lack of resources represents an important element. After the hailstorm, some municipal departments could have actively helped, but were not able to do so because of a lack of human and financial resources. Among other barriers for recovery mentioned by the interviewees are: bureaucracy, lack of political will, poor watershed management, difficulty to relocate families living in high-risk areas and infrastructure. In 2016, Civil Defence and the Municipal Planning Secretariat conducted a diagnosis of existing infrastructure, finding that the city urgently requires efficient drainage systems.

7.3.2.3. Measures to protect future climate events

Public sector representatives stated through interviews that disaster prevention policies are currently being developed in the areas of watershed protection, solid waste management, energy efficiency, agricultural development and reforestation. A strategy that is about to be deployed is a Risk Alert System which constitutes a Civil Defence measure. The Planning Secretariat is also initiating the development of the Global Urban Drainage Plan, which is urgently needed to alleviate problems related with urban flooding.

The Civil Defence team is also developing a virtual application to map areas at risk and shelter locations, including information of the contacts that are responsible for the shelters. This application cab be very valuable during imminent flooding, as it can inform people about the approaching threat and where they should go.

Another important action for disaster prevention is the effort undertaken by regional universities to examine flood risk. The University Centre for Studies and Research on Disasters (CEPED)[33] (Centro Universitário de Estudos e Pesquisas sobre Desastres) was created in 2013 as a network of public and private universities that aims to stimulate disaster-risk reduction actions. It brings together different government state-level bodies, like the State Protection System and Civil Defence (SEPDEC), the State Council for Protection and Civil Defence (CEPRODEC), the Division of Protection and Civil Defence (DPDC) and the Regional Organization for Protection and Civil Defence (CORPDEC). The centre acts to stimulate research for the production of knowledge and technological innovation, focusing on finding solutions. One of its functions is to find ways to raise funds for research and education, as well as to support institutions interested in the topic and, more importantly, to implement an effective model of integrated disaster risk management.

Civil Defence in Foz do Iguaçu enjoys the support from CEPED, based in the State University of Western Paraná (UNIOESTE), and located in the neighbouring city of Cascavel. CEPED contributes to improve the perception of climate change impacts in the city through training and diverse projects developed in partnership with the Association of Municipalities of the West of Paraná (AMOP). CEPED also contributes

[33] CEPED. <http://www.ceped.pr.gov.br/>

to develop an initiative known as the Strategic Municipal Planning for Resilient Cities.

Regarding other preparedness measures, there is also a cooperation agreement between Foz do Iguaçu and CEMADEN to install two ran gauges, one in the neighbourhood of Morumbi (central) and another in Vila C (north). With these instruments, Civil Defence will have an additional tool to conduct meteorological and hydrological studies in the city. It is believed that in the next 5 years, Parana's Civil Defence will improve its monitoring, reaching standards similar to those that exist in developed countries.

During the last municipal administration, an Integrated Management Office was created to deal with diverse topics, mainly related to public health and safety, environmental matters and security. This office complements efforts undertaken by other public sector institutions in these areas, including the fire brigade (which forms part of Civil Defence), Sanitary Surveillance, the Zoonoses Control centre, and Regional Health. These institutions regularly develop campaigns, and contribute to prepare and train Civil Defence personnel, so they can be ready to face future disasters.

The local development council of Foz do Iguaçu, CODEFOZ[34], plays an important role in promoting sustainable development. It was created November 2012 and was formed by different stakeholder groups. More than 100 entities, from public and private organizations, participate in projects to formulate and promote economic and social development policies for Foz do Iguaçu. According to interviewees, it is possible that climate change might be integrated into one of the so-called 'technical chambers' that form part of CODEFOZ.

Despite the city-level initiatives that exist in the city, most respondents had no information on existing sector-level regulations to reduce disaster risk. This represents an important gap that is waiting to be addressed.

We explored the views from the interviewees regarding other measures that can be taken at a city scale to prevent future damages derived from extreme weather events. Among the suggestions are: the need to invest money in preparedness measures, the inclusion of environmental education in schools, and the need for urban planning. Interestingly, a residential model called 'Sumidouro' was mentioned. It is an

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[34] CODEFOZ. <http://www.codefoz.org.br/>

affordable technology (rainwater retention system for groundwater recharge purposes) to recharge underground water in the urban area to be implemented in the neighbourhoods that are most affected by urban flooding. Other measures mentioned by that the interviewees are presented in the table below (Table 28).

Table 28. Interviewee suggestions to minimize the effects of extreme weather events in Foz do Iguaçu.

· Investment in public actions to prevent and prepare against extreme weather events Improve basic sanitation Maintenance of trees on public roads Debris collection after storms Improve drainage systems Municipal Disaster Fund Insurance schemes Integration of diverse networks (citizen, academia, businesses, including Itaipu Binacional) Strengthen partnerships between Copel, Civil Defence and Municipal Guard

After a period of political turmoil in Brazil, which was also reflected at the local level, many government initiatives and programmes were suspended or seriously affected. The citizens of Foz do Iguaçu recently participated in an election to choose city-level authorities. It is expected that the new representatives will quickly undertake actions oriented to disaster-risk reduction. Some of the representatives that were interviewed showed motivation and are willing to support projects and actions that can make the city more resilient to extreme weather events.

7.3.3. Puerto Iguazú

7.3.3.1. Exposure and sensitivity

Puerto Iguazú, like the other two cities of the triple-border, experiences a microclimate that differs from the rest of municipalities in the Argentinian Province of Misiones. This is due to the significant number of water bodies surrounding the triangle-region, like the Itaipu lake (135,000 hectares) and the Urugua-i lake (9,000 hectares). Due to its proximity to water, Puerto Iguazú is sensitive to weather-related events, such as hailstorms, urban and river flooding, and vector-borne diseases.

In terms of extreme weather events, such as hail, Puerto Iguazú, like its counterparts (Ciudad del Este and Foz do Iguaçu), experienced significant damages due to the 2015 hailstorm. It is estimated that between 70% and 80% of the population suffered damages related to this event, mainly in relation to properties, like houses and cars, some of which were seriously affected. One of the interviewees pointed out: ‘I have been living in Puerto Iguazú for 27 years, and the 2015 hailstorm was the worst climate event” (R05_P). According to the interviewees, among those mostly affected were families living in houses with one of the following roofing materials: corrugated cellulose fibre/asphalt panels (low density) and/or asbestos cement boards. These roofing materials are light and not designed to withstand an event like hailstorm. Results show that the event affected the population regardless of their income level, although the majority of the houses with corrugated sheet panel belonged to families with lower incomes. It is estimated that around 2,400 families lost their roofs, which represents around 19.5% of the houses in Puerto Iguazú, being poor people the sector that suffered the most.

As mentioned in other parts of the report, there are three streams running through the Municipality of Puerto Iguazú: Tacuara, Panambi and Mbocay. The two the streams that flow through urban areas, (Tacuara and Panambi), cause problems of urban flooding due to overflow. Results show that it is the Tacuara stream the one that causes more flooding, although the Panambi stream causes problems as well. People living in the floodplain and on the margins of those streams are the most affected by flooding of roads. They usually suffer disruption in basic services (e.g. energy, water), damages to property, health effects and sometimes losses of human life. There are some discrepancies among interviewees regarding the approximate number of families who have settled down on the margins of both streams, as well as the number of people directly affected by overflowing. Estimates range between 30 to 100 families, and around 800 persons affected by stream overflow.

In terms of impacts on health, results revealed that a quarter of the respondents perceive that mosquito population and the spread of vector-borne diseases are related to climate. Mosquito outbreaks have affected not only the population of Puerto Iguazú, but also the economy, as tourism is a very sensitive activity. In 2016, it was estimated that more than 2,000 people were infected by Dengue, also affecting tourism activities. Past outbreaks had similar effects in 2010, 2012, 2013 and 2014. During these events, tourism decreased from an average occupancy rate of 80% to 40%. According to one interviewee, national tourism is more sensitive to Dengue and epidemic diseases than international tourism, as the latter usually takes more precautions and sometimes is required to receive vaccines prior to embarking on the trip.

In terms of the rivers that surround Puerto Iguazú, the overflow of the Parana and Iguazú rivers does not affect the infrastructure of the city, although it affects the economy of the city. For instance, the National Park Iguazú, of which the Iguassu Waterfall is main attraction, is significantly affected by the water level of the Iguazú River. The National Park has had to be closed twice in the past due to overflow of the Parana river, and results show that this has caused direct damages to the economy, while indirectly affecting the welfare of the population.

For instance, in 1984, after an intense precipitation, the Devil's Throat (the greatest waterfall with a total height of 82 meters and the most important natural feature of the park) overflowed, leading to its closure for six months. As an interviewee stated: *“The closure of Iguazú Falls for a week is estimated to economically affect many people in Puerto Iguazú who hardly make ends meet!”* (R02_P).

The National Park also closed its doors in 2014, when the river overflowed because of a rupture in the Baixo Iguaçu dam, which was under construction upstream the Iguazú river on the Brazilian side. According to one interviewee, this not only affected the waterfalls, but also the main road access to the city, namely the Number 12 National Route. When floods like this one take place, the economy of the city becomes totally disrupted due to two main factors. On the one hand, the flow of goods by land between Argentina and Brazil is suspended. On the other, tourism and other related activities come to a halt. It is estimated that around 20,000 people become affected, as their activities are highly dependent on commerce and tourism.

7.3.3.2. Coping capacities to face climate related events

Similarly to Foz do Iguacu, we investigated how Puerto Iguazú has managed past extreme weather events with the aim of understanding the situation and identifying relevant activities addressing loss and damage associated with these phenomena. The province of Misiones relies on a provincial network (whose communications depend on Whatsapp) for extreme weather events. It mainly undertakes information-sharing activities aimed at keeping key actors updated across the province. As described before, Puerto Iguazú also has an Office of Civil Defence, which constitutes its first line of defence. It is in charge of early warning and response systems, being part of the network mentioned above. Its main goal is to provide assistance to population affected by natural disasters, epidemic disease, and accidents of different kind (including toxic spills). A third of the interviewees highlighted the role of Civil Defence as an important element in the city's coping capacity. As one of the interviewees expressed, "*when an emergency happens in Puerto Iguazú, Civil Defence is the first to receive the information*" (R01_P). Once Civil Defence receives information, a response protocol is triggered, setting out the arrangements required for emergency coordination, in order to protect and assist citizens in need.

Information is collected and distributed at the Office of Risk Prevention against Natural Phenomena and Early Warning Systems of the city of Posadas, which is the capital city of the province of Misiones[35]. According to one interviewee, information is sent from the radar in Cascavel (Brazil) and from the National Meteorological Service. The Office of Civil Defence, in Puerto Iguazú, receives from the provincial network a daily update of the weather conditions in the province. When Civil Defence receives a report, for example, of oncoming heavy rains or hails storms occurring in Jardín América, a city located about 120km from Puerto Iguazú, it alerts the community three or four hours ahead of the impact to allow the population to be prepared. This office is constituted by four staff members who work *ad honorem*: the chief, the main director, the director of operations, and the health emergency director. This office is coordinated by the Active Forces; that is, firefighters, municipal staff, Gendarmeria (a special police task force), National Naval Prefecture, and Federal and Provincial Police institutions. These Active Forces are mobilised when natural or human disasters take place in Puerto Iguazú. Among the interviewees (66%), there was a consensus that the fire department is the key actor in Civil Defence.

Hail storms and urban flooding caused by the overflow of the streams are example of events where Civil Defence has had a leading role. Regarding hail storms, Civil Defence has set up a contingency protocol in coordination with the Active Forces, leading the response to assist families by providing shelter and construction materials. For instance, during and after the 2015 hailstorm event, members of Civil Defence

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[35]http://www.opad.posadas.gov.ar/quienes_somos.php

assisted the municipality in the provision of roofing materials (corrugated cellulose fibre/asphalt panels), food, water, beds and shelter for people whose houses were significantly damaged. The amount of resources spent by the municipality was considerable. According to one interviewee, the expenses surmounted to around U$712,500[36].

Concerning urban flooding, one of the first actions taken by Civil Defence is to identify the affected areas, trying to map any electrical hazards. The main forces mobilised are the Fire Brigade, elements from the Energy Company (EMSA) and municipal staff. EMSA staff cut off the energy supply in those areas affected by water. Firefighters then arrive to the affected areas, where their duty is to rescue people from flooded houses, focusing on elderly and children first. Municipal staff later provide essential services, like operating specialised equipment, such as a backhoe loader and trucks. They also help to set up shelters and areas to provide temporary housing for affected people. As stated by one of its members: "*Recently (2017), a sports complex was opened where 10,000 families can be accommodated. Today we have 10 machines (available for emergencies) can act quickly*" (R04_P).

Urban flooding is a frequent event on some river margins, especially in areas where few actions to control the river flow have been undertaken. For instance, one interviewee living on the margins of the Tacuara stream expressed: "*after 20 to 30 minutes of heavy rains, we suffer the consequence of overflowing*" (R10_P). In fact, this person reported that '*we have had to rebuilt the house six times*' (ibid.).

Interviewees also mentioned the unwillingness of many families to be relocated, representing serious concerns for health and safety. In fact, the process of relocating families that have settled down on the margins of the Tacuara stream has been a challenge for the municipality. These families have been living there for a long period of time and now possess a high sense of belonging to the area. As expressed by one interviewee: "*despite the fact that the stream causes problems, the families are not going to leave their houses. The stream is part of their life*" (R02_P). Once again, the reason given is that families do not want to be relocated, due to their proximity to commercial areas and their workplace.

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[36] Exchange rate 1U$ =16.28 $Arg.- (7 June 2017); equivalent to $11,600,000 Argentinean pesos. 10% of the total budget from the Puerto Iguazú is allocated to Social Assistance which includes the budget for climate emergencies.

Regarding mosquito outbreaks, the municipality promotes prevention actions, such as reducing open water collections and maintaining green areas clean. In order to reduce mosquito population and diminish the risk, Puerto Iguazú has implemented a fumigation program and control of green areas. During the epidemic events in 2010, 2012, 2013 and 2014, the city lacked the required equipment to face this particular problem. Since 2015, this situation has been changing. The city initiated cleaning measures and purchased vehicles for fumigation (two vans were acquired). However, more than 2000 cases of Dengue were still recorded last year (2016), which directly affected tourism. During this event, different companies cooperated to fight the threat. They helped with water provision of water, and donated repellents, as well as fuel for the fumigation equipment. As one of the interviewee stated: "*We know that we cannot control Ciudad del Este, Presidente Franco, or Foz do Iguaçu, but we can control Puerto Iguazú*" (R01_P).

7.3.3.3. Adaptive capacities to protect against climate related events

In order to face urban flooding in the long term, Puerto Iguazú has implemented some hydrological solutions. Two different strategies have been implemented: channelization and a pipeline. The channelization of the Tacuara stream has covered almost 50% of its total length (Figure 24). It has been part of the national programme for water sanitation and flood risk management [1], with support from the provincial and local governments. This mechanism seems to reduce risks; however, the problem might increase where the stream is still not channelized. Considering that the water of the stream is confined into concrete channels, it resulted in a straighter, steeper, deeper, wider, and smoother canal, thus causing an increase in water speed, having an impact on untreated areas. This example is shown in Figure 25. For instance, an interviewee pointed out: "*Although part of the Tacuara stream is channelled, those areas where work has not been completed are still affected by overflow when normal rainfall occurs in the rest of the stream*" (R01_P).

Figure 24.The water of the Tacuara stream confined into a concrete channel

The second cause of urban flooding is the Panambi stream, which run across five neighborhoods. The national government, with support from the provincial and local governments, have started the construction of a pipeline to diminish the risk. By the time this study was conducted, about 15% of the stream had been pipelined.

Figure 25. End of the Tacuara stream channelization. Left: effect of water impact on asphalt

Puerto Iguazú does not allow building on the margins of the streams, according to a set of rules and regulations: the provincial law (year 2005/2006), municipality regulations, and a decree (number 384/10) declaring these areas as state lands. Nevertheless, many families defy the law and still build their houses at the border of the Tacuara and Panambi streams, facing numerous risks. A number of these families have been adapting to withstand extreme flooding events. As respondent stated: "*I have been living for 30 years [on the margins of the river] and I have rebuilt my house many times. The level of the water reaches up to two meters, destroying our belongings*" (R10_P). According to interviewees, around 12 to 13 thousands families live in the surrounding areas of these two streams. Furthermore, some families have rebuilt their houses over areas where the Panambi stream has been pipelined. Some interviewees reported that this represents a problem, because they are settled on state lands, and because the terrain does not offer a solid foundation for buildings.

Another action taken by the municipality to avoid flood disasters is the relocation of vulnerable families who live in the floodplain. These families have low incomes and face property-right issues. The provincial and local governments have provided housing assistance through the Provincial Institute of Housing Development (known by its acronym in Spanish: IPRODHA) in the form of affordable housing[37]. The area where these houses are built belongs to the municipality. The programme offers families the opportunity to improve their situation. However, some respondents mentioned that this mechanism faces two main problems: Firstly, many affected families find more attractive the idea of selling their new houses and relocate back again to the floodplain and wait to receive some other benefits again, attracting other families who wish to receive the same benefits. Secondly, some families completely refuse to be relocated, simply because they have a strong sense of belonging to the area.

Similarly to Foz, Puerto Iguazú also has a local development council that plays an important role in promoting sustainable development. It is called CODESPI and was created around 2015.[38] It is formed by different stakeholder groups and articulates public and private institutions. One of its main objectives is to promote the sustainable development of the city.

7.3.4. Ciudad del Este

7.3.4.1. Exposure and sensitivity

Ciudad del Este's urban areas have grown steadily for the last 30 years in an unplanned manner, making the area more vulnerable to impacts from extreme weather

[37] Within the Federal programme: "Better life quality, more health" ID. 08324 - U - 2014
[38] <http://codespi.org/institucional/> (Available on 7 June 2017)

events. The interviews reveal that the most common impacts that have affected the city are heavy rainfall (causing urban and river flooding[39]) and strong winds, occasionally suffering hailstorms and heat waves.

The Parana River divides the city of Ciudad del Este from Foz do Iguaçu. Ciudad del Este forms part of a larger metropolitan area along with the neighbouring districts of *Hernandarias* and *Presidente Franco* and the municipality of *Minga Guazú*. Two tributary streams from the Parana flow across the urban area. The *Acaray-mi* stream is located on the north of the city and the *Amambay* stream flows nearby.

River flooding occurs when the Parana River rises. The water flows back into the *Acaray* River, the *Acaray-mi* stream and even into the *Monday River*. This causes river flooding, affecting the population located close watercourses. Urban flooding, in turn, takes place during periods of intense rainfall, when the drainage system becomes overloaded. The interviews revealed that this is partly due to the accumulation of rubbish on the streets. As one interviewee said: *"this situation is mainly due to the lack of an adequate waste management system […] the garbage flows down the streets, affecting mostly the city centre"* (R09_C). Other important factors are the lack of sewage systems (a basic sanitation measure), poor law monitoring and enforcement, and inadequate urban territorial planning.

The most affected areas by river flooding, according to interviewees are: San Rafael (3-4 flooding events per year), San Agustin, San Antonio, Chela Reina, Remancito, San Juan, Barrio San Miguel and San José. Other cases occur in the south corridor, 1 to 2 kilometres away from the city centre, home to more than 76 families. Furthermore, the area around kilometre 12[40] is prone to flooding by the *Monday* River.

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[39] An urban or surface-water flood is caused by heavy rainfall independently from the overflowing of waterways. River flooding occurs when excessive rainfall over an extended period of time causes a river to exceed its capacity.
[40] Ciudad del Este's neighborhoods are mainly referred to in terms of kilometres, from 1 to 13, based on their distance to the Friendship Bridge.

Figure 26. Precarious houses of the neighbourhood San Rafael, located in the confluence of the Parana River and the stream Acaray-mi

Figure 27. River flood in the neighbourhood San Rafael

The most vulnerable communities and settlements are located along the margins of rivers and streams. According to interviewees, these people are significantly at risk. “During flood events, the inhabitants of those areas lose everything, even though legislation prohibits those illegal settlements”. Current regulations do not allow such settlements. The Law on Water Resources (Los Recursos Hídricos del Paraguay Nº 3239/2007)[41] establishes minimum distances between waterways and built-up areas. However, as is the case in the other two cities, people refuse to be relocated. As stated by one interviewee: “Many of those families don’t want to leave these places for diverse reasons, mainly due to the proximity of their work place. They have become used to live with the flood. The difficulties to relocate these people represent a complex social problem” (R03_C).

[41] Ley N° 3239/2007 de los Recursos Hídricos del Paraguay
http://www.siagua.org/sites/default/files/documentos/legislacion/ley_recursos_hidricos_paraguay_0.pdf

Figure 28. Affected families evacuating in the San Rafael neighbourhood

Apart from heavy rainfall and flooding, other extreme weather events experienced in Ciudad del Este are strong winds. These can cause significant damages to buildings and structures, especially when these are built with construction materials that are not appropriate to withstand this type of events.

The commercial sector is particularly affected by strong winds. The city centre is covered with advertisement boards and posters announcing the numerous shopping centres that make Ciudad del Este a famous destination. During strong-wind events, however, these advertisement are highly damaged, being torn away and becoming a dangerous hazard. In the aftermath of an event, business owners have to invest money to put them back up again. Two interviewees from the business sector mentioned that it would be desirable to have an affordable insurance scheme to protect them against this type of events. However, they mentioned that the premiums are normally extremely high. Businesses also register a decrease in sales after extreme events, due to transport disruptions and because people prefer to stay indoors.

The transport sector is also highly sensitive to extreme weather events. During periods of intense rainfall, high volumes of traffic are registered in Puente de la Amistad (Friendship Bridge), which connects Foz do Iguaçu with Ciudad del Este. Moreover, a significant rise in road accidents is experienced as well (R01_C).

Figure 29. View of Friendship Bridge - Puente de la Amistad after the reform of 2015

Figure 30. View of Friendship Bridge - Puente de la Amistad after the reform of 2015

7.3.4.2. Coping capacities to face climate related events

Some of the barriers that prevent effective response and recovery measures in Ciudad del Este are the lack of planning and a deficient culture of prevention. Climate risks are not considered by the population as a priority. City authorities are more concerned by other matters, spending more efforts and resources in areas such as health. As mentioned by several of the interviewees. "*Every month the city needs to provide financial aid and social assistance, like medicines and food, around $100,000 USD*" (R04_C).

Regarding recovery measures, the government and various social actors are the ones who help the city to recover when it is affected by an extreme weather event. The municipality is in charge of disaster management. The Local Council for Risk Reduction and Response relocates vulnerable people affected by the flood by providing water and transportation. The local government also provides support in relation to social assistance and infrastructure, by providing financing to help repair damaged structures. In case of acute emergencies, the municipality can also ask the National Emergency Secretariat for support, in order to deliver food, mattresses, roofing, canvasses, among others things.

As previously mentioned, Itaipu has an important role by providing early warning systems and by offering weather information to Ciudad del Este. In this sense, the Local Council for Risk Reduction and Response works closely with Itaipu, who provides daily bulletins on the status of the Parana and Iguazú Rivers. As stated by one interviewee, "*We receive alert bulletins from upper Paraná and Canindeyú, and we established two rapid response units […] in order to articulate and formalise early warning and response systems, to minimize the damages associated to climate-related events*" (R07_C). Itaipu also grants social assistance through the Fire Brigade by delivering emergency kits, mattresses, food and water, although it does not offer financial support (R02_C).

The Red Cross, which seems to exist only in Ciudad del Este, also plays a relevant role in aid delivery efforts. It offers medical attention, helps to evacuate people (depending on the type of event), organise shelters, among other activities. In terms of prevention, the Red Cross designs risk reduction plans (like evacuation drills) and works directly with the communities to improve people's perception to risk. According to interviewees, the Red Cross is trusted among the population and enjoys a good reputation. "*In 2014 almost 3,000 families were mobilized and had access to temporary shelters, as churches, and schools. We spent almost three months working, relocating families, and providing primary health care"* (R06_C). This is an important aspect, because the direct and constant contact with the community allows the Red Cross to better understand the situation and react faster during and after an extreme event.

The Volunteer Fire Brigades (the yellow-dressed fire fighters) constitute another important source of support. These brigades are independent and support the community through an emergency phone line (911 and 312). They currently participate in Ibero-American training and networking programmes, and receive international donations. Other social actors that were identified are the Infantry division, Rotaract, JCI (Junior Chamber International), TECHO (youth-led non-profit organization), Lions Club, CODELESTE (Ciudad del Este's Economic Development Council), Chamber of Commerce, Technology Chamber, and the Catholic Church. During disasters, these organisations tend to get together and contribute with clothing, mattresses, food, and water, but do not offer financial support.

7.3.4.3. Adaptive capacities to protect against future climate related events

As part of the preventive actions planned by the municipality, either already implemented or in development, interviewees mentioned efforts to build an underground electrical system (to replace the aerial) and construct corridors to connect different neighbourhoods from the city centre to kilometre 13. The School of Arts and Culture is examining the construction of a bus terminal at kilometre 7. Similarly, the Environment Department of the Municipality is working on projects related to waste and community campaigns, like the Amambay Stream Cleaning Project (R05_C). This project seeks to strengthen education actions towards increasing awareness of solid waste management in the city to prevent urban flooding.

The Eastern Development Plan[42] (Plan de Desarrollo del Este), developed by Gustavo Taniguchi (Curitiba's territorial planner) and supported by local authorities, seeks to re-design the city so that it is able to cope with the high levels of growth that are expected in the following decades (R09_C). This plan aims to build a more accessible and organised city, a fundamental aspect in urban resilience.

Regarding the private sector, Itaipu is conducting an environmental impact assessment for the construction of drinking and sanitary water systems for the metropolitan area of Ciudad del Este, including Hernandarias, Minga Guazú and Presidente Franco. This project is being conducted with civil engineering students from the National University of del Este, and supported by the municipality.

The business sector is also strengthening billboard structures or replacing them for stronger ones that can withstand storms (R08_C). In a similar manner, the International Centre for Hydro-informatics (CIH/ITAIPU) is currently developing several applications based on free software to map affected areas and to monitor the hydrological conditions of the main rivers in real time. They aim to develop a dynamic and collaborative interface that helps to improve the prevention and response actions in Ciudad del Este.

Some of the measures that were commonly mentioned by interviewees are a protocol and strong law enforcement to establish minimum distances between watercourses and built-up areas. Moreover, it was also emphasised that after

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[42] Plan de Desarrollo del Este http://www.stp.gov.py/pnd/wp-content/uploads/2014/12/pnd2030.pdf

relocating vulnerable population, high-risk areas should not be left unused to avoid people building back again in the same places. "*These lands should not be left unused. Instead, they should be used for recreation and leisure"* (R04_C), (R07_C). Likewise, a number of interviewees expressed their concerns regarding the feasibility of relocating people and the importance of implementing proper urban planning. *"It is a priority to create a multi-sectoral awareness campaign to relocate people living in illegal settlements, applying territorial planning"* (R02_C). In the case of the San Rafael neighbourhood, hydrological and hydraulic modelling of the *Acaray-mí* stream has demonstrated the effectiveness of some infrastructure solutions, which can deal with the problem of recurrent flooding.

Other possible solutions highlighted by interviewees are better communication channels between different key institutions at different levels. As one interviewee expressed: "*This situation can only be resolved if meetings were constantly held among the Municipalities of Presidente Franco and Ciudad del Este, the National Emergency Secretariat, state-level authorities, ITAIPU and the Red Cross"* (R02_C).

Other proposed measures include the creation of an emergency operation centre (R06_C), retaining walls in major rivers and streams, and educational/outreach programmes for disaster-risk prevention.

7.4. Cooperation between the cities

7.4.1. Indigenous groups

The matter of cooperation in the triple-border can be traced back to the time when indigenous people occupied the region. Such communities understood cooperation in a different way, as they did not need bridges or borders to live in a harmonious way. The communities, however, have been increasingly reduced and are now scattered across the region. However, their presence in some areas of the cities is visible, and they enjoy the freedom to move across borders. As an informant stated: "Here (in Puerto Iguazú) indigenous peoples do not have borders. They cross to Paraguay, Brazil and Argentina. For them, this is one place, there are no borders"

(R01_P).

Indigenous communities are distributed as follows. Approximately 300 people of the Maká tribe live in a community in Ciudad del Este and are included in social programmes of the municipality. In Puerto Iguazú, there are four indigenous communities: Mborore, Yryapu, Cati Pora, Ita Poty y Tupa mbae. The largest community is Mborore with around 90 people with an average family size of five to six members. In the natural protected area known as the “600 hectares”, there are around 150 houses and one thousand people. In Foz do Iguaçu, 70 people grouped in 13 indigenous families were located and registered in 1982, before the construction of the Itaipu Hydroelectric Plant. They formed the community of Jacutinga[43], the "Avá" branch of the Guarani Nation. These families were then transferred to the Ocoy Indigenous Reserve, approximately 40 kilometres from the border.

Figure 31. Guarani family in the province of Misiones.

There are few cooperation efforts to address the rights and welfare of indigenous people in the region. Regarding health, the Border Health Work Group was created to establish joint and coordinated actions in the three countries with the support of Itaipu. However, political and cultural issues involving indigenous people still need urgent attention and care, to ensure their rights.

7.4.2. Triangle-city cooperation

The border began to experience a more cooperative coexistence in the 80’s

[43] Itaipu Binacional. <https://www.itaipu.gov.br/meioambiente/comunidades-indigenas>

through the implementation of political protocols and other measures. Cooperation between cities has been mainly driven due to their proximity and common economic interests, like joint energy production, tourism and commerce. Cooperative initiatives related to tourism and trade have been stronger[44], seeking to promote a greater integration and a sense of identity among the inhabitants of the tree riparian cities.

The analysis of the interviews reveals, however, that cooperation among cities is not balanced. A number of the interviewees pointed out that the cooperation between Ciudad del Este and Foz do Iguaçu is stronger, mainly due to their energy partnership through Itaipu Binacional. Due to the income generated by Itaipu, GDP is higher in these cities, also reflected in the local economy through larger public investments. As expressed by an interviewee, the two cities have “expanded their actions and in terms of cooperation, whether financial or not, always value the presence of Itaipu in carrying out the activities / projects / actions across the border” (R6_F). On the other hand, the integration of Puerto Iguazú with the other two cities is incipient. Considering the economic and structural conditions of neighbouring countries, Puerto Iguazú is the least dynamic municipality in economic terms. Consequently, this city welcomes the idea to intensity its cooperation in relation to economic, social and cultural issues.

As previously identified, cooperation among cities does exist but at an informal level, mainly involving the Development Councils and members from the Fire Brigades. For instance, Puerto Iguazú has offered assistance in the form of fire trucks to control fires in Ciudad del Este. Foz do Iguaçu has offered assistance as well, especially in relation to Security and Civil Defence. According to various respondents, the attitude towards collaboration has possibly increased in recent years, as a result of informal networks that are formed by key players who are willing to cooperate.

Past disasters offer examples of informal cooperation efforts. After an extreme weather event, informal social mobilization and volunteering are common. During the 2015, many families from Paraguay and Argentina went to the Porto Meira in Foz do Iguaçu to bring donations and offer solidarity. “The residents of Porto Meira also have relatives who live in these neighboring cities” (R9_F). However, institutional cooperation between governments was scarce. After the event, each locality sought to

[44] The region of the three frontiers is also known as the Trinational Region, due to a tourism trade initiative in Foz do Iguaçu

alleviate their own troubles individually. Meanwhile, informal communication channels (mostly based on Whatsapp) were busy sharing experiences and knowledge about how the cities dealt with the disaster.

Informal networks are also considered to be excellent channels of communication, because until disaster information reaches public authority, volunteers are already helping and cooperating, including the contact between the Amateur Radio Group and Members and the Civil Defence of each city. Contact between these people is essential in case of loss of communication systems.

And so it was through informal networks of contacts, with the realization of some events, that businessman from Foz do Iguaçu joined together with representatives of other sectors of civil society and began the process of creation of the Economic Development Council of Foz do Iguaçu - CODEFOZ. With the support of SEBRAE, based on the Council of another city of Paraná: Maringá, the Council was created with social participation, not only of the businessmen, but of other sectors such as Federal Police, Federal Public Prosecutor's Office and social observatories, to promote a greater force to the Council. It was a result of a joint effort to bring together public and private organizations, around projects and ideas that promote sustainable development in the region.

This type of Council is important because the issues addressed and projects are local in scope and do not suffer direct interference from federal agencies which are far removed from the municipal scope. Therefore, another process was initiated to create mechanisms for the trinational frontier to start functioning in a more integrated, peaceful and free way.

The Fronteiras Cooperativas[45] program (Cooperative Borders Program), which promotes integrated development strategies in the trinational area since 2013, has been helping to broaden the business environment and opportunities for small businesses in the border region. And so, CODEFOZ became a reference point and was the source of the other two councils in the region: first in Ciudad del Este Economic Development Council (CODELESTE) and later in Puerto Iguazú (CODESPI).

The three Councils, through the Cooperative Borders Program, understand that there is a need to gain strength in integration, having a representative with the right to

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[45] Programa Fronteiras Cooperativas <http://fronteirascooperativas.blogspot.com.br/p/historico.html>

vote in PARLASUL - Mercosur Parliament. So, it is possible to create common rules and legislation to meet frontier demand as a border region and extend to other countries. The main goal is to strengthen the cooperation among these cities.

The suggestion that appeared in the interviews to strengthen the cooperation was the creation of a Super Economic Development Council of the 3 frontiers. But it is necessary to formalize and create clear rules, criteria for everyone to contribute. It is a very complex relationship because the difference in the tax burden is different in each of the three countries. 'Via Council will be faster to become something more real, more palpable to everyone' (R01_F).

One of the recent achievements of the three Councils is the Conecta Dell initiative, with their presidents (Figure 32). This is a project supported by the Inter-American Development Bank (IDB) which aims to carry out projects focusing on regional development and integration among the three cities. General survey of data, to be held in Ciudad del Este and Puerto Iguazú.

Figure 32. Presidents of three Development Councils

Other possible solutions were highlighted: ´to improve communication among the three city actors,formalizing the communication channels´ (R11_C). In particular, start working in an interinstitutional way, with main representants. Other proposed measures mentioned that could be developed is the ´creation of an emergency operations centre´ (R06_C), a retaining wall near the watercourses, and educational/outreach programs for risk prevention.

In the area of security, there is cooperation from a Tripartite Command of the Tri-Border Area, with the Federal Police of Brazil, the National Police of Paraguay and the Argentine Army. In addition, the Brazilian Federal Police has already carried out several actions in Paraguay to combat international drug trafficking. In cases of emergency, a very fast and efficient way is opened, with the support of the police, the Civil Defence and the Fire Department on any of the bridges connecting the cities.

Nevertheless, the organization and improvement of training and acquisition of equipment and vehicles of the Civil Defence of the three cities is still necessary, so that they work more integrated in both technical and operational so as to avoid bureaucracy.

In the environmental area, trinational cooperation is important to protected areas such as national parks. In this sense, cooperation exists between Foz do Iguacu and Puerto Iguazú in terms of the National Parks. These natural areas share wildlife which do not recognise International borders. Therefore, the teams from these two cities are always in contact and seeking partnerships. It has already jointly held the Campaign between Foz do Iguaçu and Puerto Iguazú, in june, 2012, with funding from the Iguassu Fund and Itaipu Binacional, to choose the Destination of the Iguassu Falls to be voted worldwide as one of the 7 wonders of the world.

In the health sector, the analysis revealed strong cooperation between Foz do Iguaçu and Ciudad del Este, and few cooperation among the others. Foz do Iguaçu has a specific budget to treat patients from Paraguay, known as "Brasiguaios". This program is not extended to Argentinians, and according to some interviewees, this service ends up overloading the Municipal Health System of Foz do Iguaçu. It was constantly mentioned in the interviews the importance that the three countries work together, especially in relation to the fight against common diseases such as dengue and yellow fever, in this case with donations vaccines for Ciudad del Este, as well as cooperation technicians to eradicate the H1N1 influenza virus. In the case of dengue, the Zoonoses Control centre in Foz do Iguaçu has already been to Ciudad del Este to help combating this epidemic in last years. Likewise, informal communication strategies like WhatsApp have been applied to exchange experiences and knowledge about how cities have dealt with dengue cases.

There is also cooperation between Brazil and Paraguay during the dry season, when Ciudad del Este is without sufficient drinking water and Foz do Iguaçu donates. Considering Puerto Iguazú, matters related to bureaucracy were reported. For example: In cases of emergency disasters, if the hospital in Puerto Iguazú is unable to care for the wounded, it will not be allowed to cross the border to use the hospitals in

Foz do Iguaçu, for example, because it is considered illegal. There is a collective action between Puerto Iguazú and Ciudad del Este, with an anti-drug prevention program that was conducted with the community of Ciudad del Este.

In the triangle city, some key actors knows theirs peers (the same function) between these cities, like Civil Defence and the Fire department, which know each other and exchange information. And, specially, the three municipal councils of economic development are increasingly closer, developing actions and projects, seeking funding, together. Tourism Sector in Puerto Iguazú knows the Tourism Sector in Brazil and they have formed partnerships to develop joint campaigns, such as the Iguassu Destination Campaign already mentioned.The PVT - Programa Vida em Trânsito (Life Transit Program) in the last 2 years has already carried out trinational actions. The Legislative Branch of Foz do Iguaçu wants to reinforce the invitation for councilors from neighboring countries to accompany the meetings of the City Council of Foz do Iguaçu, and that this may become routine among the three cities.

7.4.2.1. Barriers

There are some factors that do not allow strong cooperation between cities. This can be seen in the absence of effective communication and established and planned state policy of diplomatic relations, consular and embassy levels, as well as in international border policy. Adapting the Federal bureaucracies with a trinational model, more localized, less complex, is an example which can be reflected in transport dynamics in the border area. The Federal bureaucracies in the international customs barriers hinder the flow in the two international bridges that make foreign exchange with Brazil. There are many trucks circulating at the border and this interferes with the flow of public roads in cities, causing congestion. In addition, historical constraints between countries influence dynamic cooperation, especially between Brazil and Paraguay. Another point considered like a barrier is about the contact between the three Municipalities and Mercosur. Unfortunately, the local realities are unknown by Mercosul representants and the regional realities of Mercosur are not analyzed by Municipalities.

7.4.2.2. Solutions

Throughout the interviews the team explored ways in which cooperation in the triangle-city could be improved. As in our first workshop[46], interviewees shared many ideas. The most mentioned were the areas that need this cooperation are Politics, Economy, Public Health and Institutional Integration, because these areas still needs some attention in frontier. And these interviews suggested about the creation of a Super Economic and Social Trinational Development Council.

Some other ideas were also shared by interviewees, such as some solutions to strengthen cooperation in three frontier, as part of the preventive actions to implemented in this region. One of them was that it is necessary approach International Policies. Institutional Integration at the border is necessary, with the creation of an organ or entity that integrates the three cities, carrying out procedures to maintain this union and the development of the cities, so that they grow together. It would also be a way to integrate cooperation by preparing teams from the 3 neighboring cities for each climatic event that takes place in the region, with equipment, training.

In fact, an International Committee of Mercosur would give direction and contents to do this cooperation. Moreover, in a more local context, ´these political barriers could be overcome by an International Committee of Mercosur´ (R11_F). Through the MERCOSUR international agreement there may be investments in the standardization of the identification of individuals and also of the plates of vehicles in the everyday life of the border. The creation of a training or joint meetings for the exchange of information, to know the ongoing initiatives and projects in each cities. Likewise, having multi-sectoral programs between cities, the application of technology for the automation of information.

As a result of the good political relationship Brazil-Paraguay for 25 years, the second bridge between Foz do Iguaçu and Ciudad del Este is under construction, for the massive transportation in the border.

Cooperation between nations is a result of integration. Be it in the early days, with examples from indigenous communities (without frontiers), or in the current

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[46] First Workshop, realized in March, 2017, in Foz do Iguaçu. With key actors about three cities to know the Triangle-city- cooperation Program and discuss about effects and prevention in the context of Climate Changes.

context, in which cooperative processes are happening timidly but have the potential to ensure diplomacy, quality of life and resilience to extreme weather events in border. Regardless of policy changes, the dynamics of cooperation must be maintained in order to ensure the resilience of a region. The notion of an Adapted frontier is to withstand impacts of climate change, through multi-industry cooperatives and transdisciplinary actions between cities, as an opportunity for a common goal: resilience.

Preliminary Solutions

Soluções Preliminares

Soluciones Preliminares

8. PRELIMINARY SOLUTIONS

As presented in the previous sections, during the first stages of the research, the main climate vulnerabilities that take place in the trinational region were identified. Likewise, the interviews and events held by the project brought together actors from different sectors of the three participating municipalities (Foz do Iguaçu, Ciudad del Este and Puerto Iguazú). Among these contacts, key actors were identified for the holding of focus groups[47], in order to discuss possible solutions capable of increasing the resilience of cities in relation to climate change, towards the identified vulnerabilities. The groups were composed of representatives from various sectors of the three municipalities, these being the public sector, private sector, civil society and academia, with the intention of obtaining an overview close to the reality on the subject.

At total, four focus groups were conducted over a week. The meetings initially took place in each city to discuss specific local issues, being the first one in Puerto Iguazú and the following in Foz do Iguaçu and Ciudad del Este. The fourth meeting was held in Foz do Iguaçu, with the intention of bringing together actors from the three localities[48], so that they could share information and seek joint solutions for the triple frontier, with a focus on cooperation and based on a common challenge, the effects of climate change. In this section, the main solutions raised by the participants during the four focal groups are described in a preliminary way. They were divided according to the following categories: planning, structural measures, non-structural measures and cooperation.

8.1. Planning

In the three local groups, it was pointed out that the **realization of urban**

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[47] According to Powell and Single (1996, p. 499), "a focus group is a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research". The authors point out that the use of such qualitative data collection methodology allows to raise the most important variables of complex subjects, among other indications.

[48] However, due to logistics and the availability of the guests, this meeting was only attended by representatives from Puerto Iguazú and Foz do Iguaçu.

planning and land use planning is paramount for advancing on the development and resilience of the municipalities, in order to solve, for example, problems related to flooding and irregular riverbank occupations. As previously discussed, this is a matter that affects the three municipalities in a significant way, not only from the environmental point of view, but also from the social one. The reasons for these occupations to happen are diverse and also very similar among cities, such as the economic vulnerability of families who do not have the financial resources to buy or rent a house and end up settling in such places.

Thus, the participants of the groups emphasized the importance of any planning being done with the active participation of the entire population, so that all voices are heard and attended. The need to **collect data and conduct technical studies** that could support the planning of adaptation measures was also discussed during the local meetings. Another recurrent issue was the **demand for specific climate information** to allow a better reading of the climate in the three cities and to provide reliable forecasts.

8.2. Structural measures

In addition to the undoubted importance of developing adequate planning for local demands, some solutions related to structural measures were proposed. In the three cities several common points were mentioned, such as the **adaptation of the the constructions with materials that are more resistant to climatic events**, mainly the hailstorms and windstorms. In the opinion of some participants, this could be done by **establishing lines of credit and financing**, for example. Another proposed alternative, somewhat simpler but with the same objective, would be to develop an initiative to **adapt roofs with more resistant materials**, especially for the most vulnerable populations. In Ciudad del Este, possibilities were discussed in terms of **adapting the existing housing in risk areas** to minimize or eliminate the need to relocate families already installed in these locations, as well as **possible technical solutions to contain the floods**. Another issue discussed in the three cities was the need to **devise solutions so that risk areas will not be re-occupied or gain new housing**. Some participants also indicated the i**nvestment in buildings with low**

consumption of natural resources and in **green infrastructure**, as well as **adapted architecture**, as interesting possibilities.

In addition, the need to i**nvest in basic sanitation** was mentioned in the three local groups. It should be remembered that cities do not yet have 100% of the domestic sewage collection, especially in districts farthest from the central regions, whose population is more lacking in financial resources. According to the participants, this would be an urgent measure, as people who are already in vulnerable conditions are even more susceptible to diseases caused by the lack of this service.

The need to **invest in efficient drainage systems** was also mentioned in two of the three local groups. One of the solutions identified for Foz do Iguaçu, for example, is the mapping of drainage points throughout the city, which can be done with the help of the Itaipu Technological Park (PTI), in order to invest in future works to improve the system. In Ciudad del Este, in turn, it was mentioned that a project in that sense is being developed with the support of Itaipu, involving systems for provision of potable water, sewage and drainage of rainwater.

In Puerto Iguazú and Foz do Iguaçu, the importance of **revitalizing the ciliary forest of springs, streams and riverbanks** was also discussed. Participants emphasized that this is essential for environmental preservation and reducing flooding problems, as silting rivers tend to escape from their beds more easily during rains, causing flooding and overlapping of the banks.

Another point discussed in the three cities was the **improvement of solid waste management systems**, as improperly disposed of garbage aggravates and increases the likelihood of flooding (among other problems, such as the proliferation of waterborne diseases). Participants indicated that public sector investment is required for the **collection and disposal of recyclable waste**, as well as **education and environmental awareness campaigns** for the entire population.

8.3. Non-structural measures

Therefore, a common point addressed in the three cities was the importance of **developing awareness and environmental education actions**, as well as **improving communication with the population about climate change and**

sustainability. Some of the target audiences mentioned for that were schools, universities and churches. The **creation of information systems and discussion forums** with the population was also indicated as a way to support such processes and ensure that everyone knows how to act in case of extreme events and alerts. For that, the participants suggested to **seek support from the media**, such as radio and television, as well as the university students in the region. One idea would be to count on their collaboration to **promote campaigns and disseminate information** to the population, with the help of local councils and public authorities.

8.4. Cooperation

In the fourth focal group, focused on the topic of cooperation, issues related to education and communication were also central. Participants discussed possibilities for **integration and/or synergy between educational actions and alert communication systems** in the three municipalities, both within the population and among the competent bodies, such as those responsible for civil defense actions at each location.

Another demand related to integration, brought by one of the municipalities, was that councils, associations and municipalities **seek greater dialogue** among themselves, to work together for solutions for cities. In addition, the proposal to **create funds or savings for the three municipalities** was made, in order to count on emergency reserves for disasters and to invest in infrastructure, especially in drainage systems and in the construction of houses to relocate families in vulnerable conditions.

Some participants also brought up their joint work experiences that already take place between organs of the three cities and countries. However, as discussed in previous sections, at the present this cooperation is carried out in an informal and still unusual ways. Some proposals were made, such as the **creation of a Tri-National Civil Defense Council** involving the three cities, in an institutionalized and committed way, formalizing the channels of information exchange, which could improve communication between the parties. Some participants also suggested to **articulate existing projects in the region**, which do not always dialogue, in order to boost their results.

Another proposal was to **create**, through the local councils (CODEFOZ, CODELESTE and CODESPI), **Tri-national Chambers**, where integrated planning between cities could be developed, and among the Chambers, to **create a specific one to discuss climate changes**, with the aim to produce data and develop strategies related to the tri-border resilience. In one of the local groups, the relevance of cities to cooperate in a more direct way was also emphasized, since the formal processes for that are generally discussed at the national level and not locally. In that sense, a participant recurred to the concept of paradiplomacy[49]. Another suggestion was to t**ake advantage of instances of Mercosur and its parliament (Parlasul)** to enable such cooperation between the three cities, with the right to vote and the possibility of creating common laws for the three countries, or by encouraging some international procedures to facilitate the traffic in the international bridges that connect the three cities, thus promoting regional integration, the Mercosur premise. It was mentioned that the Trinational region could manifest itself in dialogue with the newly created Working Subgroup 18 on border integration. In this way, the project would be institutionally and politically strengthened.

Regarding the solutions addressed during all the meetings held by the team, it is noticeable that much of what was mentioned by the actors is very similar, which shows the convergence between the problems and also the possible solutions. This highlights the importance of cross-border cooperation in the quest for climate resilience, understanding that the factors that affect one city inevitably affect others as well. In addition, the suggested solutions are in line with the guidelines and institutional arrangements established for adaptation to climate change in the three cities and countries, as earlier discussed, which represents an opportunity for its implementation.

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[49] According to Moreira, Senhoras and Vitte (2009, p. 3), paradiplomacy is characterized by a process of extroversion of subnational actors such as local and regional governments, international organizations, multilateral companies that negotiate and practice agreements aimed at obtaining resources and acting in specific areas where there is no state government intervention.

Conclusions

Conclusões

Conclusiones

9. CONCLUSIONS

This report presents a first assessment of the vulnerability of the triangle-city region to climate variations and extremes. It provides a background to understand the history and characteristics of the three cities. It examines their current disaster risk reduction strategies, policies and institutional settings with the aim of finding differences and gaps. The report also investigates past and future climate trends, so as to provide insights into what the cities might expect in the following decades. Moreover, it presents an urban vulnerability index to compare the situation among the three cities and identify urgent areas of action. Stakeholders' perceptions and views are also analysed to understand the situation that each city faces in terms of their experiences with extreme weather events. In addition, the report examines the level of cooperation that exists between the cities, and takes a closer look at how they interact when threatened by extreme weather events. Furthermore, it gathers some specific solutions recommended by different actors.

As explained in Chapter 3, the cities have expanded in a rapid manner during the last decades, experiencing high population growth rates. This growth has been fuelled by an expansion of their economies, mainly in the energy, tourism and commerce sectors. However, this uncontrolled growth has generated a myriad of challenges in the social, economic and environmental spheres, among others. Although the three cities face different problems on an individual basis, they share common challenges. The local economies have not had the capacity to generate the level of formal employment opportunities required to meet the growing demand for jobs. Moreover, the lack of adequate urban planning, along with weak institutions that have been unable to enforce existing legal and regulatory frameworks, has given way to difficulties related to access to public services (e.g. water, health, sewerage, security), illegal and clandestine practices, environmental hazards, unsafe and unaffordable housing, among other issues. Moreover, the advancement of agriculture, the expansion of the urban sprawl, and tourism activities have exerted significant pressure on the natural environment.

In terms of climate issues, as explained in Chapter 4, the three cities have experienced impacts from extreme weather events during the last decades. An examination of past climate information is useful in order to determine how climate patterns have changed over the years. The trends suggest that there have been changes in weather conditions and climate variability over time. Seven types of extreme weather and climate-related events were analysed, all of which have affected the triangle-city region to a certain extent: (i) intense precipitation, (ii) strong winds, (iii) hail storms, (iv) heat waves, (v) cold waves, (vi) floods, (vii) and droughts.

The analysis of past climate trends produced interesting findings. Regarding temperature, records in the region show that annual maximum and minimum temperatures have increased over the years, with a maximum recorded value of 40.2°C, and a minimum of -4°C.

Concerning precipitation, results indicate that the annual amount of rainfall, as well as the annual maximum of daily precipitation, has been increasing over time. This suggests that precipitation events have become more intense.

Hail storms, on the other hand, are rare and show a low-probability of occurrence. Nonetheless, these events have proven to be devastating whenever they have struck. Even though they tend to last only a few minutes (between 5 and 15), the diameter of hailstones can be considerable. As experienced in September 7, 2015, some neighbourhoods in the triangle-city region suffered heavy damages, due to the intensity of the storm and the size of hailstones. The fragile infrastructure and roofing materials, associated with a lack of awareness and preparedness measures, led to high economic and social costs.

The study also identified that the triangle-city region is located within an area recognized to be prone to severe thunderstorms, including the occurrence of tornadoes (Brooks, et al., 2003; Nascimento & Doswell III, 2005; Silva Dias, 2011). In fact, an increase in the number of tornado alerts in southern Brazil has been reported since 1970 (Silva Dias, 2011).

In general, the findings obtained from the analysis of past trends provide some evidence that climate patterns are gradually changing in the region. This message tends to agree with the future climate outlook presented by relevant studies conducted at global and regional scales. According to future climate projections presented by the IPCC (2014), the frequency and intensity of extreme weather events are expected to increase across the world, and South America is not an exception. Climate models for this region show that, in general, the continent will face rising trends in annual rainfall, especially in south-eastern areas. An increase in temperature extremes have also been predicted for tropical and subtropical areas in South America. The projections presented in Chapter 5 similarly indicate that climate variability will be present in the triangle-city region. In concordance with IPCC scenarios, future projections developed by different models show that temperature will tend to increase in the region. On the other hand, it is difficult to determine the changes in mean precipitation, but it is expected that the region will continue to experience variability. Extreme daily precipitation events, however, are expected to become more intense across the region. In this sense, Chapter 5 clearly shows the challenge ahead. The triangle-city region is expected to face rising climate variability and thus needs to be prepared for future climate-related events.

With the aim of investigating what the triangle-city region is doing to face that challenge, Chapter 6 presents evidence of the legal, institutional and policy settings regarding disaster risk reduction and climate change adaptation. It was found that adaptation policy and planning is happening at national levels, but not at a local scale. Moreover, any existing efforts at the city level are conducted unilaterally. The three cities have framed their actions according to climate policy of their respective countries without seeking regional coordination. Furthermore, gaps were found. The three cities do not have formal disaster risk reduction protocols, which seriously affects their capacity to adapt and build climate resilience. The study identified the existence of some early warning systems, but these still need to be further improved and integrated across the cities. Puerto Iguazu appears to be the city that lags behind, while climate change policies appear more advanced in Foz do Iguaçu.

In terms of their capacity to respond to extreme weather events, Foz do Iguaçu and Puerto Iguazú both rely on Civil Defence organizations, while in CDE the municipality is in charge of attending disasters. The three cities are also strongly supported by their fire departments, which provide valuable services to assist affected population in the case of disasters.

Chapter 7 presents the vulnerability assessment of the 3 cities. This has been done through the development of indicators, complemented by interviews to key actors. An urban vulnerability index (UVI) was developed in order to measure the inherent characteristics (physical, social and economic attributes), as well as their capacities to respond, recover and adapt. According to the UVI, Ciudad del Este and

Puerto Iguazú share similar levels of vulnerability in comparison to Foz do Iguaçu. Ciudad del Este obtained the largest score (indicating higher vulnerability), while Foz obtained the lowest. Foz do Iguacu is less sensitive to EWEs due to its larger amount of green areas, lower levels of poverty, better access to public services (e.g water, waste treatment, education), lower mortality rates, a larger public budget, and a more dynamic and diversified economy. The results also show that Foz do Iguaçu has higher levels of preparedness and a higher capacity to recovery. Moreover, its institutions for emergency management have a good reputation, while the city has a better disposition to adopt good practices.

The indicators were complemented and validated by information provided by experts in academia, the business sector, emergency-service organisations, among others. These actors provided information on what is currently being done in the three cities to improve their climate resilience. As part of the preventive actions under development in Ciudad del Este, the municipality is building an underground electricity grid. It also has projects to improve waste management and prevent littering by creating public awareness of their environmental consequences. Moreover, the International Center for Hydroinformatics (CIH/ITAIPU) is currently developing applications based on free software to monitor in real time the hydrological conditions of the Paraná River. In Puerto Iguazú, urban flood events have been partially solved due to the construction of canals and drainage systems. Furthermore, in Foz do Iguaçu there have been efforts to relocate people that live in risk areas, albeit with ineffective results.

Overall, the findings show that vulnerability to climate variations and extremes is shared among the three cities that comprise the triangle-city region. Therefore cooperation is an integral part of any solution. We explored the level of cooperation between the three cities and found that it mainly depends on informal networks and on voluntary actions at individual or institutional levels with a lack of formal frameworks or agreements. However, the findings offer evidence that there is substantial willingness to strengthen cooperation links. Actors in the three cities show good disposition to work together and undertake efforts to formalise cooperation between the cities. Specifically, the local development councils (CODESPI, CODEFOZ and CODELESTE) are inclined to create more spaces and opportunities for policy making with the aim to integrate the triangle-city region. Some actors, in this sense, offered their views to improve cooperation. They suggested numerous actions, such as strengthening the integration of educational actions, develop synergies among existing projects, seek greater dialogue among councils, associations and municipalities, create early warning systems, establish recovery funds and invest in infrastructure. Some actors even suggested the creation of a Tri-National Civil Defense Council with members from the three cities to discuss climate change strategies, collect data and develop strategies to build climate resilience in the triangle-city region. Structural and non-structural solutions were also proposed. Urban planning with active participation of the three cities is paramount for advancing on the development and resilience of the three cities. The need to collect data and conduct technical studies that could support the planning of adaptation measures and to provide a better understanding of climate events and weather forecasts in the region is also required. Furthermore, the importance of developing awareness and improving environmental education was highlighted.

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11. Annexes

List of Annexes:

11.1. ANNEX A: Extreme weather and climate events in the triple-border region

A.1 Location of Weather Stations.

A.1.1. Ciudad del Este Weather Station.

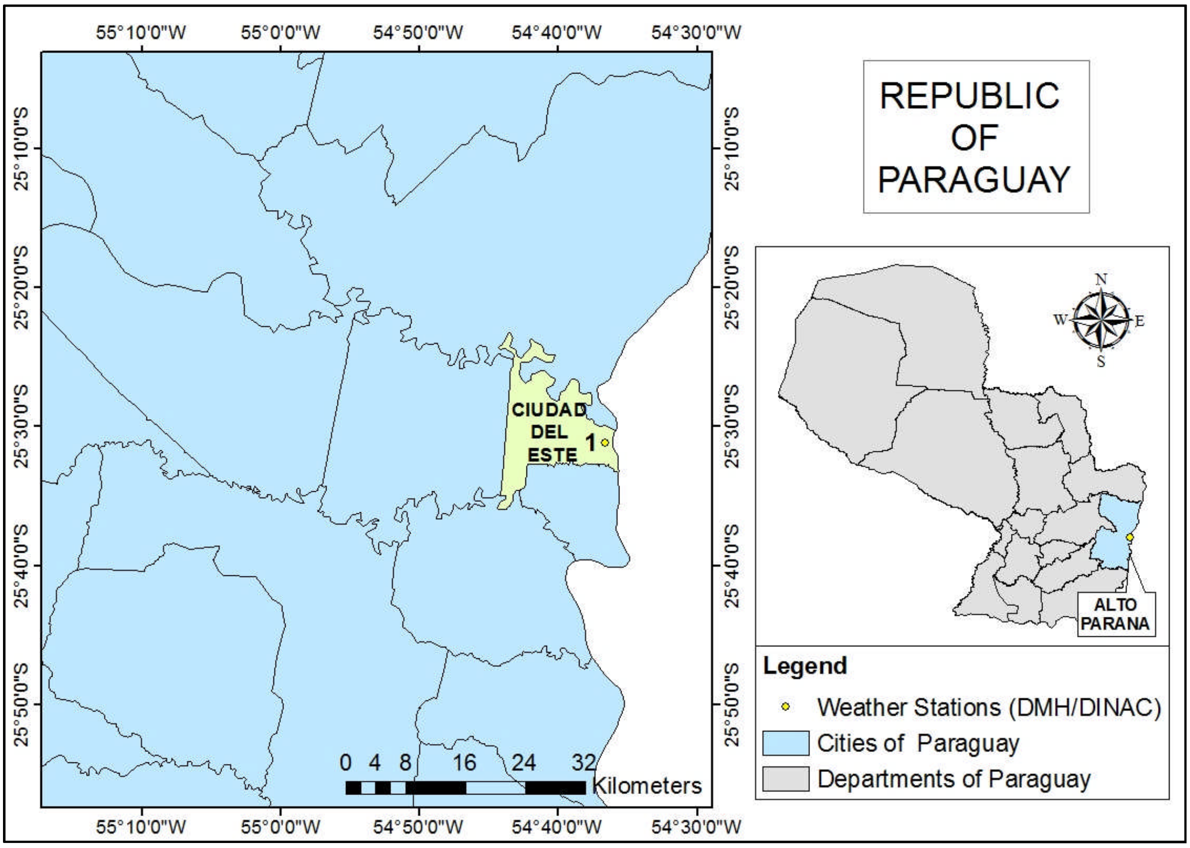

Figure A 1. Ciudad del Este Weather Station.

Table A 1. Ciudad del Este Weather Station.

#	Institution	Name of the Weather Station	Department	City	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)
1	DMH/DINAC	Ciudad del Este	Alto Paraná	Ciudad del Este	-54.61	-25.52

A.1.2. Iguazú Aero Weather Station.

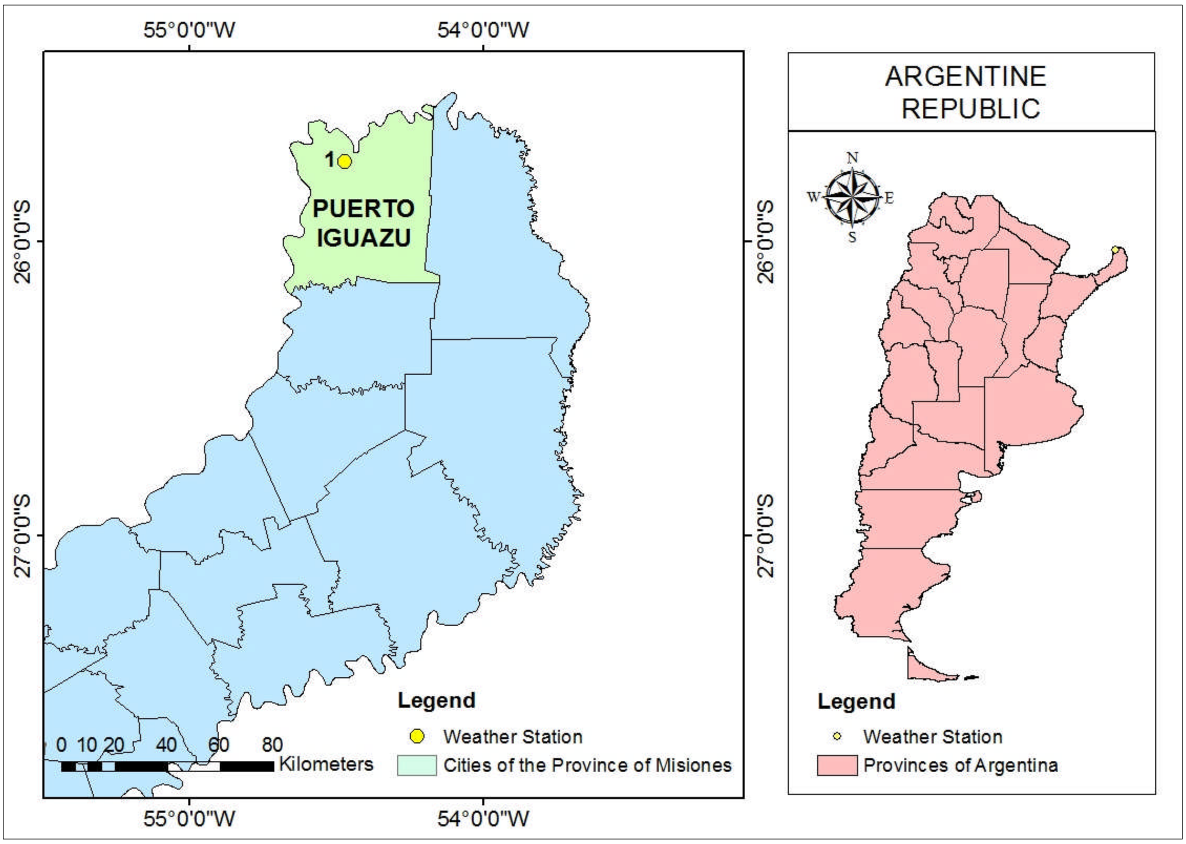

Figure A 2. Iguazú Aero Weather Station.

Table A 2. Iguazú Aero Weather Station.

#	Institution	Name of the Weather Station	Province	City	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)
1	SMN	Iguazú Aero	Misiones	Puerto Iguazú	-54.47	-25.73

A.2. Maximum Annual Daily Precipitation.

A.2.1. Ciudad del Este Weather Station.

Table A 3. Maximum annual daily precipitation. Ciudad del Este Weather Station.

Year	Maximum precipitation (mm/d)	Year	Maximum precipitation (mm/d)	Year	Maximum precipitation (mm/d)
1966	123.60	1980	93.40	1994	90.00
1967	77.70	1981	161.40	1995	77.00
1968	138.00	1982	107.60	1996	108.00
1969	85.10	1983	123.70	1997	213.80
1970	63.30	1984	117.00	1998	182.80
1971	101.70	1985	52.10	1999	72.40
1972	140.00	1986	133.40	2000	92.00
1973	88.70	1987	87.70	2001	73.80
1974	101.30	1988	92.70	2002	112.00
1975	89.00	1989	85.80	2003	143.00
1976	90.40	1990	153.40	2004	68.80
1977	81.00	1991	109.20	2005	113.40
1978	78.40	1992	67.20	2006	133.70
1979	68.30	1993	86.00		

A.2.2. Iguazú Aero Weather Station.

Table A 4. Maximum annual daily precipitation. Iguazú Aero Weather Station.

Year	Maximum precipitation (mm/d)	Year	Maximum precipitation (mm/d)	Year	Maximum precipitation (mm/d)
1969	120.00	1985	58.00	2001	76.00
1970	70.00	1986	107.00	2002	180.00
1971	103.00	1987	128.50	2003	156.00
1972	123.00	1988	92.00	2004	131.00
1973	110.50	1989	126.50	2005	107.00
1974	101.00	1990	186.30	2006	101.00
1975	64.30	1991	139.00	2007	120.00
1976	76.00	1992	94.00	2008	90.00
1977	109.20	1993	135.00	2009	121.00
1978	110.00	1994	183.70	2010	133.00
1979	131.80	1995	105.00	2011	83.00
1980	180.00	1996	133.00	2012	130.00
1981	94.20	1997	162.1	2013	94.50
1982	86.00	1998	97.00	2014	188.00
1983	147.30	1999	91.10	2015	87.00
1984	103.00	2000	67.00	2016	106.00

A.3. Seasonal Distribution of Annual Maximum Daily Precipitation.

A.3.1. Ciudad del Este Weather Station.

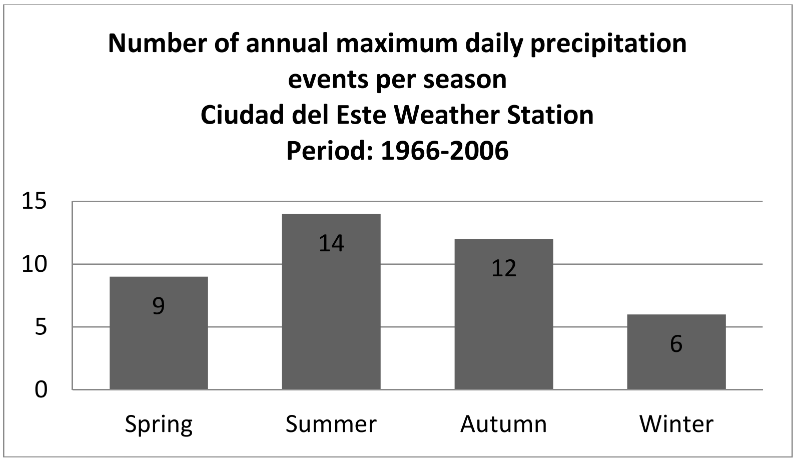

Figure A 3. Seasonal distribution of annual maximum daily precipitation. Ciudad del Este Weather Station.

A.3.2. Iguazú Aero Weather Station.

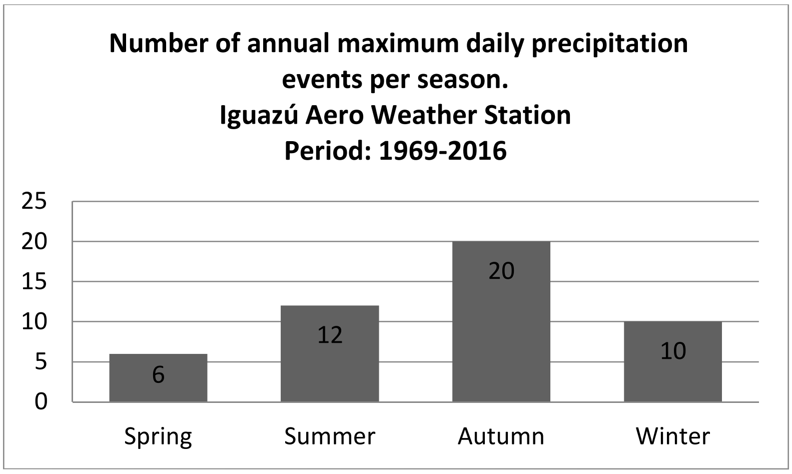

Figure A 4. Seasonal distribution of annual maximum daily precipitation. Yguazú Aero Weather Station.

A.4. Seasonal Distribution of Extreme Precipitation Events.

A.4.1. Ciudad del Este Weather Station.

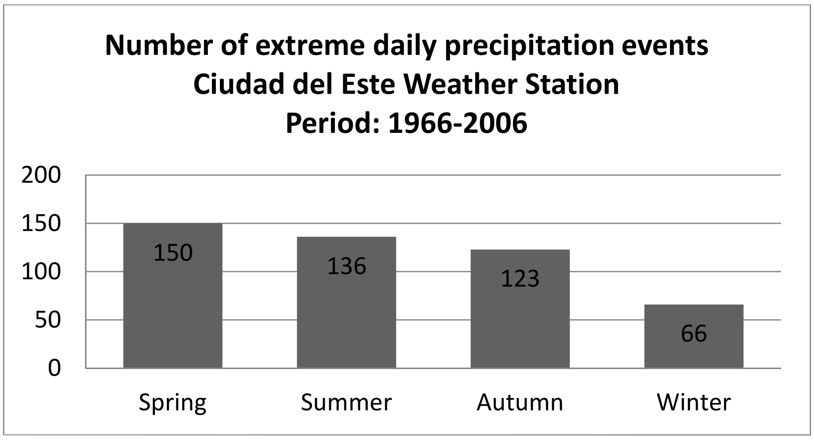

Figure A 5. Seasonal distribution of the number of extreme precipitation events. Ciudad del Este Weather Station.

A.4.2. Iguazú Aero Weather Station.

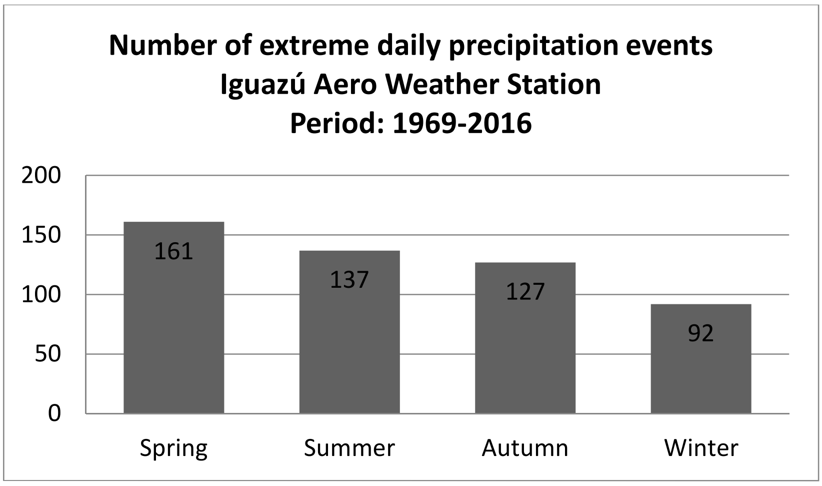

Figure A 6. Seasonal distribution of the number of extreme precipitation events. Iguazú Aero Weather Station.

A.5. Monthly Distribution of Annual Maximum Daily Temperatures.

A.5.1. Ciudad del Este Weather Station.

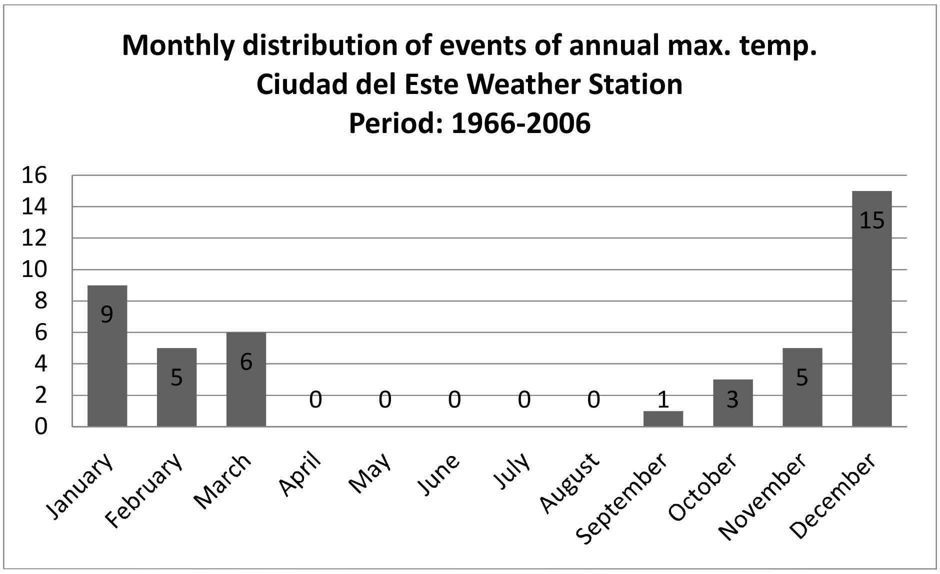

Figure A 7. Monthly distribution of events of annual maximum daily temperatures. Ciudad del Este Weather Station.

A.5.2. Iguazú Aero Weather Station.

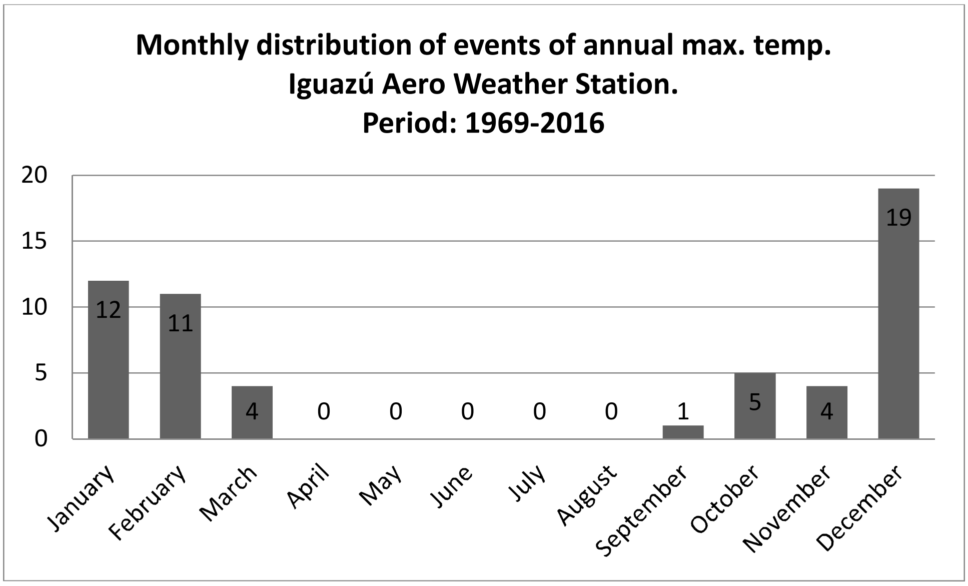

Figure A 8. Monthly distribution of events of annual maximum temperatures. Iguazú Aero Weather Station.

A.6. Seasonal Distribution of Annual Maximum Daily Temperatures.

A.6.1. Ciudad del Este Weather Station.

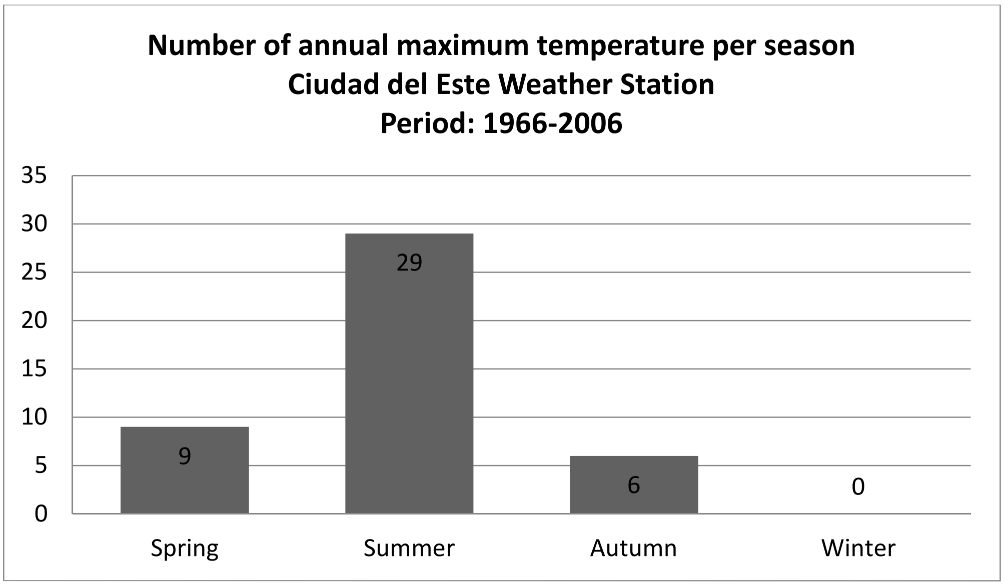

Figure A 9. Seasonal distribution of events of annual maximum daily temperatures. Ciudad del Este Weather Station.

A.6.2. Iguazú Aero Weather Station.

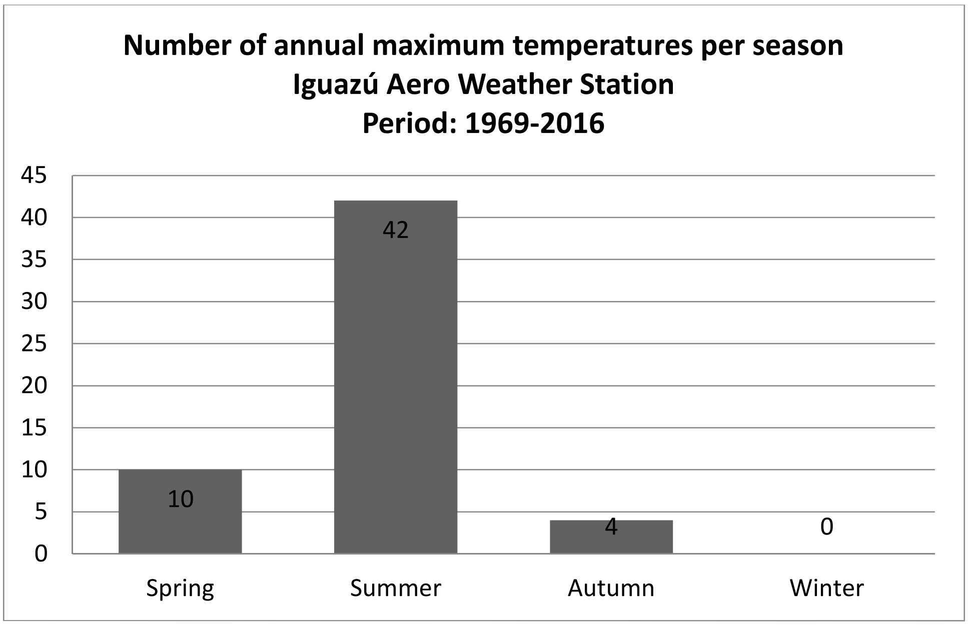

Figure A 10. Seasonal distribution of events of annual maximum daily temperatures. Iguazú Aero Weather Station.

A.7. Heat waves.

A.7.1. DMH/DINAC Approach.

A.7.1.1. Ciudad del Este Weather Station.

Table A 5. Heat wave events. DM/DINAC Approach. Ciudad del Este Weather Station.

Heat Waves – Ciudad del Este Weather Station - DMH/DINAC Approach.					
Event Number	**Start date**	**End date**	**Days**	**Max. Temp. (°C)**	**Min. Temp. (°C)**
Event N°1	14/03/1966	16/03/1966	3	36	19.4
Event N°2	10/12/1966	14/12/1966	5	37	22.8
Event N°3	01/03/1968	03/03/1968	3	36.5	17.4
Event N°4	23/11/1968	25/11/1968	3	35.7	17
Event N°5	12/12/1968	14/12/1968	3	37.4	20
Event N°6	03/02/1969	05/02/1969	3	36.4	22
Event N°7	03/02/1971	07/02/1971	5	37.2	21.6
Event N°8	24/10/1972	26/10/1972	3	36.8	19.5
Event N°9	11/01/1973	13/01/1973	3	36.2	23.6
Event N°10	13/02/1975	16/02/1975	4	37	23
Event N°11	24/02/1977	28/02/1977	5	37	22
Event N°12	06/03/1977	12/03/1977	7	38	22.2
Event N°13	22/10/1977	24/10/1977	3	37	18.4
Event N°14	28/01/1978	02/02/1978	6	38	22
Event N°15	22/02/1978	24/02/1978	3	37.2	18.4
Event N°16	15/03/1978	22/03/1978	8	37.2	21.4
Event N°17	02/02/1979	06/02/1979	5	38.8	20.6
Event N°18	06/12/1979	08/12/1979	3	36.8	20.6
Event N°19	20/03/1980	23/03/1980	4	36	22
Event N°20	27/10/1984	29/10/1984	3	35.8	20.2
Event N°21	30/01/1985	01/02/1985	3	37.4	18.6
Event N°22	11/11/1985	19/11/1985	9	39.6	21.6
Event N°23	06/12/1985	12/12/1985	7	40.2	18.6
Event N°24	16/12/1985	19/12/1985	4	39.2	21.8
Event N°25	29/12/1985	31/12/1985	3	37.6	18.6
Event N°26	19/11/1987	21/11/1987	3	35.5	18
Event N°27	27/01/1988	29/01/1988	3	35.8	25.6
Event N°28	23/03/1988	27/03/1988	5	36	20.2
Event N°29	09/11/1988	12/11/1988	4	36.6	17.5
Event N°30	04/12/1988	07/12/1988	4	38	21
Event N°31	13/11/1990	15/11/1990	3	37	24.6
Event N°32	06/02/1992	08/02/1992	3	36.4	21.4
Event N°33	02/01/1993	05/01/1996	4	37.8	23
Event N°34	22/09/1994	24/09/1994	3	37	18.3

Event N°35	10/12/1994	14/12/1994	5	36	22
Event N°36	24/12/1994	26/12/1994	3	36.6	22.2
Event N°37	07/11/1995	09/11/1995	3	36.4	21.6
Event N°38	25/02/1997	27/02/1997	3	35.8	24.6
Event N°39	19/01/1998	21/01/1998	3	36	21.4
Event N°40	28/11/1998	02/12/1998	5	36	18.8
Event N°41	03/03/1999	05/03/1999	3	35	23.7
Event N°42	29/11/1999	01/12/1999	3	37.2	18.4
Event N°43	17/12/1999	19/12/1999	3	37.4	20.2
Event N°44	08/04/2000	10/04/2000	3	35.6	20
Event N°45	08/03/2002	12/03/2002	5	37.2	23.4
Event N°46	14/03/2002	17/03/2002	4	37.4	24.4
Event N°47	25/02/2003	28/02/2003	4	37	23.8
Event N°48	09/11/2003	11/11/2003	3	37.2	17
Event N°49	14/02/2005	16/02/2005	3	36.6	20.6
Event N°50	18/02/2005	23/02/2005	6	38.2	20.4
Event N°51	06/03/2005	08/03/2005	3	38.2	21
Event N°52	09/03/2005	12/03/2005	4	39.6	21.4
Event N°53	19/03/2005	21/03/2005	3	37	24.4
Event N°54	27/03/2005	29/03/2005	3	35	21.4
Event N°55	07/01/2006	12/01/2006	6	37.6	24
Event N°56	14/01/2006	16/01/2006	3	37.8	23.4
Event N°57	01/02/2006	04/02/2006	4	36.6	22.6
Event N°58	26/10/2006	28/10/2006	3	36.6	23
Event N°59	10/12/2006	12/12/2006	3	35.4	22.8
Event N°60	14/12/2006	17/12/2006	4	38	23.8

A.7.2. Iguazú Aero Weather Station.

Table A 6. Heat wave events. DMH/DINAC Approach. Iguazú Aero Weather Station.

Heat Waves – Iguazú Aero Weather Station – DMH/DINAC approach					
Event Number	**Start date**	**End date**	**Number of days**	**Max. Temp. (°C)**	**Min. Temp. (°C)**
Event N°1	15/03/1969	17/03/1969	3	36	16.4
Event N°2	19/12/1996	21/12/96	3	36.4	16.3

Event N°3	18/01/1970	20/01/1970	3	35	15.3
Event N°4	05/03/1970	07/03/1970	3	35.4	19.9
Event N°5	03/02/1971	05/02/1971	3	37	20.9
Event N°6	15/11/1971	17/11/1971	3	35.4	11.2
Event N°7	18/12/1971	21/12/1971	4	37	17.9
Event N°8	28/12/1971	30/12/1971	3	35	17.9
Event N°9	05/03/1972	07/03/1972	3	35	16.3
Event N°10	24/10/1972	26/10/1972	3	37	17.9
Event N°11	16/12/1972	20/12/1972	5	36	10.9
Event N°12	10/01/1973	14/01/1973	5	37	19.9
Event N°13	16/01/1973	18/01/1973	3	36	19.6
Event N°14	06/02/1973	10/02/1973	5	37.2	20.9
Event N°15	20/02/1973	25/02/1973	6	37	19.9
Event N°16	12/02/1975	16/02/1975	5	36.8	22
Event N°17	09/03/1977	12/03/1977	4	37.4	20
Event N°18	23/01/1978	25/01/1978	3	36.9	21
Event N°19	27/01/1978	31/01/1978	5	38.9	20
Event N°20	19/03/1978	25/03/1978	7	37.9	19
Event N°21	02/02/1979	06/02/1979	5	37.9	17
Event N°22	22/03/1980	25/03/1980	4	35.6	20.4
Event N°23	06/01/1984	10/01/1984	5	37.2	20
Event N°24	27/10/1984	29/10/1984	3	36.6	20
Event N°25	12/10/1985	14/10/1985	3	36.7	19
Event N°26	13/11/1985	19/11/1985	7	39.9	19.8
Event N°27	06/12/1985	09/12/1985	4	39.8	17.6
Event N°28	16/12/1985	19/12/1985	4	40	18
Event N°29	29/12/1985	02/01/1986	5	37.5	20
Event N°30	09/11/1988	11/11/1988	3	37.3	11.5
Event N°31	04/12/1988	07/12/1988	4	37.8	20.2
Event N°32	15/12/1988	17/12/1988	3	37	17.1
Event N°33	11/03/1990	13/03/1990	3	37	21.9
Event N°34	13/11/1990	15/11/1990	3	37.9	22.7
Event N°35	14/01/1991	16/01/1991	3	35	18.7
Event N°35	02/01/1993	05/01/1993	4	38.4	20
Event N°36	12/01/1994	14/01/1994	3	35	16.3
Event N°37	20/09/1994	24/09/1994	5	37	16.8
Event N°38	10/12/1994	14/12/1994	5	36.8	18.4
Event N°39	24/12/1994	26/12/1994	3	37.6	20

Event N°40	06/11/1995	09/11/1995	4	36.5	19.2
Event N°41	15/12/1995	17/12/1995	3	37	16.8
Event N°42	25/02/1997	27/02/1997	3	35.1	22.7
Event N°43	09/11/1997	11/11/1997	3	36	20.7
Event N°44	28/11/1998	30/11/1998	3	36	18
Event N°45	29/11/1999	01/12/1999	3	36.5	21.6
Event N°46	17/12/1999	20/12/1999	4	38.2	17.7
Event N°47	09/03/2002	11/03/2002	3	37	22.3
Event N°48	14/03/2002	17/03/2002	4	36.5	21.7
Event N°49	26/02/2003	28/02/2003	.3	36.5	21.8
Event N°50	06/09/2004	08/09/2004	3	36	16.3
Event N°51	16/02/2005	23/02/2005	8	38.5	18.1
Event N°52	10/03/2005	12/03/2005	3	38.5	20.4
Event N°53	07/01/2006	12/01/2006	6	36.2	22.7
Event N°54	14/01/2006	16/01/2006	3	38.5	20.8
Event N°55	02/02/2006	04/02/2006	3	36.5	20.6
Event N°56	05/03/2007	07/03/2007	3	35.3	20.1
Event N°57	27/03/2007	29/03/2007	3	36.2	21.8
Event N°58	01/12/2007	03/12/2007	3	38	20.6
Event N°59	23/12/2008	22/12/2008	3	36.2	20.6
Event N°60	28/12/2008	31/12/2008	4	36.8	20.1
Event N°61	01/11/2009	05/11/2009	5	37.5	19.5
Event N°62	05/02/2010	07/02/2010	3	37.8	23.1
Event N°63	20/12/2011	23/12/2011	4	38.4	19.2
Event N°64	04/01/2012	06/01/2012	3	35.8	17.4
Event N°65	08/01/2012	10/01/2012	3	36	21.4
Event N°66	02/02/2012	07/02/2012	6	37.2	20.4
Event N°67	16/02/2012	20/02/2012	5	36.6	20.6
Event N°68	05/03/2012	10/03/2012	6	36.4	19.2
Event N°69	28/01/2013	01/02/2013	5	36.7	18
Event N°70	19/01/2014	22/01/2014	4	36.2	20.3
Event N°71	30/01/2014	08/02/2014	10	39	20
Event N°72	10/02/2014	12/02/2014	3	37	19.6
Event N°73	15/10/2014	17/10/2014	3	39	21.4
Event N°74	16/09/2015	18/09/2015	3	36.7	17.2
Event N°75	23/01/2016	25/01/2016	3	37	19.9

A.7.2. SMN Approach.

A.7.2.1. Ciudad del Este Weather Station.

Table A 7. Heat wave events. SMN Approach. Iguazú Aero Weather Station.

Heat Waves – Ciudad del Este Weather Station - SMN Approach.					
Event Number	**Start date**	**End date**	**Days**	**Max. Temp. (°C)**	**Min. Temp. (°C)**
Event N°1	11/01/1973	14/01/1973	4	36.2	23.6
Event N°2	09/03/1977	11/03/1977	3	37	23.6
Event N°3	07/01/1978	09/01/1978	3	36	24.2
Event N°4	29/01/1978	02/02/1978	5	38	23.6
Event N°5	27/01/1988	29/01/1988	3	35.8	24.2
Event N°6	11/03/1990	13/03/1990	3	35.6	23.8
Event N°7	13/11/1990	16/11/1990	4	37	24.6
Event N°8	02/01/1993	04/01/1993	3	37.8	24
Event N°9	20/01/1994	22/01/1994	3	35.5	23.9
Event N°10	12/12/1994	14/12/1994	3	36	25
Event N°11	25/02/1997	27/02/1997	3	35.8	24.8
Event N°12	20/01/1998	22/01/1998	3	36.2	24.3
Event N°13	03/03/1999	05/03/1999	3	35	23.7
Event N°14	09/01/2000	11/01/2000	3	35.6	24
Event N°15	09/03/2002	12/03/2002	4	37.2	24
Event N°16	14/03/2002	17/03/2002	4	37.4	24.4
Event N°17	25/02/2003	01/03/2003	5	37	23.8
Event N°18	07/01/2006	09/01/2006	3	35.6	24
Event N°19	10/01/2006	12/01/2006	3	37.6	25
Event N°20	03/02/2006	05/02/2006	3	36.6	24.4
Event N°21	14/12/2006	17/12/2006	4	38	23.8

A.7.2.2. Iguazú Aero Weather Station.

Table A 8. Heat wave events. SMN Approach. Iguazú Weather Station.

Heat Waves – Iguazú Aero Weather Station – SMN approach					
Event Number	**Start date**	**End date**	**Number of days**	**Max. Temp. (°C)**	**Min. Temp. (°C)**
Event N°1	05/02/196	10/02/1969	6	38	22.1
Event N°2	05/01/1970	08/01/1970	4	37	22.6
Event N°3	04/02/1971	08/02/1971	5	37.3	22.6
Event N°4	07/02/1973	09/02/1973	3	36	22.1

Event N°5	12/02/1975	16/02/1975	5	36.8	22
Event N°6	14/01/1976	17/01/1976	4	35.9	22
Event N°7	05/02/1977	08/02/1977	3	35	22
Event N°8	29/01/1978	02/02/1978	5	38.9	22
Event N°9	07/01/1984	10/0/1984	4	37.2	22.6
Event N°10	13/03/1990	15/03/1990	3	37	22
Event N°11	13/11/1990	15/11/1990	3	37.9	22.7
Event N°12	12/12/1994	14/12/1994	3	36	22.5
Event N°13	25/02/1997	27/02/1997	3	35	22.7
Event N°14	18/01/2000	20/01/2000	3	36	22.4
Event N°15	09/03/2002	12/03/2002	4	37	22.3
Event N°16	07/01/2006	12/01/2006	6	36.2	22.7
Event N°17	02/02/2010	07/02/2010	6	37.8	22.8
Event N°18	03/02/2012	05/02/2012	3	36.7	22

A.8. Monthly Distribution of Annual Minimum Temperatures.

A.8.1. Ciudad del Este Weather Station.

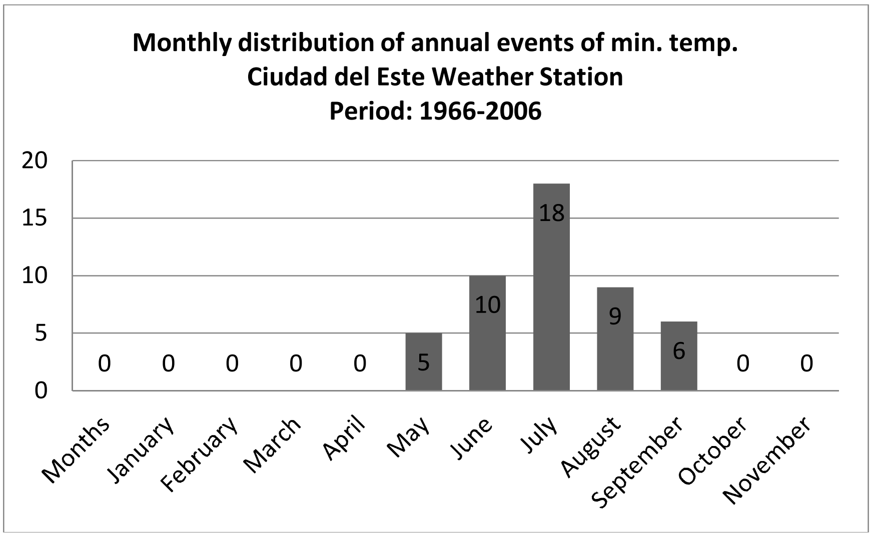

Figure A 11. Monthly distribution of annual events of minimum temperatures. Ciudad del Este Weather Station.

A.8.2. Iguazú Aero Weather Station.

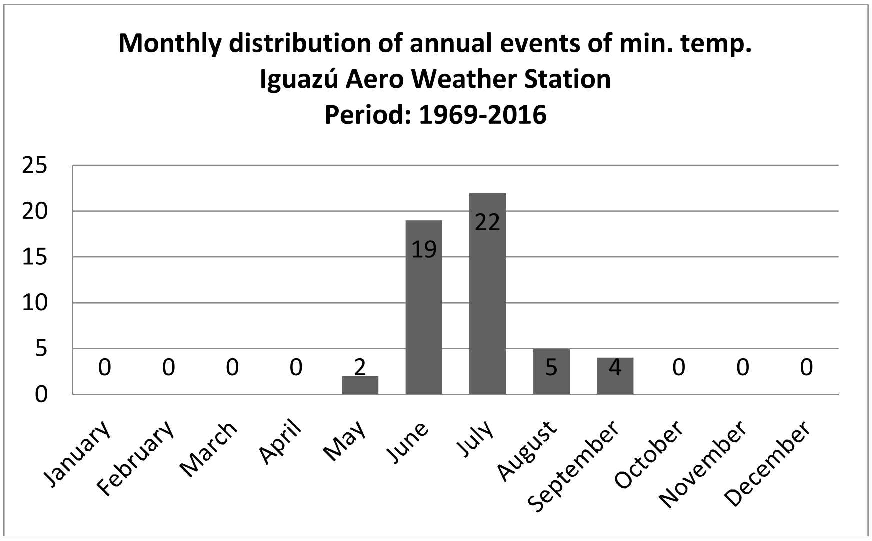

Figure A 12. Monthly distribution of annual events of minimum temperatures. Iguazú Aero Weather Station.

A.9. Seasonal Distribution of Annual Minimum Daily Temperatures.

A.9.1. Ciudad del Este Weather Station.

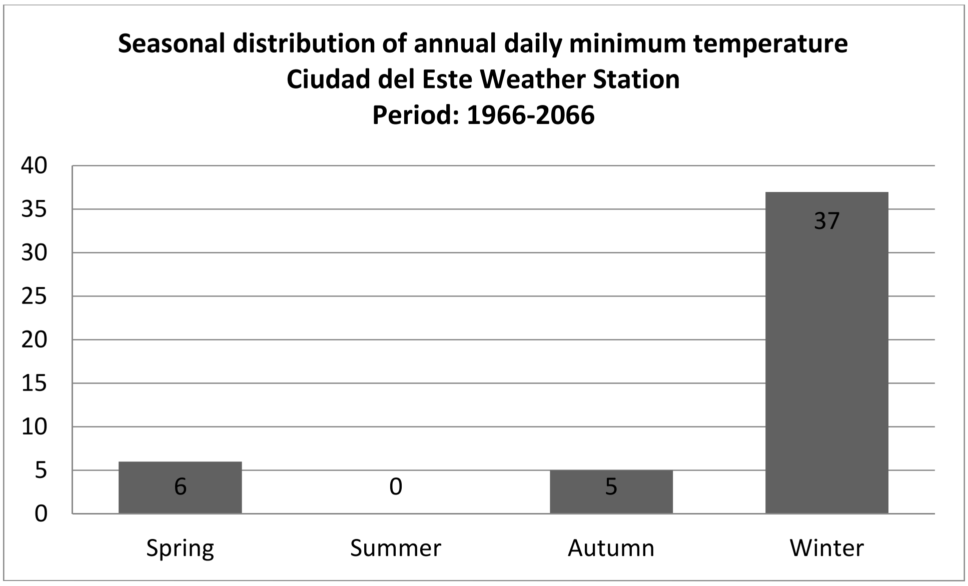

Figure A 13. Seasonal distribution of annual mínimum daily temperaturas. Ciudad del Este Weather Station.

A.9.2. Iguazú Aero Weather Station.

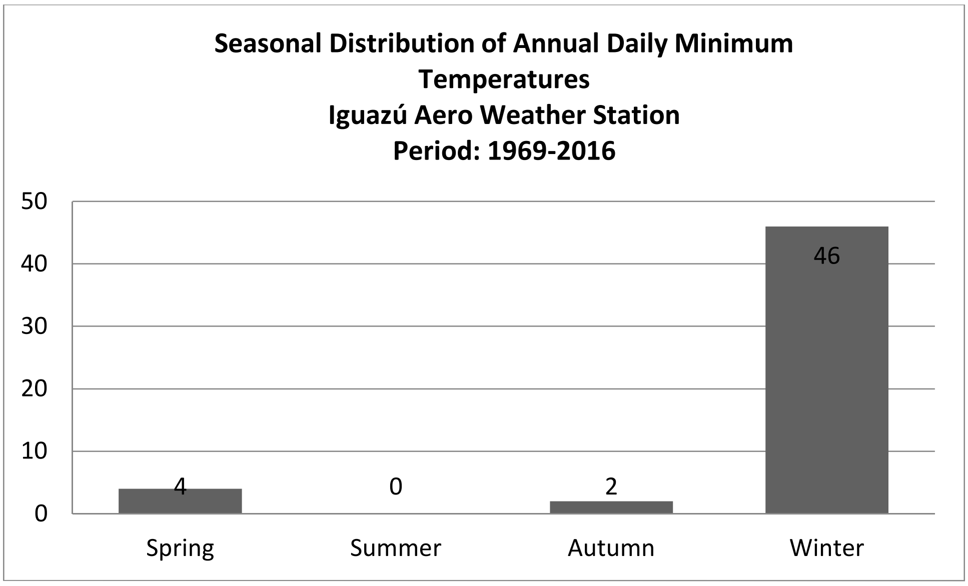

Figure A 14. Seasonal distribution of annual mínimum daily temperaturas. Iguazú Aero Weather Station.

A.10. Cold Waves Events.

A.10.1. DMH/DINAC Approach.

A.10.1.1. Ciudad del Este Weather Station.

Table A 9. Cold Waves events. DMH/DINAC Approach. Ciudad del Este Weather Station.

Cold Waves –Ciudad del Este Weather Station - DMH/DINAC Approach				
Event Number	**Start date**	**End date**	**Number of days**	**Min. Temp. (°C)**
Event N°1	04/08/1966	10/08/1966	7	-0.4
Event N°2	21/09/1966	25/09/1966	5	5
Event N°3	06/06/1967	15/06/1967	10	0
Event N°4	30/06/1967	04/07/1967	5	3.8
Event N°5	29/04/1968	04/05/1968	6	2.4
Event N°6	15/05/1968	23/05/1968	9	-0.2
Event N°7	28/07/1968	02/08/1968	6	5.6
Event N°8	10/08/1968	16/08/1968	7	3.4
Event N°9	01/09/1968	06/09/1968	6	3.2
Event N°10	02/06/1969	06/06/1969	5	1.8
Event N°11	07/07/1969	14/07/1969	8	0.8
Event N°12	18/08/1969	22/08/1969	5	4.8
Event N°13	23/06/1970	27/06/1970	5	3.4
Event N°14	29/06/1970	04/07/1970	6	2.2
Event N°15	07/08/1970	12/08/1970	6	1
Event N°16	31/08/1970	04/09/1970	5	4.2
Event N°17	23/04/1971	27/04/1971	5	4.6
Event N°18	27/05/1971	31/05/1971	5	4.2
Event N°19	08/06/1971	14/06/1971	7	1
Event N°20	05/07/1971	09/07/1971	5	4.5
Event N°21	14/08/1971	18/08/1971	5	5
Event N°22	28/04/1972	02/05/1972	5	6.8
Event N°23	07/07/1972	11/07/1972	5	0.6
Event N°24	30/08/1972	03/09/1972	5	0.8
Event N°25	11/05/1973	17/05/1973	7	1.2
Event N°26	26/06/193	30/06/193	5	2.4
Event N°27	21/07/1973	31/07/1973	11	2.8
Event N°28	02/06/1974	07/06/1974	6	1

Event N°29	02/07/1974	12/07/1974	11	7.4
Event N°30	06/08/1974	10/08/1974	5	6
Event N°31	15/08/1974	21/08/1974	7	0.4
Event N°32	17/07/1975	23/07/1975	7	-3
Event N°33	27/06/1976	06/07/1976	10	2
Event N°34	13/08/1976	17/08/1976	5	1.4
Event N°35	08/09/1976	12/09/1976	5	8
Event N°36	17/05/1977	22/05/1977	6	4
Event N°37	22/06/1977	27/06/1977	6	4
Event N°38	17/05/1978	06/06/1978	21	0.2
Event N°39	13/08/1978	18/08/1978	6	2
Event N°40	24/05/1979	03/06/1979	11	2.2
Event N°41	16/07/1979	23/07/1979	8	3
Event N°42	14/06/1981	22/06/1981	9	0.6
Event N°43	18/07/1981	28/07/1981	11	1
Event N°44	01/06/1983	08/06/1983	8	5.6
Event N°45	21/07/1984	30/07/1984	10	3.6
Event N°46	25/08/1984	30/08/1984	6	-1
Event N°47	03/06/1985	12/06/1985	10	2.8
Event N°48	23/05/1987	27/05/1987	5	2.6
Event N°49	16/06/1987	20/06/1987	5	1.4
Event N°50	23/06/1987	28/06/1987	6	0.6
Event N°51	06/08/1987	10/08/1987	5	5
Event N°52	17/08/1987	22/08/1987	6	4.4
Event N°53	31/08/1987	06/09/1987	6	4.6
Event N°54	30/05/1988	07/06/1988	9	0
Event N°55	07/07/1988	16/07/1988	10	-1
Event N°56	03/07/1989	10/07/1989	8	-0.2
Event N°57	29/07/1989	02/08/1989	5	4.6
Event N°58	28/07/1990	01/08/1990	5	0.3
Event N°59	29/06/1991	05/07/1991	7	5.2
Event N°60	12/07/1991	16/07/1991	5	3
Event N°61	15/07/1992	21/07/1992	7	0.5
Event N°62	13/07/1993	17/07/1993	5	1
Event N°63	22/06/1994	29/06/1994	8	1.2
Event N°64	08/07/1994	12/07/1994	5	0.2
Event N°65	19/05/1995	23/05/1995	5	6
Event N°66	01/06/1996	06/06/1996	6	3.8

Event N°67	21/06/1996	25/06/1996	5	8.2
Event N°68	27/06/1996	01/07/1996	5	1.8
Event N°69	10/07/1996	16/07/1996	7	5
Event N°70	28/06/1997	02/07/1997	5	3.6
Event N°71	11/07/2000	27/07/2000	17	-0.8
Event N°72	18/06/201	24/06/201	7	3
Event N°73	10/07/2003	14/07/2003	5	1.8
Event N°74	25/08/2003	31/08/2003	7	3.5
Event N°75	09/07/2004	13/07/2004	5	2.6
Event N°76	08/08/2005	13/08/2005	6	3
Event N°77	02/05/2006	06/05/2006	5	7.4
Event N°78	29/07/2006	01/08/2006	6	4.6
Event N°79	03/09/2006	07/09/2006	5	1.6

A.10.1.2. Iguazú Aero Weather Station.

Table A 10. Cold Wave Events. DMH/DINAC Approach. Iguazú Aero Weather Station.

Cold Waves – DMH/DINAC Approach – Iguazú Aero Weather Station				
Events	**Start date**	**End date**	**Number of days**	**Min. Temp. (°C)**
Event N°1	07/07/1969	14/07/1969	8	0.9
Event N°2	29/08/1969	03/09/1969	6	4.5
Event N°3	08/08/1970	12/08/1970	5	-0.1
Event N°4	23/04/1971	27/04/1971	5	2.5
Event N°5	27/05/1971	31/05/1971	5	2.2
Event N°6	08/06/1971	14/06/1971	7	0.9
Event N°7	05/07/1971	09/07/1971	5	3.9
Event N°8	15/08/1971	19/08/1971	5	1.9
Event N°9	28/04/1972	02/05/1972	5	3.7
Event N°10	07/07/1972	14/07/1972	8	0
Event N°11	03/08/1972	07/08/1972	5	2.9
Event N°12	29/08/1972	04/09/1972	7	-0.1
Event N°13	11/05/1973	16/05/1973	6	1.8
Event N°14	26/06/1973	30/06/1973	5	2
Event N°15	17/07/1973	24/07/1973	8	5.9
Event N°16	26/07/1973	31/07/1973	6	1.9
Event N°17	14/08/1973	18/08/1973	5	2.3
Event N°18	29/08/1973	02/09/1973	5	3.9

Event N°19	03/06/1974	10/06/1974	8	-0.5
Event N°20	16/08/1974	20/08/1974	5	0
Event N°21	17/07/1975	22/07/1975	6	-1.6
Event N°22	27/06/1976	01/07/1976	5	-0.1
Event N°23	19/08/1976	23/08/1976	5	1
Event N°24	16/05/1977	23/05/1977	8	1.6
Event N°25	21/05/1978	06/06/1978	17	-0.6
Event N°26	12/08/1978	17/08/1978	6	1.4
Event N°27	24/05/1979	03/06/1979	11	-0.2
Event N°28	16/07/1979	23/07/1979	8	1
Event N°29	17/06/1981	21/06/1981	5	-0.6
Event N°30	17/07/1981	27/07/1981	11	-0.8
Event N°31	01/06/1983	08/06/1983	8	2
Event N°32	12/06/1983	17/06/1983	6	0.1
Event N°33	17/07/1983	22/07/1983	6	3.1
Event N°34	01/08/1983	07/08/1983	7	3.2
Event N°35	21/07/1984	26/07/1984	6	1.2
Event N°36	24/08/1984	29/08/1984	6	-2.7
Event N°37	23/05/1987	27/05/1987	5	1.3
Event N°38	16/06/1987	20/06/1987	5	-2
Event N°39	23/06/1987	28/06/1987	6	-1.8
Event N°40	17/08/1987	22/08/1987	6	1.8
Event N°41	30/05/1988	07/06/1988	9	-0.3
Event N°42	07/07/1988	16/07/1988	10	-4
Event N°43	23/07/1988	27/07/1988	5	-2.3
Event N°44	02/07/1989	11/07/1989	10	-1.8
Event N°45	27/07/1990	02/08/1990	7	-0.3
Event N°46	29/06/1991	05/07/1991	7	4.2
Event N°47	15/07/1992	19/07/1992	5	-0.5
Event N°48	29/07/1993	02/08/1993	5	-1.6
Event N°49	19/08/1993	02/09/1993	5	2.1
Event N°50	25/06/1994	29/06/1994	5	-1
Event N°51	08/07/1994	12/07/1994	5	-0.9
Event N°52	19/05/1995	26/05/1995	8	3.4
Event N°53	16/08/1995	20/08/1995	5	3.9
Event N°54	01/06/1996	07/06/1996	7	1.5
Event N°55	27/06/1996	01/07/1996	5	-0.9
Event N°56	10/07/1996	16/07/1996	6	3.7

Event N°57	26/04/1997	30/04/1997	5	7.4
Event N°58	11/07/2000	21/07/2000	10	-1.3
Event N°59	23/07/200	28/07/2000	6	0.5
Event N°60	17/06/2001	24/06/2001	8	0.4
Event N°61	13/07/2002	18/07/2002	6	4
Event N°62	10/07/2003	14/07/2003	5	-0.1
Event N°63	07/08/2003	13/08/2003	7	1.7
Event N°64	25/08/2003	31/08/2003	7	1.8
Event N°65	08/08/2005	13/08/2005	6	2.2
Event N°66	12/09/2005	16/09/2005	5	5.6
Event N°67	29/07/2006	02/08/2006	5	1.2
Event N°68	19/08/2006	24/08/2006	6	1.6
Event N°69	03/09/2006	07/09/2006	5	1.5
Event N°70	23/07/2007	29/07/2007	7	0
Event N°71	01/06/2009	07/06/2009	7	1.5
Event N°72	23/07/2009	27/07/2009	5	-2
Event N°73	13/07/2010	17/07/2010	5	0
Event N°74	02/08/2010	06/08/2010	5	1.4
Event N°75	30/06/2011	26/06/2011	5	-0.8
Event N°76	09/07/2011	03/07/2011	7	0.6
Event N°77	20/08/2011	24/08/2011	5	2.2
Event N°78	05/06/2012	09/06/2012	5	-1
Event N°79	12/07/2012	16/07/2012	5	4.1
Event N°80	22/07/2013	28/07/2013	7	-0.7
Event N°81	24/08/2013	30/08/2013	7	0.3
Event N°82	27/04/2016	02/05/2016	6	4.4
Event N°83	06/06/206	14/06/2016	9	0
Event N°84	17/07/2016	22/07/2016	6	2

A.10.2. SMN Approach.

A.10.2.1. Ciudad del Este Weather Station.

Table A 11. Cold Wave Events. SMN Approach. Ciudad del Este Weather Station.

Cold Waves – SMN Approach - Ciudad del Este Weather Station					
Events	**Start date**	**End date**	**Number of days**	**Max. Max. Temp. (°C)**	**Min. Min. Temp. (°C)**
Event N°1	02/06/1969	05/06/1969	4	16.4	1.8
Event N°2	08/07/1969	11/07/1969	4	16	0.8
Event N°3	23/06/1970	25/06/1970	3	17.4	3.4
Event N°4	08/06/1971	13/06/1971	6	17	1.6
Event N°5	16/08/1974	18/08/1974	3	17.6	0.6
Event N°6	17/07/1975	19/07/1975	3	16	-3
Event N°7	28/09/1976	02/07/1976	5	17.4	2
Event N°8	13/08/1978	15/08/1978	3	15	2
Event N°9	17/06/1981	19/06/1981	3	14.4	0.6
Event N°10	18/07/1981	21/07/1981	4	17	1
Event N°11	04/06/1983	08/06/1983	5	17	5.6
Event N°12	06/06/1985	08/06/1985	3	16.6	2.8
Event N°13	03/06/1988	05/06/1988	3	15	1.5
Event N°14	08/07/1988	12/07/1988	5	17.4	-1
Event N°15	05/07/1989	07/07/1989	3	17.6	-0.2
Event N°16	20/07/1990	23/07/1990	4	14.6	0.5
Event N°17	16/07/1992	20/07/1992	5	17.5	0.5
Event N°18	13/07/1993	15/07/1993	3	17.8	1
Event N°19	08/07/1994	10/07/1994	3	12.8	0.2
Event N°20	12/07/2000	14/07/2000	3	16.6	-0.8
Event N°21	16/07/2000	20/07/2000	5	17	-0.2
Event N°22	10/07/2003	12/07/2003	3	16.8	1.8

A.10.2.2. Iguazú Aero Weather Station.

Table A 12. Cold Wave Events. SMN Approach. Iguazú Aero Weather Station.

Cold Waves – SMN Approach – Iguazú Aero Weather Station					
Events	**Start date**	**End date**	**Number of days**	**Max. Max. Temp. (°C)**	**Min. Min. Temp. (°C)**
Event N°1	08/07/1969	11/07/1969	4	16	0.9
Event N°2	10/06/1971	13/06/1971	4	17.4	0.9
Event N°3	17/07/1975	19/07/1975	3	16	-4
Event N°4	27/06/1976	29/06/1976	3	16.9	-0.1
Event N°5	13/08/1978	15/08/1978	3	12.5	1.4
Event N°6	29/05/1979	01/06/1979	4	16.7	-0.2
Event N°7	17/06/1981	19/06/1981	3	16.1	-0.6
Event N°8	18/07/1981	21/07/1981	4	16.3	-0.8
Event N°9	04/06/1983	07/06/1983	4	16.2	2
Event N°10	04/06/1988	06/06/1988	3	16.8	-0.3
Event N°11	08/07/1988	12/07/1988	5	16.5	-4
Event N°12	21/07/1990	23/07/1990	3	15	-1.2
Event N°13	28/07/1990	30/07/1990	3	17.4	-0.3
Event N°14	16/07/1992	20/07/1992	5	15	-0.5
Event N°15	30/07/1993	01/08/1993	3	14.6	-1.6
Event N°16	08/07/1994	10/07/1994	3	11.4	-0.9
Event N°17	11/07/2000	14/07/2000	4	16	-1.3
Event N°18	16/07/2000	18/07/2000	3	16.2	-1.3
Event N°19	20/06/2001	22/06/2001	3	17.3	0.4
Event N°20	10/07/2003	12/07/2003	3	16.5	-0.1
Event N°21	29/05/2007	31/05/2007	3	17.4	0
Event N°22	24/07/2007	26/07/2007	3	16.6	0
Event N°23	24/07/2009	26/07/2009	3	14	-2
Event N°24	13/07/2010	15/07/2010	3	14.6	0
Event N°25	03/08/2010	05/08/2010	3	10.8	5.4
Event N°26	26/06/2011	28/06/2011	3	13.8	-0.8
Event N°27	04/07/2011	07/07/2011	4	16.4	0.6
Event N°28	06/06/2012	08/06/2012	3	16.8	-1
Event N°29	22/07/2013	24/07/2013	3	13.3	-0.6
Event N°30	08/06/2016	12/06/2016	5	16.8	0

11.2. ANNEX B: Socio-economic vulnerabilities of climate events in the triple border region

Table B 1.Sensitivity indicators included in Triangle Cooperation City's data model.

Sub-dimension	Indicator	Threat (Flood, HW, Hail, Wind)	Vulnerability Response*	Source (Foz do Iguaçu)	Source (Puerto Iguazú)	Source (Ciudad del Este)
Land Use	% Area of urban sprawl	flood, heat wave	↑	Plano Municipal de Saneamento Básico de Foz do Iguaçú (2012)	Gran Atlas de Misiones (2010)	Municipalidad de Ciudad del Este, Departamento de Catastro, 2017
	% of Forest Areas	flood, heat wave	↓	INPE (2011)	Gran Atlas de Misiones (2010)	Instituto Nacional Florestal, INFONA (26/05/2014)
Strategical Infrastructure (IFR)	Materials mostly used for construction of regular houses	Flood, HW, Hail, Wind	-	interviews	interviews	interviews
	Most common house structure	Flood, Wind	-	interviews	interviews	interviews
	Most common roof design	Wind	-	interviews	interviews	interviews
	Most common roof material	HW, Hail, Wind	-	interviews	interviews	interviews
	Quality of existing main infrastructure in the city (bridges, roads, public buildings, water distribution, etc.)	Flood, HW, Wind	-	interviews	interviews	interviews
	Number of public bus lines or other public transport services	Flood, HW, Hail,	↓	FozTrans – Instituto de Transportes e Trânsito de	Gran Atlas de Misiones (2010)	Municipalidad de Ciudad del Este,

				Foz do Iguaçu (2017)		Departamento de División de Tránsito (2017)
	Average price for one-way ticket	Flood, HW, Hail,	↑	FozTrans – Instituto de Transportes e Trânsito de Foz do Iguaçu (2017)	Interview (CEIBA – Centro de Investigaciones del Bosque Atlântico)	Municipalidad de Ciudad del Este, Departamento de División de Tránsito (2017)
	Motorization rate	Flood, HW, Hail,	↓	Car fleet: Denatran (2016); Population: IBGE (2016)	Interview (CEIBA – Centro de Investigaciones del Bosque Atlântico)	Municipalidad de Ciudad del Este, División impuesto a los rodados (2017)
	Number of Public Transport Modes	Flood, HW, Hail,	↓	FozTrans – Instituto de Transportes e Trânsito de Foz do Iguaçu (2017)	Interview (CEIBA – Centro de Investigaciones del Bosque Atlântico)	Municipalidad de Ciudad del Este, Departamento de División de Tránsito (2017)
	Number of local TV and radio networks	Flood, HW, Hail, Wind	↓	ANATEL (2016)	Interview (CEIBA – Centro de Investigaciones del Bosque Atlântico)	Municipalidad de Ciudad del Este, Departamento Divisón de tránsito

Population	Population	All	↑	IBGE (2016)	IPEC (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2012)
	Population density	All	↑	IBGE (2010)	IPEC (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos) (2012)
	Households	All	↑	IBGE (2010)	Instituto Provincial de Estadística y Censos 2015.	DGEEC (Dirección General de Estadisticas, Encuestas y Censos) (2002)
	Population age composition	All	↑	IBGE (2010)	IPEC (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos) (2002)
	Labour force	All	↑	IBGE (2010)	IPEC (2010)	DGEEC (Dirección General de

						Estadisticas, Encuestas y Censos)(2010)
Poverty	Percentage of low income population	All	↑	IBGE (2010)	IPEC (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Percentage of the population living in slums	All	↑	IBGE (2010)	IPEC , Sistema de Información Estadística Local (SIEL, 2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
Well-being	Percentage of households with access to clean water supply	Flood, HW,	↓	IBGE (2010)	IPEC, SIEL (2010)	Municipalidad de Ciudad del Este, Departamento de Desarrollo Urbano, 2016
	Percentage of households with access to waste water system	Flood	↓	IBGE (2010)	IPEC, SIEL (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Percentage of households with	Flood	↓	IBGE (2010)	IPEC, SIEL	DGEEC

	access to waste disposal				(2010)	(Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Mortality rate	Flood, HW,	↑	DATASUS (2015)	UNICEF (2013)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Childhood Mortality Rate	Flood, HW,	↑	DATASUS (2015)	UNICEF (2013)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Childhood Mortality Rate - until 5 years	Flood, HW,	↑	DATASUS (2015)	UNICEF (2013)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Percentage of illiterate people	All	↑	IBGE (2010)	IPEC, SIEL (2010)	DGEEC (Dirección General de Estadisticas,

						Encuestas y Censos)(2002)
	Percentage of children until 17 years old in the school	All	⬆	IBGE (2015)	IPEC, SIEL (2010)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2002)
	Crime rate	-	⬆	Secretaria de Segurança Pública Foz do Iguaçu (2016)	Sistema Nacional de Información Criminal (SNIC) (2015)	Ministerio del Interior (2017)
	Murder rate	-	⬆	Secretaria de Segurança Pública Foz do Iguaçu (2016)	Sistema Nacional de Información Criminal (SNIC) (2015)	Ministerio del Interior (2017)
	Gini inequality index	All	⬇	IBGE (2010)	Dirección Nacional de Relaciones Económicas con las Provincias – DINREP (2013)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2015)
Economic size and	Gross domestic product,	All	⬇	IBGE (2014)	Direccion General Rentas	DGEEC (Dirección

diversification					(DGR 2014); IPEC (2014)	General de Estadisticas, Encuestas y Censos)(2013)
	% of GDP in agriculture, industry, services and public	All	⬆	IBGE (2014)	DGR (2014); IPEC (2014)	DGEEC (Dirección General de Estadisticas, Encuestas y Censos)(2013)
Public Finances	Latest Public Spending	All	⬇	IBGE (2014)	Interview (President HCD)	Ministerio de Hacienda, 2017
Business Sector	Number of businesses,	All	⬇	MTE/RAIS (2015)	Per. Com. (President Codespi)	Interviews
	Level of simplicity to open business activities	All	⬇	interviews	interviews	interviews

Table B 2. Coping and Adaptive Capacity indicators included in Triangle Cooperation City's data model.

Sub-dimension	Indicator	Source and time (Foz do Iguaçu)	Source and time (Puerto Iguazú)	Source and time (Ciudad del Este)
Preparedness	Government budget targeting preparedness	interviews	interviews	interviews
	Existence of official early warning systems	interviews	interviews	interviews
	Existence of disaster risk reduction plans or strategies	interviews	interviews	interviews
Response	Medical services quality	interviews	interviews	interviews
	Formal emergency services quality	interviews	interviews	interviews
	Informal medical emergency services quality	interviews	interviews	interviews
	Existence of emergency response services	interviews	interviews	interviews
Recovery	Existence of Recovery funds	interviews	interviews	interviews
	Existence of insurance systems	interviews	interviews	interviews
	Insurance use	interviews	interviews	interviews
	Existence of Financing mechanisms to recover	interviews	interviews	interviews
Network	Reputation of emergency institutions	interviews	interviews	interviews
	Number of existing formal stakeholder networks and organisation	interviews	interviews	interviews
	Existence of effective participation networks	interviews	interviews	interviews
Awareness	Existence of Climate Change Adaptation plan	interviews	interviews	interviews
Capacity to Change	Difficulty to implement public policies	interviews	interviews	interviews
	Existence of policy inspired on other cities	interviews	interviews	interviews
Cooperation	Number of cooperation agreements with other cities	interviews	interviews	interviews

11.3. APPENDIX C: Equations used to build the Urban Vulnerability Index

The Urban Vulnerability Index for a municipality (UVI_m) is the of the Index of Sensitivity (SI_m) and th Capacity Index (CI_m), as shown below:

Equation 1. UVIm´s mathematic expression

$$\mathrm{UVI}_m = \frac{(SI_m + CI_m)}{2} \quad \text{, where} \quad 1 \leq \mathrm{UVI}_m \leq 10 \; ; \quad \text{m = municipality}$$

Sensitivity Index (SI_m) is the combination of three index dimensions: Physical Attributes Normalized Index (PHI_m), Social Attributes Normalized Index (SAI_m), and Economic Normalized Attributes (EAI_m). Each dimension index has its corresponded sub-dimension in which indicators were considered. The sensitivity index is an arithmetical mean of the three normalized indices (equation 2).

Equation 2. SIm´s mathematic expression

$$\mathrm{SI}_m = \frac{(PHI_m + SAI_m + EAI_m)}{3} \quad \text{, where} \quad 1 \leq \mathrm{SI}_m \leq 10 \; ; \quad \text{m = municipality}$$

$$\mathrm{PHI}_m = \frac{(LUI_m + SII_m)}{2} \quad \text{(Physical Attributes Normalized Index - PHI}_m\text{)}$$

where,

LUI_m = Land Use Index;

SII_m = Strategic Infrastructure Index;

And,

$$LUI_m = 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{USP}} + 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{FOA}}$$

$$SII_m = 0,25 * \left(0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{MHO}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{RHO}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{RDG}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{RTL}}\right) + 0,25 * \left(0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFB}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{RQINFR}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFFD}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFPS}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFPSc}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFH}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFW}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFWT}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFE}} + 0,1 * \mathrm{I}^{\mathrm{S}}_{\mathrm{QINFCD}}\right) + 0,25 * \left(0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{PBL}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{TCK}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{MRT}} + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{TRM}}\right) + 0,25 * \mathrm{I}^{\mathrm{S}}_{\mathrm{RNW}}$$

All variables are in Table C 1.

$$\mathrm{SAI}_m = \frac{(POPI_m + POVI_m + WBI_m)}{3}$$ (Social Attributes Normalized Index - SAI_m)

where,

$POPI_m$ = Population Index;

$POVI_m$ = Poverty Index;

WBI_m = Well-being Index;

And,

$$POPI_m = 0,2 * \mathrm{I}^{\mathrm{S}}_{\mathrm{POP}} + 0,2 * \mathrm{I}^{\mathrm{S}}_{\mathrm{POD}} + 0,2 * \mathrm{I}^{\mathrm{S}}_{\mathrm{HOU}} + 0,2 * \mathrm{I}^{\mathrm{S}}_{\mathrm{AGE}} + 0,2 * \mathrm{I}^{\mathrm{S}}_{\mathrm{LAB}}$$

$$POVI_m = 0,5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{LOW}} + 0,5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{SLU}}$$

$$WBI_m = 0,20 * \left(0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{WAT}} + 0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{WAS}} + 0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{WSD}}\right) + 0,20 * \left(0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{MRR}} + 0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{CMR}} + 0,33 * \mathrm{I}^{\mathrm{S}}_{\mathrm{CM5}}\right) + 0,20 * \left(0,50 * \mathrm{I}^{\mathrm{S}}_{\mathrm{ILL}} + 0,50 * \mathrm{I}^{\mathrm{S}}_{\mathrm{CSC}}\right) + 0,20 * \left(0,50 * \mathrm{I}^{\mathrm{S}}_{\mathrm{CRI}} + 0,50 * \mathrm{I}^{\mathrm{S}}_{\mathrm{MUR}}\right) + 0,20 * \mathrm{I}^{\mathrm{S}}_{\mathrm{GIN}}$$

All variables are in Table C 1.

$$\mathrm{EAI}_m = \frac{(SDI_m + PFI_m + BSI_m)}{3}$$ (Economic Attributes Normalized Index - EAI_m)

where,

SDI_m = Size and Diversification Index;

PFI_m = Public Finance Index;

BSI_m = Business Sector Index;

And,

$$SDI_m = 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{GDP}} + 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{GDS}}$$

$$PFI_m = \mathrm{I}^{\mathrm{S}}_{\mathrm{PUS}}$$

$$SDI_m = 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{BUS}} + 0{,}5 * \mathrm{I}^{\mathrm{S}}_{\mathrm{SIM}}$$

All variables are in Table C 1.

Similarly, the Capacity Index (CI_m) is the combination of two index dimensions: Coping Capacity Normalized Index (CC_m), and Adaptive Capacity Normalized Index (ACI_m). Each dimension has its corresponded sub-dimension in which indicators were considered. The Capacity Index is an arithmetical mean of the two normalized indices .

Equation 3. CIm´s mathematic expression

$$\mathrm{CI}_m = \frac{(CC_m + ACI_m)}{2}$$, where $1 \leq \mathrm{CI}_m \leq 10$; m = municipality

$$CC_m = \frac{(PRI_m + RESI_m + RECI_m)}{3}$$ (Coping Normalized Index - CC_m)

where,

PRI_m = Preparedness Index;

$RESI_m$ = Response Index;

$RECI_m$ = Recovery Index;

And,

$$SDI_m = 0{,}33 * \mathrm{I}_{\mathrm{BDG}}^{\mathrm{C}} + 0{,}33 * \mathrm{I}_{\mathrm{EWS}}^{\mathrm{C}} + 0{,}33 * \mathrm{I}_{\mathrm{DDR}}^{\mathrm{C}}$$

$$RESI_m = 0{,}33 * \mathrm{I}_{\mathrm{MEQ}}^{\mathrm{C}} + 0{,}33 * \mathrm{I}_{\mathrm{EMQ}}^{\mathrm{C}} + 0{,}33 * \mathrm{I}_{\mathrm{IMQ}}^{\mathrm{C}}$$

$$RESI_m = 0{,}25 * \mathrm{I}_{\mathrm{REC}}^{\mathrm{C}} + 0{,}25 * \mathrm{I}_{\mathrm{INS}}^{\mathrm{C}} + 0{,}25 * \mathrm{I}_{\mathrm{INU}}^{\mathrm{C}} + 0{,}25 * \mathrm{I}_{\mathrm{FRE}}^{\mathrm{C}}$$

All variables are in Table C 1.

$$AC_m = \frac{(NETI_m + ANPI_m + CTCI_m + COOI_m)}{3}$$ (Coping Normalized Index - CC_m)

where,

$NETI_m$ = Network Index;

$ANPI_m$ = Awareness and planning Index;

$CTCI_m$ = Capacity to Change Index;

$COOI_m$ = Cooperation Index;

And,

$$NETI_m = 0{,}33 * \left(\sum_i (0{,}1 * \mathrm{I}_{REPi}^{C}) \right) + 0{,}33 * \mathrm{I}_{\mathrm{STK}}^{\mathrm{C}} + 0{,}33 * \mathrm{I}_{\mathrm{NET}}^{\mathrm{C}}$$

where i Є A = {Fire Department, Civil Defense, Police, Federal Police, City Hall, Army, NGOs, Health Department, Education

Department)

$$ANPI_m = \mathrm{I}_{\mathrm{CCA}}^{\mathrm{C}}$$

$$CTCI_m = 0{,}5 * \mathrm{I}_{\mathrm{DIF}}^{\mathrm{C}} + 0{,}5 * \mathrm{I}_{\mathrm{INP}}^{\mathrm{C}}$$

$$COOI_m = \mathrm{I}_{\mathrm{COO}}^{\mathrm{C}}$$

All variables are in Table C 1.

Table C 1. Re-scaling indicators functions

Indicator	Unit	Possible Values*	Re-scaling function (normalization)
Sensitivity			
% area of urban sprawl (USP)	%	15% - 98.30% (min – max)	$I^{S}_{USP} = 10.804x_{USP} - 0.621$
% of forest areas (FOA)	%	1.2% - 45% (min – max)	$I^{S}_{FOA} = -20.43x_{FOA} + 10.242$
Material mostly used for construction of regular houses (MHO)	NM**	Wood with superficial foundation (M); Masonry with superficial foundation (AS); Structural masonry with superficial foundation (AES); Structural masonry with deep foundation (AEP);	$I^{S}_{MHO} = \begin{cases} 1, & x_{MHO} = AEP \\ 4, & x_{MHO} = AES \\ 7, & x_{MHO} = AS \\ 10, & x_{MHO} = M \end{cases}$
Most common roof house structure material (RHO)	NM	Iron (A); Wood (M); Concrete (CA);	$I^{S}_{RHO} = \begin{cases} 1, & x_{RHO} = A \\ 5.5, & x_{RHO} = M \\ 10, & x_{RHO} = CA \end{cases}$
Most common roof design (RDG)	NM	Shed Roof (B1); Box Gable Roof (B2); Roof without eaves with plankton (P); Roof on different levels (D);	$I^{S}_{RDG} = \begin{cases} 1, & x_{RDG} = B2 \\ 4, & x_{RDG} = P \\ 7, & x_{RDG} = B1 \\ 10, & x_{RDG} = D \end{cases}$
Most common roof material (tiles) (RTL)	NM	Asphalt (AS); Metal (M); Plastic Polymer (PP); Clay (A); Concrete (C); Wood (MA); Recycled (R)	$I^{S}_{RTL} = \begin{cases} 1, & x_{RTL} = M \text{ or } C \\ 4, & x_{RTL} = AS \\ 6, & x_{RTL} = PP \text{ or } A \\ 8, & x_{RTL} = M \\ 10, & x_{RTL} = R \end{cases}$
Quality of existing main bridges in the city bridges (QINFB)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I^{S}_{QINFB} = \begin{cases} 1, & x_{QINFB} = G \\ 4, & x_{QINFB} = MG \\ 7, & x_{QINFB} = MB \\ 10, & x_{QINFB} = B \end{cases}$

Quality of existing main roads in the city (QINFR)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFR}^{S} = \begin{cases} 1, & x_{QINFR} = G \\ 4, & x_{QINFR} = MG \\ 7, & x_{QINFR} = MB \\ 10, & x_{QINFR} = B \end{cases}$
Quality of existing main fire department in the city (QINFFD)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFFD}^{S} = \begin{cases} 1, & x_{QINFFD} = G \\ 4, & x_{QINFFD} = MG \\ 7, & x_{QINFFD} = MB \\ 10, & x_{QINFFD} = B \end{cases}$
Quality of existing main police station in the city (QINFPS)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFPS}^{S} = \begin{cases} 1, & x_{QINFPS} = G \\ 4, & x_{QINFPS} = MG \\ 7, & x_{QINFPS} = MB \\ 10, & x_{QINFPS} = B \end{cases}$
Quality of existing main public schools in the city (QINFPSc)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFPSc}^{S} = \begin{cases} 1, & x_{QINFPSc} = G \\ 4, & x_{QINFPSc} = MG \\ 7, & x_{QINFPSc} = MB \\ 10, & x_{QINFPSc} = B \end{cases}$
Quality of existing main hospitals in the city (QINFH)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFH}^{S} = \begin{cases} 1, & x_{QINFH} = G \\ 4, & x_{QINFH} = MG \\ 7, & x_{QINFH} = MB \\ 10, & x_{QINFH} = B \end{cases}$
Quality of existing main civil defence in the city (QINFCD)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFCD}^{S} = \begin{cases} 1, & x_{QINFCD} = G \\ 4, & x_{QINFCD} = MG \\ 7, & x_{QINFCD} = MB \\ 10, & x_{QINFCD} = B \end{cases}$
Quality of existing main waste treatment infrastructure in the city (QINFW)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFW}^{S} = \begin{cases} 1, & x_{QINFW} = G \\ 4, & x_{QINFW} = MG \\ 7, & x_{QINFW} = MB \\ 10, & x_{QINFW} = B \end{cases}$
Quality of existing main water infrastructure in the city (QINFWT)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I_{QINFWT}^{S} = \begin{cases} 1, & x_{QINFWT} = G \\ 4, & x_{QINFWT} = MG \\ 7, & x_{QINFWT} = MB \\ 10, & x_{QINFWT} = B \end{cases}$

Quality of existing main energy infrastructure in the city (QINFE)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$I^{S}_{QINFE} = \begin{cases} 1, & x_{QINFE} = G \\ 4, & x_{QINFE} = MG \\ 7, & x_{QINFE} = MB \\ 10, & x_{QINFE} = B \end{cases}$
Number of public bus lines or other public transport services(PBL)	number of municipal bus lines	6 – 44 municipal bus lines (min – max)	$I^{S}_{PBL} = -0.24x_{PBL} + 11.421$
Average price for one-way ticket (TCK)	US$	0,45 – 1,06 (min – max)	$I^{S}_{TCK} = 14.717x_{TCK} - 5.574$
Motorization rate (MRT)	(car/thousand people)	143.6 – 399.73 (min – max)	$I^{S}_{MRT} = 0.035x_{MRT} - 4.047$
Number of Public Transport Modes (TRM)	-	3 – 4 (min – max)	$I^{S}_{TRM} = 9x_{TRM} - 26$
Number of local TV and radio networks (RNW)	-	5 – 11 (min – max)	$I^{S}_{RNW} = -1.5x_{RNW} + 17.5$
Population (POP)	people	42,846 – 296,597 (min – max)	$I^{S}_{POP} = 3.54 * 10^{-5}x_{POP} - 0.519$
Population density (POD)	pop/km²	415 – 2,852 (min – max)	$I^{S}_{POD} = 3.69 * 10^{-3}x_{POD} - 0.531$
Number of households (HOU)	households	11,386 – 79,161 (min – max)	$I^{S}_{HOU} = 1.32 * 10^{-4}x_{HOU} - 0.512$
Population age composition (AGE)	%	30.50% – 35,64% (min – max)	$I^{S}_{AGE} = 175.09x_{TRM} - 52.39$
Labour force (LAB)	people	28,230 – 166,223 (min – max)	$I^{S}_{LAB} = 6.52 * 10^{-5}x_{LAB} - 0.841$
Percentage of low income population (LOW)	%	7.4% – 23.00% (min – max)	$I^{S}_{LOW} = 57.54x_{LOW} - 3.241$
Percentage of the population living in slums (SLU)	%	2.5% – 25.70% (min – max)	$I^{S}_{SLU} = 38.81x_{SLU} - 0.024$
Percentage of households with access to clean water supply (WAT)	%	30.00% – 99.63% (min – max)	$I^{S}_{WAT} = -12.93x_{WAT} + 13.877$
Percentage of households with access to waste water system (WAS)	%	2.5% – 25.70% (min – max)	$I^{S}_{WAS} = -11.37x_{WAS} + 12.358$
Percentage of households with access to waste disposal (WSD)	%	2.5% – 25.70% (min – max)	$I^{S}_{WSD} = -19.18x_{WSD} + 20.011$
Mortality rate (MRR)	death/thousand people	5.1 – 11.87 (min – max)	$I^{S}_{MRR} = 1.329x_{MRR} - 5.8$
Childhood Mortality Rate (CMR)	death/thousand new borns	6 – 46.24 (min – max)	$I^{S}_{CMR} = 0.224x_{CMR} - 0.342$
Childhood Mortality Rate - until 5 years (CM5)	death/thousand new borns	10 – 17.10 (min – max)	$I^{S}_{CM5} = 1.268x_{CM5} - 11.676$

Percentage of illiterate people (ILL)	%	5.13 – 23 (min – max)	$I_{ILL}^{S} = 49.831x_{ILL} - 1.556$
Percentage of children until 17 years old in the school (CSC)	%	83 – 85.57 (min – max)	$I_{CSC}^{S} = -307.77x_{CSC} + 264.347$
Crime rate (CRI)	crimes/100,000 people	114 – 3.995 (min – max)	$I_{CRI}^{S} = 0.0023x_{CRI} - 0.7365$
Murder rate (MUR)	murder/100,000 people	5.9 – 25.89 (min – max)	$I_{MUR}^{S} = 0.45x_{MUR} - 1.658$
Gini inequality index (GIN)	-	0.426 – 0.545 (min – max)	$I_{GIN}^{S} = -75.82x_{GIN} + 42.353$
Gross domestic product (GDP)	US$ 1,000	172,567 – 2,675,247 (min – max)	$I_{GDP}^{S} = -3.6 * 10^{-6}x_{GDP} + 10.62$
Diversification % of GDP in agriculture, industry, services and public (GDS)	%	$y_{GDS} = \{\mathrm{Max}\, x_i\} - \{\mathrm{Min}\, x_i\}$ where, i = % of each GDP in agriculture, industry, services and public	$I_{PUS}^{S} = 34.61y_{GDS} - 13.88$
Public Spending (PUS)	US$ 1,000	7,829 – 204,118 (min – max)	$I_{PUS}^{S} = 4.6 * 10^{-5}x_{PUS} + 10.359$
Number of businesses (BUS)	companies	2,245 – 15,000 (min – max)	$I_{BUS}^{S} = -7 * 10^{-4}x_{BUS} + 11.58$
Level of simplicity to open business activities (SIM)	NM	low; median; high	$I_{SIM}^{S} = \begin{cases} 1, & x_{SIM} = low \\ 5.5, & x_{SIM} = median \\ 10, & x_{SIM} = high \end{cases}$
CAPACITY			
Existence of Government budget targeting preparedness (BDG)	NM	yes; no	$I_{BDG}^{C} = \begin{cases} 1, & x_{BDG} = yes \\ 10, & x_{BDG} = no \end{cases}$
Existence of official early warning systems (EWS)	NM	yes; no	$I_{EWS}^{C} = \begin{cases} 1, & x_{EWS} = yes \\ 10, & x_{EWS} = no \end{cases}$
Existence of disaster risk reduction plans or strategies (DDR)	NM	yes; no	$I_{DDR}^{C} = \begin{cases} 1, & x_{DDR} = yes \\ 10, & x_{DDR} = no \end{cases}$
Medical services quality (MEQ)	NM	very good (VG), good (G), bad (B), very bad (VB)	$I_{MEQ}^{S} = \begin{cases} 1, & x_{MEQ} = VG \\ 4, & x_{MEQ} = G \\ 7, & x_{MEQ} = B \\ 10, & x_{MEQ} = VB \end{cases}$

Formal emergency services quality (EMQ)	NM	very good (VG), good (G), bad (B), very bad (VB)	$\mathrm{I}^{\mathrm{S}}_{\mathrm{EMQ}} = \begin{cases} 1, & x_{EMQ} = VG \\ 4, & x_{EMQ} = G \\ 7, & x_{EMQ} = B \\ 10, & x_{EMQ} = VB \end{cases}$
Informal medical emergency services quality (IMQ)	NM	very good (VG), good (G), bad (B), very bad (VB)	$\mathrm{I}^{\mathrm{S}}_{\mathrm{IQM}} = \begin{cases} 1, & x_{IQM} = VG \\ 4, & x_{IQM} = G \\ 7, & x_{IQM} = B \\ 10, & x_{IQM} = VB \end{cases}$
Existence of Recovery funds (REC)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{REC}} = \begin{cases} 1, & x_{REC} = yes \\ 10, & x_{REC} = no \end{cases}$
Existence of insurance systems (INS)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{INS}} = \begin{cases} 1, & x_{INS} = yes \\ 10, & x_{INS} = no \end{cases}$
Insurance use (INU)	NM	low; median; high	$\mathrm{I}^{\mathrm{S}}_{\mathrm{INU}} = \begin{cases} 1, & x_{INU} = high \\ 5.5, & x_{INU} = median \\ 10, & x_{INU} = low \end{cases}$
Existence of Financing mechanisms to recover (FRE)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{FRE}} = \begin{cases} 1, & x_{FRE} = yes \\ 10, & x_{FRE} = no \end{cases}$
Reputation of emergency institutions (REP*i*)	NM	Good (G); Median Good (MG); Median Bad (MB); Bad (B).	$\mathrm{I}^{\mathrm{S}}_{\mathrm{REP}i} = \begin{cases} 1, & x_{REPi} = G \\ 4, & x_{REPi} = MG \\ 7, & x_{REPi} = MB \\ 10, & x_{REPi} = B \end{cases}$ where *i* Є A = {Fire Department, Civil Defense, Police, Federal Police, City Hall, Army, NGOs, Health Department, Education Department)
Existing formal stakeholder networks and organisation (STK)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{STK}} = \begin{cases} 1, & x_{STK} = yes \\ 10, & x_{STK} = no \end{cases}$
Existence of effective participation networks (NET)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{NET}} = \begin{cases} 1, & x_{NET} = yes \\ 10, & x_{NET} = no \end{cases}$
Existence of Climate Change Adaptation plan (CCA)	NM	yes; no	$\mathrm{I}^{\mathrm{S}}_{\mathrm{CCA}} = \begin{cases} 1, & x_{CCA} = yes \\ 10, & x_{CCA} = no \end{cases}$

Simplicity to implement public policies (DIF)	NM	low; median; high	$\mathrm{I}_{\mathrm{DIF}}^{\mathrm{S}} = \begin{cases} 1, & x_{DIF} = high \\ 5.5, & x_{DIF} = median \\ 10, & x_{DIF} = low \end{cases}$
Existence of policy inspired on other cities (INP)	NM	yes; no	$\mathrm{I}_{\mathrm{INP}}^{\mathrm{S}} = \begin{cases} 1, & x_{INP} = yes \\ 10, & x_{INP} = no \end{cases}$
Existence of cooperation agreements with other cities (COO)	NM	yes; no	$\mathrm{I}_{\mathrm{COO}}^{\mathrm{S}} = \begin{cases} 1, & x_{COO} = yes \\ 10, & x_{COO} = no \end{cases}$

*Minimum and maximum values for quantitative values. All possible values for qualitative indicators.
**NM = No numeric value.

11.4. ANNEX D: Vulnerability indices

Table D 1. Urban Vulnerability Index Complete Results – Physical Attributes Dimension

Sub-dimension				Normalization			
Land Use							
	Value			Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Land use							
Urban Areas (%)	31%	98.30%	15%	0.5	2.73	10.00	1.00
Forest areas (%)	45%	1.2%	35%	0.5	1.00	10.00	3.09
Land use Vulnerability Index				**0.5**	**1.86**	**10.00**	**2.05**
Strategic Infrastructure							
	Value			Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Built environment (type and quality)				**0.25**	**4.00**	**6.00**	**4.75**
Material	Masonry with concrete foundation	Masonry with concrete foundation	Masonry with concrete foundation	0.25	4.00	7.00	7.00
Structure	Wood	Wood	Wood	0.25	10.00	10.00	10.00
Roof Design	Box Gable	Box Gable	Box Gable	0.25	1.00	1.00	1.00
Roof Material	Fibrocement	Clay roof tile	Metal tile	0.25	1.00	6.00	1.00
Quality of infrastructure				**0.25**	**4.30**	**4.30**	**4.30**
Bridges	Median Good	Median Good	Median Good	0.10	4.00	4.00	4.00
Roads	Median Bad	Median Good	Median Good	0.10	7.00	4.00	4.00

Fire Departments (Infrastructure)	Good	Median Good	Good	0.10	1.00	4.00	1.00
Police Statios (infrastructure)	Median Good	Median Good	Good	0.10	4.00	4.00	1.00
Public Schools (infrastructure)	Median Good	Median Good	Median Good	0.10	4.00	4.00	4.00
Hospital (infrastrucutre)	Median Good	Median Good	Median Good	0.10	4.00	4.00	4.00
Civil Defense (infrastrucutre)	Median Bad	Median Good	Median Good	0.10	7.00	4.00	4.00
Waste (infrastrucutre)	Median Good	Median Bad	Median Bad	0.10	4.00	7.00	7.00
Water (infrastrucutre)	Median Good	Median Bad	Median Bad	0.10	4.00	7.00	7.00
Energy (infrastrucutre)	Median Good	Good	Median Bad	0.10	4.00	1.00	7.00
Diversity and affordability of transport networks				**0.25**	**5.50**	**3.25**	**7.23**
Number of public bus lines	44	6	8	0.25	1.00	10.00	9.53
Average price for one-way ticket	1.06	0.45	0.94	0.25	10.00	1.00	8.24
Motorization rate	399.73	143.62	147.70	0.25	10.00	1.00	1.14
Number of Public Transport Modes	3	3	4	0.25	1.00	1.00	10.00
Communications local tv and radio stations (Number of local TV and radio networks)	11	7	5	**0.25**	**1.00**	**7.00**	**10.00**
Strategical Infrastructure Vulnerability Index				**0.50**	**3.70**	**5.14**	**6.57**
Physical Attributes Vulnerability Index					**2.78**	**7.57**	**4.31**

Table D 2. Urban Vulnerability Index Complete Results – Social Attributes Dimension

Sub-dimension Population				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Population	256,088	296,597	42,849	0.2	**8.56**	**10.00**	**1.00**
Population density	415	2,852	1,128	0.2	**1.00**	**10.00**	**3.63**
Number of households	79,161	47,536	11,386	0.2	**10.00**	**5.80**	**1.00**
Population - Age composition (sensitive age)	30.50%	35.64%	35.28%	0.2	**1.00**	**10.00**	**9.38**
Labor force – PEA	133,547	166,223	28,230	0.2	**7.87**	**10.00**	**1.00**
Population Index				**0.33**	**5.69**	**9.16**	**3.20**

Sub-dimension Poverty				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Percentage of poor	7.4%	9.2%	23.0%	0.5	**1.00**	**2.05**	**10.00**
Percentage of the population living in slums	2.5%	25.7%	22.0%	0.5	**1.00**	**10.00**	**8.46**
Poverty Index				**0.33**	**1.00**	**6.03**	**9.23**

Sub-dimension Well-being				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Water				**0.20**	**1.00**	**9.64**	**5.90**
Access to clean water supply (Percentage of households with access to clean water supply)	99.63%	30.00%	69.00%	0.33	1.00	10.00	4.96
Access to sanitation (Percentage of households with access to waste water system)	99.90%	30.35%	21.00%	0.33	1.00	8.91	10.00
Access to sanitation (Percentage of households with access to waste disposal)	99.13%	52.20%	90.00%	0.33	1.00	10.00	2.75

Health				**0.20**	**4.43**	**9.07**	**1.10**
Health (Mortality rate)	5.80	11.87	6.00	0.33	1.00	10.00	1.30
Health (Childhood Mortality Rate)	15.48	46.24	10.40	0.33	2.28	10.00	1.00
Health (Childhood Mortality Rate - until 5 years)	17.10	15.70	12.60	0.33	10.00	7.20	1.00
Education				**0 .20**	**1.00**	**2.04**	**10.00**
Access to education (Percentage of illiterate people)	5.13%	5.80%	23%	0 .50	1.00	1.33	10.00
Access to education (percentage of children until 17 years old in the school)	85.57%	85.00%	83%	0 .50	1.00	2.74	10.00
Security and rule of law				**0 .20**	**4.29**	**5.50**	**5.50**
Security and rule of law (crimes, conflicts, thefts, corruption, etc.) (number of crimes for 100,000)	1,227	114	3995	0.50	3.58	1.00	10.00
Security and rule of law (murder rate for 100,000 inhabitants)	14.80	25.89	5. 90	0.50	5.00	10.00	1.00
Inequality (Gini inequality index)	0.5454	0.506	0.4267	**0.20**	**1.00**	**3.99**	**10.00**
Index Well-being				**0 .33**	**2.34**	**6.05**	**6.50**
Social Attributes Index					**3.01**	**7.08**	**6.31**

Table D 3. Urban Vulnerability Index Complete Results – Economic Attributes Dimension

Sub-dimension: Size and diversification	Value			Normalization			
				Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Gross domestic product (GDP)	2,675,248	461,258	172,568	**0.5**	**1.00**	**8.96**	**10.00**
Economic diversification	47.98%	43.00%	69.00%	**0.5**	**2.72**	**1.00**	**10.00**
Agriculture	0.65%	31.00%	2.00%				
Industry	48.63%	15.00%	25.00%				
Services	38.39%	49.00%	70.00%				
Government	12.34%	6.00%	1.00%				
Size and diversification Index				**0.33**	**1.86**	**4.98**	**10.00**

Sub-dimension: Public finances	Value			Normalization			
				Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Public budget (spending)	204,118	7,829	13 ,942	**1**	**1.00**	**10.00**	**9.72**
Public Finances Index				**0.33**	**1.00**	**10.00**	**9.72**

Sub-dimension: Business sector	Value			Normalization			
				Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Number of businesses	6,999	15,000	2,245	**0.5**	**6.65**	**1.00**	**10.00**
Business environment (simplicity to conduct business activities, legal settings, taxes, access to markets, etc.)	medio	medio	baixo	**0.5**	**5.50**	**5.50**	**1.00**
Business sector Index				**0.33**	**6.07**	**3.25**	**5.50**

Economic Attributes Index		**2.98**	**6.08**	**8.41**

Table D 4. Urban Vulnerability Index Complete Results – Coping Capacity Dimension

Sub-dimension: Preparedness				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Preparedness measures (Existence of Government budget targeting preparedness)	YES	NO	NO	**0.33**	**1.00**	**10.00**	**10.00**
Early warning systems (Existence of official early warning systems)	NO	NO	NO	**0.33**	**10.00**	**10.00**	**10.00**
Regulation (Existence of disaster risk reduction plans or strategies)	YES	NO	NO	**0.33**	**1.00**	**10.00**	**10.00**
Preparedness Index				**0.33**	**4.00**	**10.00**	**10.00**

Sub-dimension: Response				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Access to medical services (Medical services quality)	Good	Bad	Very bad	**0.33**	**4.00**	**7.00**	**10.00**
Access to formal medical emergency services (Formal medical emergency services quality)	Good	Bad	Very bad	**0.33**	**4.00**	**7.00**	**10.00**
Access to informal medical emergency services (informal medical emergency services quality)	Very bad	Bad	Very bad	**0.33**	**10.00**	**7.00**	**10.00**
Response Index				**0.33**	**6.00**	**7.00**	**10.00**

Sub-dimension: Recovery				**Normalization**			
	Value			**Weight**	**Score**		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Existence of Recovery funds	YES	NO	NO	**0.25**	**1.00**	**10.00**	**10.00**

Insurance systems (Existence of insurence systems)	YES	YES	YES	**0.25**	**1.00**	**1.00**	**1.00**
Insurance dissemination (nível de utilização)	Low	Low	Low	**0.25**	**10.00**	**10.00**	**10.00**
Financing mechanisms (Existence of Financing mechanisms to recover)	YES	NO	NO	**0.25**	**1.00**	**10.00**	**10.00**
Recovery Index				**0 .33**	**4.00**	**7.00**	**7.00**
Coping Capacity Index					**4.67**	**8.00**	**9.00**

Table D 5. Urban Vulnerability Index Complete Results – Adaptive Capacity Dimension

Sub-dimension				Normalization			
Networks							
	Value			Weight	Score		
Indicators	**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**		**Foz do Iguaçu**	**Ciudad del Este**	**Puerto Iguazú**
Institutional structure				**0.33**	**3.73**	**6.73**	**7.55**
Fire Department	Good	Median Good	Median Good	0.09	1.00	4.00	4.00
Civil Defense (Province)	Good	Bad	Bad	0.09	1.00	10.00	10.00
Civil Defense (Municipality)	Median Good	Bad	Bad	0.09	4.00	10.00	10.00
Police (Civil)	Median Good	Good	Bad	0.09	4.00	1.00	10.00
Military Police	Median Good	Median Bad	n/a	0.09	4.00	10.00	10.00
Federal Police	Median Good	Median Bad	Median Bad	0.09	4.00	7.00	7.00
City Hall	Median Bad	Median Bad	Median Bad	0.09	7.00	7.00	7.00
Army	Median Good	Median Bad	Median Bad	0.09	4.00	7.00	7.00
NGOs	Median Good	Median Good	Median Good	0.09	4.00	4.00	4.00
Health Department	Median Good	Median Bad	Median Bad	0.09	4.00	7.00	7.00
Education Department	Median Good	Median Bad	Median Bad	0.09	4.00	7.00	7.00
Governance structure and presence of networks (local governments, private sector, civil society, academics) - (existing formal stakeholder networks and organisation)	YES	YES	YES	**0.33**	**1.00**	**1.00**	**1.00**
Mechanisms for citizens to engage with government (Existence of effective participation networks)	YES	YES	YES	**0.33**	**1.00**	**1.00**	**1.00**
Network Index				**0.25**	**1.91**	**2.91**	**3.18**

Sub-dimension	Normalization

Awareness and planning							
	Value			Weight	Score		
Indicators	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú		Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Presence of adaptation and mitigation programs (Existence of CC plan)	NO	NO	NO	**0.33**	**10.00**	**10.00**	**10.00**
Awareness and Planning Index				**0.25**	**10.00**	**10.00**	**10.00**

Sub-dimension Capacity to change				Normalization			
	Value			Weight	Score		
Indicators	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú		Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Simplicity to implement policies	Median	Low	Low	**0.50**	**5.50**	**10.00**	**10.00**
Wllingness to learn from other cities (Existence of policy copied from other cities)	YES	NO	NO	**0.50**	**1.00**	**10.00**	**10.00**
Capacity to Change Index				**0.25**	**3.25**	**10.00**	**10.00**

Sub-dimension Cooperation				Normalization			
	Value			Weight	Score		
Indicators	Foz do Iguaçu	Ciudad del Este	Puerto Iguazú		Foz do Iguaçu	Ciudad del Este	Puerto Iguazú
Existence of cooperation agreements with other cities	YES	NO	NO		**1.00**	**10.00**	**10.00**
Cooperation Index				**0.25**	**1.00**	**10.00**	**10.00**
Adaptive Capacity Index					**4.04**	**8.23**	**8.30**

11.5. ANNEX E: Qualitative Analysis

Table E 1. Amount of interviews by city and type of stakeholder

	Foz do Iguaçu	Puerto Iguazú	Ciudad del Este
Government Sector	9	6	5
Civil Society	1	5	2
Business Sector	4	1	3
Academy	2	1	1
Total: ***40 interviewees***	16	13	11

The following photos are used courtesy of:

Figure 14. Google Earth tomada por CNES/Airbus en 02/15/2017.

Figure 16. (a) Google Earth (2017), (b) Angela Tischner (2017)

Figure 17. (a), (b), (c), (e), (f), (h) Angela Tischner (2017); (d) GoogleMaps (2017); (g) SANEPAR (2017)

Figure 18. Bogler (2015)

Figure 19. Câmara Municipal de Foz do Iguaçu, 2015[27]

Figure 20. H2Foz, 2015[28,29]

Figure 21. JIE[30]/Itaipu Binacional (2009)

Figure 22. Jean Pavão (2017)

Figure 23. 34º BIMEC. Exército Brasileiro, 2015.[32]

Figure 24. Lucas López (2017)

Figure 25. Lucas López (2017)

Figure 26. ABC/ Color[39], 2015

Figure 27. ABC/ Color[39], 2015

Figure 28. Última Hora[39], 2014

Figure 29. ABC Color[39], 2017

Figure 30. VisiteFoz[39], 2017

Figure 31. Courtesy of Paola Sakai, 2017

Figure 32. Fanpage Codeleste, 2017.

About Climate Resilient Cities Initiative in Latin America (CRC)
It is a joint initiative between Climate and Development Knowledge Network (CDKN), International Development Research Center of Canada (IDRC) and the Fundación Futuro Latinoamericano (FFLA). CRC Initiative is funding six innovative research projects for decision-making and action in 13 small and medium-sized cities in Latin America to promote climate-resilient urban development.

About Climate and Development Knowledge Network (CDKN)
CDKN supports decision makers in the design and implementation of climate-friendly development. CDKN does this by combining research, advisory services and knowledge management in support of policy processes worked and managed locally. CDKN works in partnership with decision makers in the public, private and non-governmental sectors at different scales.

About the International Development Research Center (IDRC)
IDRC invests in knowledge, innovation and solutions to improve the living conditions of people in the developing world. By bringing together the right partners around impact opportunities, IDRC helps train leaders today and tomorrow and drive change for those who need it most. The climate change program aims to support research, alliances and networks that report cost-effective solutions to extreme weather events and climate change, and generate long-term social and economic gains.

About Fundación Futuro Latinoamericano (FFLA).
FFLA is a member and CDKN Regional Coordinator for Latin America and the Caribbean. The work of FFLA focuses on the promotion of constructive dialogue, and the strengthening of citizen, political and institutional capacities. It works on issues of importance for sustainable development, including natural resource management, socio-environmental conflicts and climate change. FFLA also provides training, facilitation and advisory services in related areas.

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This document is an output from the joint Initiative "Climate Resilient Cities in Latin America" supported by the Climate and Development Knowledge Network (CDKN) and Canada's International Development Research Centre (IDRC). This document was created under the responsibility of Fundación Futuro Latinoamericano (FFLA) as a recipient of support through the joint initiative. CDKN is a programme funded by the UK Department for International Development (DFID) and the Netherlands Directorate-General for International Cooperation (DGIS) and is led and administered by PricewaterhouseCoopers LLP. Management of the delivery of CDKN is undertaken by PricewaterhouseCoopers LLP, and an alliance of organisations including Fundación Futuro Latinoamericano, LEAD Pakistan, the Overseas Development Institute, and SouthSouthNorth. The Initiative is funded by DFID and IDRC. The views expressed and information contained in this document are not necessarily those of or endorsed by DFID, DGIS, IDRC and its Board of Directors, or the entities managing CDKN which can accept no responsibility or liability for such views, completeness or accuracy of the information or for any reliance placed on them. This publication has been prepared for general guidance on matters of interest only, and does not constitute professional advice. You should not act upon the information contained in this publication without obtaining specific professional advice. No representation or warranty (express or implied) is given as to the accuracy or completeness of the information contained in this publication, and, to the extent permitted by law, IDRC and the entities managing the delivery of CDKN do not accept or assume any liability, responsibility or duty of care for any consequences of you or anyone else acting, or refraining to act, in reliance on the information contained in this publication or for any decision based on it.