Climate Change Adaptation in Ciudad del Este: Starting-Point Vulnerability Assessment

PAOLA SAKAI
School of Earth and Environment, Sustainability Research Institute, University of Leeds, United Kingdom.
p.h.m.d.oca@leeds.ac.uk

DANIEL OBERLING
Instituto Polo Internacional Iguassu, Brazil.

THAÍS SCHNEIDER
Instituto Polo Internacional Iguassu, Brazil.

LUCAS LÓPEZ
Facultad de Ciencias Forestales, Universidad Nacional de Misiones, Argentina.

NORMA CABALLERO
Facultad Politécnica, Universidad Nacional de Asunción, Paraguay.

FIORELLA OREGGIONI
Centro de Tecnología Apropiada, Facultad de Ciencias y Tecnología, Universidad Católica "Nuestra Señora de la Asunción".

MARCO SAKAI
School of Earth and Environment, Sustainability Research Institute, University of Leeds, United Kingdom.

ANGELA TISCHNER
Instituto Polo Internacional Iguassu, Brazil.

CELESTE AQUINO
Facultad Politécnica, Universidad Nacional de Asunción, Paraguay.

ANA FRANZINI
Instituto Polo Internacional Iguassu, Brazil.

GENARO CORONEL
Facultad Politécnica, Universidad Nacional de Asunción, Paraguay.

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ABSTRACT

It is becoming increasingly common that cities are being negatively impacted by extreme weather events. Moreover, climate projections point to an increase in the frequency and severity of those events. Cities across the world must thus assess their vulnerabilities to extreme events and adapt accordingly. Compared to big metropolises, smaller cities face more opportunities to adapt their practices to defend and protect from these impacts, since in many cases they are still not locked-in by existing infrastructure, and show greater potential for future sustainable urban planning. Nevertheless, few studies have assessed the vulnerability of small cities, which generally present fastest population growth rates, along with lack of capacities, resources and financing options. This paper investigates the vulnerability of Ciudad del Este, Paraguay, which is expected to be among the top five fastest growing cities in Latin America by 2030. The analysis is based on a mixed methods approach, combining quantitative and qualitative techniques. Quantitatively, an Urban Vulnerability Index was built using 73 economic, social, climatic and environmental indicators, in order to quantify the sensitivity of the city to extreme weather events, as well as its capacity to cope and adapt to those events. In qualitative terms, data collected from interviews was used to complement the quantitative findings. The results show that the city is highly sensitive to extreme weather events, due to its vastly urbanised area, lack of green spaces and amount of vulnerable and exposed population. The city also shows a lack of adequate urban planning and a low capacity to plan for weather and climate disasters. The paper, in this sense, highlights areas of urgent attention to reduce its vulnerability.

KEY-WORDS: Extreme weather events, Urban Vulnerability Index, Paraguay, Coping and adaptive capacity.

RESUMEN

Se ha vuelto bastante común que los eventos meteorológicos extremos impacten negativamente las ciudades. Además, las proyecciones climáticas apuntan a un incremento en la frecuencia y severidad de esos eventos. Por lo tanto, las ciudades alrededor del mundo deben evaluar sus vulnerabilidades a los eventos extremos y adaptarse a ellos apropiadamente. Las ciudades pequeñas, en comparación con grandes metrópolis, poseen mayores oportunidades para adaptar sus prácticas para defenderse y protegerse de esos impactos, debido a que en muchos casos no se encuentran limitadas por la infraestructura existente, y muestran mayor potencial para futuras planeaciones urbanas sustentables. Sin embargo, pocos estudios se han enfocado en evaluar la vulnerabilidad de pequeñas ciudades, las cuales generalmente presentan mayores tasas de crecimiento poblacional, además de falta de capacidad, recursos y opciones de financiamiento. Este trabajo investiga la vulnerabilidad de Ciudad del Este, Paraguay, la cual se espera que esté entre las primeras cinco ciudades con mayor crecimiento poblacional en América Latina para el 2030. El análisis se basa en un enfoque de métodos mixtos, combinando técnicas cuantitativas y cualitativas. Cuantitativamente, se construyó el Índice de Vulnerabilidad Urbana utilizando 73 indicadores económicos, sociales, climáticos y ambientales, con el objetivo de cuantificar la sensibilidad de la ciudad a los eventos meteorológicos extremos, así como para cuantificar la capacidad de responder y adaptarse a ellos. En términos cualitativos, datos recolectados por medio de entrevistas fueron utilizados para complementar los hallazgos cuantitativos. Los resultados muestran que la ciudad es muy sensible a los eventos meteorológicos extremos, debido a su gran área urbanizada, falta de espacios verdes y a la cantidad de población vulnerable. La ciudad también muestra falta de planificación urbana y baja capacidad de planeación para enfrentarse a desastres climáticos. Esta publicación, en este sentido, resalta las áreas de atención urgente y subraya las áreas de acción para reducir su vulnerabilidad.

PALABRAS CLAVE: *Eventos meteorológicos extremos, Índice de Vulnerabilidad Urbana, Paraguay, Capacidad de afrontamiento y adaptación.*

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INTRODUCTION

Urbanisation and climate change represent important challenges for global sustainability. Cities represent the highest pinnacles of a complex and interconnected human system. Concentrating people in interactive and collective spaces has provided several advantages, generating wealth and innovations (UN-Habitat 2012). However, nowadays, cities require global action to reduce the high amounts of greenhouse gas (GHG) emissions generated by the activities of urban centers (IPCC 2014b), while reducing vulnerabilities and adapting to climate change.

Concentrating more than half of the world's population and most of its economic activities, cities play a critical role in the face of climate change (UN-Habitat 2015). It is vital that institutions, people, businesses and other organisations in urban spaces undertake actions towards being prepared for weather-related extreme events. In this sense, implementing disaster risk management strategies is paramount, as well as building climate resilient development, managing immediate reconstruction strategies and effectively reestablishing basic services in order to being able to respond and continue their social, institutional and economic activities after an adverse event (IPCC 2012).

Urban areas are most susceptible to external shocks and stresses. 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. According to the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC 2014), the adverse effects of climate change are likely to increase extreme temperatures and precipitation depending on location, with an impact on the frequency, intensity and location of floods and droughts patterns. The number and intensity of floods, droughts, landslides and heat waves can have a greater impact on urban systems. In fact, extreme weather events have the capacity to compromise economic welfare to the extent that the Sustainable Development Goals (SDGs), specifically the Climate Action Goal 13, have emphasised the need for strengthening resilience and adaptive capacity to climate- and weather-related hazards and natural disasters (United Nations 2015). This means that social, economic, and environmental sustainability can be improved by the disaster risk management and the adaptation approach. Addressing the fundamental causes of vulnerability is a prerequisite for sustainability in the context of climate change (IPCC 2012).

In addition to extreme weather events, common problems related to fast and disorganised urbanisation processes, such as lack of infrastructure, sanitation and education or irregular land occupation, constitute vulnerabilities that raise the cities' exposure to the risks and impacts of climate change. In order to protect their development and build climate resilience, it is vital that cities address their vulnerabilities and investn in adaptation. In that sense, this study presents an assessment of vulnerabilities and adaptation strategies that was conducted at the triangle-city region, where Ciudad del Este share borders with Foz do Iguaçu (BR) and Puerto Iguazú (ARG), as part of the project called Triangle-city cooperation: building climate-resilient development in the Parana basin (www.triangle-city.leeds.ac.uk). The results discussed in this article correspond to the first part of the research, presented in the report titled Vulnerability Assessment and Adaptation Strategies of the Triangle-City Region (Sakai *et al.* 2017).

As a member of the United Nations Framework Convention on Climate Change (UNFCCC) and of the Sendai Framework for Disaster Risk Reduction (SFDRR), Paraguay has developed legal and institutional settings for climate adaptation, such as the National Adaptation Plan (NAP), released in 2016. The document provides the guidelines for adaptation at city level, requiring the incorporation of climate change aspects in territorial planning and management and the elaboration of local adaptation plans (SEAM 2016).

It is worth to note, however, that this setting is relatively new and has not trickled down to local governments yet. That is the case of Ciudad del Este, which currently relies on a responsive approach towards extreme weather events. Although the strategies used in the face of emergency or disaster situations are not yet formalized in a local contingency plan, the municipality has an organised structure to deal with such occurrences, headed by the local Council for Risk Reduction and Response, with the support of the district's Fire Brigade, the local organisation of the Red Cross and Itaipu Binational, among other institutions. On the other hand, investments are being made for the development of emergency protocols and the expansion of the country's monitoring network for early warning, with the aim of implementing a Regional Meteorology Centre with a unit in Ciudad del Este (PNUD 2016).

Those measures are of big relevance, given the growth that the city has experienced over the last decades, constituting an international trade hub with one of the biggest commercial flows in the world (Dreyfus 2005, Rabossi 2004). With only 60 years of existence, Ciudad del Este is the second most populous city in Paraguay (DGEEC 2015), and is expected to be among the five fastest growing cities in Latin America by 2030 (United Nations 2015).

Historical trends suggest that climate patterns have changed during the last five decades in the triangle-city region. The annual amount of precipitation has increased over the years, as well as the number and frequency of extreme precipitation, while temperature trends suggest that the climate is getting warmer. Episodes of heavy rainfall, flooding, hailstorms and droughts have been reported in the region, causing large economic and social impacts (Sakai *et al.* 2017). The area is also prone to wind storms and the future occurrence of tornados (Fujita 1973). Meanwhile, future projections indicate that the mean temperatures in the region are expected to increase by the end of the 21st century, as well as extreme weather events, especially those related to high temperatures (Sakai *et al.* 2017, Mercogliano *et al.* 2017, Chou *et al.* 2014, Collins *et al.* 2013, Seneviratne *et al.* 2012).

Thus, this article aims to contribute to the understanding of city-scale vulnerabilities and adaptation strategies towards climate change, focusing on the case of Ciudad del Este. The first part of the article describes the methodology that was adopted in the study, combining quantitative and qualitative methods. The findings are discussed next, followed by an analysis of the city's exposure and sensitivity to climate impacts, as well as its coping and adaptive capacities. The objective is to comprehend the city's needs, opportunities and obstacles for adaptation, given the vulnerability assessment as a starting point for such process.

METHODS

Vulnerability has a long tradition, and it has been a powerful analytical tool to understand the direct and indirect relation to biophysical and socioeconomic aspects (O'Brien *et al.* 2007, Adger 2006, Eakin and Luers 2006, Füssel and Klein 2006, Janssen and Ostrom 2006, Brooks *et al.* 2005, O'Brien *et al.* 2004, Brooks 2003, Cutter *et al.* 2003). Vulnerability is a contested term and no consensus has been achieved regarding a universally accepted definition (Carter *et al.* 2015). 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.* 2016). 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 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.* 2016). Finally, 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*" (Agard *et al.* 2014).

Different interpretations of vulnerability have implications on the assessment of the results and, consequently, on the recommendations for policy-makers (O'Brien *et al.* 2004, Kelly and Adger 2000). 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). There are two main branches of vulnerability, the starting point and the ending point vulnerability. The first refers to the 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). The latter involves the development of climate scenarios, looking at the biophysical impact and the adaptive options, so then the residual consequences after adaptation has taken place correspond to the vulnerability of the unit of analysis (O'Brien *et al.* 2007, Kelly and Adger 2000).

There are various methods and frameworks to assess vulnerability (Nguyen *et al.* 2017; Tehelen and 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). Another way to assess vulnerability has been through maps (Adger 2006), and through mathematical models (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). An important aspect that needs to be taken into account is that quantitative indicators cannot describe all aspects of climate change vulnerability (Winogard 2007).

An assessment of the vulnerabilities to climate variations and extremes must start with a clear idea of what is to be assessed. Vulnerability is understood here from the starting point as it provides a wider comprehension of the phenomenon as the social context is widely taken into account, rather than just the biophysical impact, allowing a greater granularity in the study of the vulnerability of a city. In this sense, vulnerability encompasses the sensitivity of a city, 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 these 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 capacity of action by a city to reduce its risk by decreasing its vulnerability. For this reason, a vulnerability assessment usually considers the capacities of cities to react and respond to climate events.

The Urban Vulnerability Index (UVI) is based on the sequential implementation of a number of analytical steps. 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 to capture the different elements of each dimension. A set of interviews were conducted to 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 that was 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 the UVI.

Indicators for sensitivity, coping and adaptive capacity were developed. It was assumed that the city's vulnerability is fundamentally associated with people, things and places, regardless of whether they experience a hazard that could cause damage (Carter *et al.* 2015). It was also assumed that the city would properly respond to these changes if it has sufficient adaptive capacity to adjust.

Measuring urban sensitivity encompasses, among others, a city's physical, social and economic factors (Carter *et al.* 2015, EEA 2012). In this article, 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 (floods and high temperatures) (Klok *et al.* 2012, Swart *et al.* 2012, Gábor and Jombach 2009). It is important to mention that 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 Ciudad del Este. The Strategical Infrastructure sub-dimension was selected to provide indicators about the quality of the built environment, housing, emergency and transport infrastructure, considered as proxies for the city´s ability to maintain its crucial external public services after climate events (Hunt and 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, and it was represented by access to the education and health systems, water, security, inequality and vulnerable population. Some of the relationships between types of infrastructure and social sensitivity, however, were not examined in this article and it is recommend that future research should be undertaken in this area (EEA 2012).

The economic factors sub-dimension involves 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 captures responses (and capacities to adapt to) to all possible types of events is neither completely feasible nor desirable. It was opted for more generic indicators, which are relevant for several climate hazards. In these sense, indicators that were appropriate across at least two of the climatic threats mentioned by key informants during the fieldwork were selected (e.g. heat and flooding). To measure adaptive capacity, 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.

In total, 15 sub-dimensions and 73 different types of indicators were identified. Table 1 summarises this information. The main indicator selection criteria were data coverage and comparability, rather than precision and accuracy. Quality-based criteria was used on relevance on relevance and interpretability (in accordance to the literature), and reduced redundancy (i.e. avoiding indicators that measure similar trends). In order to increase data coverage, a flexible approach was adopted with regard to temporal and geographical harmonisation. 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.

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

Table 1. 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, road 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

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.

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 presenting 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.

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.

The UVI is calculated as the average of the Sensitivity Index (SI) and the Capacity Index (CI) (Table 2). 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 ranges from 1 (lowest vulnerability grade) up to 10 (highest vulnerability grade). The SI comprises a linear aggregation of eight sub-indices, one for each sub-dimension and is calculated as the arithmetic mean of re-scaled indicators (Table 2). The CI comprises a linear aggregation of seven sub-indices for each sub-dimension and is also calculated as the arithmetic mean of re-scaled indicators (Table 2).

The UVI is not exhaustive, in the sense that it does not include all potential aspects that can influence the vulnerability of Ciudad del Este. 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 the exposure. In addition, the index shows a static condition, ignoring the temporal evolution of each indicator. Nevertheless, the analysis presented here represents an initial approach and can be useful as benchmark for future comparisons.

This paper developed a set of indicators to operationalize the proposed context. The qualitative analysis was based on semi-structured interviews which involved the following themes: 1) What are the main events related to the climate that the city experienced and how did they affect it? 2) What are the actions that the city performs when it faces climatic events? 3) What actions is the city taking to protect itself from future climate events? These three themes facilitated the reading of the current context regarding the vulnerability of the city to the effects of climate change. The aim was to capture the perception of different stakeholders of the climate-related problems that Ciudad del Este has faced, and identify the coping and adaptive strategies the city has undertaken. Key stakeholders were interviewed (N=11) between February and April 2017 in Ciudad del Este, including government officials, NGOs, business representatives and civil society. The interviews lasted around one hour. They were recorded, transcribed and analysed according to the framework proposed in this paper.

Table 2 . Equations to calculate UVI

Equation 1. UVI´s mathematic expression

$$UVI = \frac{SI+CI}{2} \qquad 1 \leq UVI \leq 10;$$

Where,

SI = Sensitivity Index

CI = Capacity Index

Equation 2. SI´s mathematic expression

$$SI = \frac{(PHI+SAI+EAI)}{3} \qquad 1 \leq SI \leq 10;$$

Where,

PHI = Physical Attributes Normalized Index

SAI = Social Attributes Normalized Index

EAI = Economic Normalized Attributes Index

Equation 3. CI´s mathematic expression

$$CI = \frac{(CC+ACI)}{2} \qquad 1 \leq CI \leq 10;$$

Where,

CC = Coping Capacity Normalized Index

ACI = Adaptive Capacity Normalized Index

RESULTS AND DISCUSSION

Sensitivity

Urban areas in Ciudad del Este have grown steadily for the last 30 years in an unplanned manner, making the area more vulnerable to impacts from extreme weather events. The interviews reveal that the most common impacts that have affected the city are heavy rainfall (causing urban and river flooding) 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 to 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"*. 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*, *Che La Reina*, *Remancito*, *San Juan*, *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 (Ciudad del Este's neighbourhoods are mainly referred to in terms of kilometres,

from 1 to 13, based on their distance to the Friendship Bridge) is prone to flooding by the *Monday* river.

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 N° 3239/2007 (Poder Legislativo del Paraguay 2007) 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*".

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 advertisements 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. 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 signifi-

Table 3. Results of the Urban Vulnerability Index (UVI) and its components for Ciudad del Este (PAR) and Foz do Iguaçu (BR)

Dimension		Ciudad del Este	Foz do Iguaçu
Urban Vulnerability Index		3.64	7.51
Sensitivity Index (SI)		2.92	6.91
Capacity Index (AC)		4.35	8.11
Dimension	**Sub-dimension**	**Ciudad del Este**	**Foz do Iguaçu**
Physical attributes (Sensitivity)	Land Use	10.00	1.86
	Strategical Infrastructure	5.14	3.70
	Physical Index	7.57	2.78
Social attributes (Sensitivity)	Population	9.16	5.69
	Poverty	6.03	1.00
	Well-being	6.05	2.34
	Social Index	7.08	3.01
Economic attributes (Sensitivity)	Size and diversification	4.98	1.86
	Public finances	10.00	1.00
	Business sector	3.25	6.07
	Economic Index	6.08	2.98
Coping Capacity (Capacity)	Preparedness	10.00	4.00
	Response	7.00	6.00
	Recovery	7.00	4.00
	Coping Capacity Index	8.00	4.67
Adaptive Capacity (Capacity)	Networks	2.91	1.91
	Awareness and planning	10.00	10.00
	Capacity to change	10.00	3.25
	Cooperation	10.00	1.00
	Adaptive Index	8.23	4.04

cant rise in road accidents is experienced as well.

The UVI was applied to Ciudad del Este, Foz do Iguaçu and Puerto Iguazú to facilitate comparisons between cities with close features. Hereby, the results for Ciudad del Este are presented using Foz do Iguaçu as a reference point (while results from Puerto Iguazú are presented elsewhere). The results are shown in Table 3.

Ciudad del Este has a higher level of vulnerability (7.51). A closer examination shows that its vulnerabilities are explained by high values for certain factors. Ciudad del Este presents high Sensitivity (6.91) and levels of Capacity (8.11). Taking a closer look at the UVI, it can be seen that the Physical Attributes indicates that Ciudad del Este presents a larger sensitivity than Foz (7.57 against 2.78). Land Use is the most important factor for CDE, followed by "built environment". The Land Use indicators for Ciudad del Este depict no significant green areas (1.2% of the municipal territory) (Table 4), compared to Foz, which has more green zones and lies close to a national park (Parque Nacional Iguazú). Highly-urbanised areas without sufficient green spaces are important factors for the so-called Urban Heat Island (UHI) effect, (UHI describes the increased temperature of the urban air compared to its rural surroundings, and the temperature difference can be up to 10 °C or more (Steeneveld *et al.* 2011), 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 Ciudad del Este, 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 2014a). Most notably, the cooling effect of vegetated surfaces is replaced by the storage of heat in surfaces such as concrete, asphalt and stone. In this sense, Ciudad del Este can display sensitivity to impacts associated with high temperatures, depending on a number of factors.

Table 4. Physical Attributes Index Scoring.

Sub-dimension	Factor	Indicator	Foz do Iguaçu	Ciudad del Este
Land Use	Land Use	% of Urban Areas	31%	98,30%
		% of Forest Areas	45%	1,2%
Strategic Infrastructure	Built environment (type and quality)	Material	Masonry with concrete foundation	Masonry with concrete foundation
		Structure	Wood	Wood
		Roof Design	Box Gable	Box Gable
		Roof Material	Fibrocement	Clay roof tiles
	Quality of infrastructure	Bridges	Medium Good	Medium Good
		Roads	Medium Bad	Medium Good
		Fire Departments	Good	Medium Good
		Police Station	Medium Good	Medium Good
		Public Schools	Medium Good	Medium Good
		Hospital	Medium Good	Medium Good
		Civil Defence	Medium Bad	Medium Good
		Waste	Medium Good	Medium Bad
		Water	Medium Good	Medium Bad
		Energy	Medium Good	Good
	Diversity and affordability of transport networks	Number of public bus lines	44	6
		Average price for one-way ticket*	1.06	0.45
		Motorization rate **	399.73	143.62
		Number of Public transport Modes	3	3
	Communications local TV and radio stations	(Number of local TV and radio networks)	11	7

* Current US$
** (cars/people)*1,000

The proportion of urbanised areas was used as a proxy for sensitivity to floods. In this respect, Ciudad del Este is considered sensitive because of its 98% of urbanised area (Table 4). Low-lying human settlements in flood-prone areas increases the potential damage derived from extreme precipitations. 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 extreme weather events was 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. A closer look at the indicators suggest that most strategical infrastructure was considered 'medium good' by interviewers, similar to the Foz do Iguaçu results. Regarding the built environment, masonry-built houses with superficial foundation, wood structured roofing and ceramic tiles are predominant in Ciudad del Este, which confers some resistance to weather events, such as strong winds and hails. However, the hail storm of 2015

showed that these tiles have low resistance to hail, especially those made with fibre cement and ceramic. On the other hand, the affordability and diversity of public transport and communications were considered low, which is not enough to indicate that they are not sensitive to extreme weather events. Finally, the structure of waste collection and disposal and the structure of water supply in CDE are precarious according to the indicators, which suggest that these services can be significantly sensitive under weather and climate emergencies.

The social attribute index suggests that Ciudad del Este (7.08) has more sensitivity than Foz do Iguaçu (3.01). Population and poverty, access to water and sanitation, and the health indices are vital for CDE sensitivity factor, indicating an insufficient public service supply. Ciudad del Este'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 social sensitivity (Table 5). This group can be particularly affected by water scarcity, droughts and increased temperatures. In the case of heat waves, senior citizens (over 65 years 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 events, low-income groups spend a considerable amount of their income on securing water and on recovering their homes. Ciudad del Este has important portions of its populations living in slums (25.7%, while Foz has 2.5%), which usually are exposed to floods and other hazards.

The set of well-being indicators illustrates important factors that influence Ciudad del Este's vulnerability to extreme weather and climate events. Ciudad del Este'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

Table 5. Social Attributes Indicators.

Sub-dimension	Factor	Indicator	Foz de Iguazú	Ciudad del Este
Population	Population	Number of people	256,088	296,597
	Population density	Population density (pop/km^2)	415	2,852
	Households	Number of households	79,161	47,536
	Sensitive groups	% of people with more than 65 and from 0-14	30.5%	35.6%
	Labour Force	Number of people	133,547	166,223
Poverty	-	% of poor	7.4%	9.2%
		% of the population living in slums	2.5%	25.7%
Well-being	Water	% of households with access to clean water supply	99.6%	30.0%
		% of households with access to waste water system	99.9%	30.4%
		% of households with access to waste disposal	99.1%	52.2%
	Health	Mortality rate (by thousand people)	5.80	11.87
		Childhood mortality rate (by thousand new borns)	15.48	46.24
		Childhood mortality rate – under 5 years old (by thousand new borns)	17.10	15.70
	Education	% of illiterate people	5.1%	5.8%
		% of children under 17 years old in school	85.6%	85.0%
	Security and rule of law	Crime rate	1,227	114
		Murder rate	14.8	25.89
	Inequality	Gini Index	0.545	0.506

index of 0.506). The lower performance for the set of indicators of well-being indicates that Ciudad del Este has already displayed a series of sensitivities to several threats, not being restricted to the climatic ones. Therefore, any new threats can put its population at risk, making them more sensitive to an uncertain climate change.

The economic attributes indicated, in general, low economic diversification and low public investment, although they suggest there is a good business environment (Table 6). The aggregated index is 6.08 for Ciudad del Este and 2.98 for Foz do Iguaçu. Despite the differences, Ciudad del Este's indicators show evidence of a less robust and diversified economy (stronger industry and services sectors) than Foz. Therefore, it cannot be claimed that Ciudad del Este does not have enough capacity to withstand weather and climate disturbances.

Ciudad del Este is based heavily on commerce and is sensitive to extreme events that impact its dense commercial activities or its access to other regions. 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. On the other hand, the relative importance of tourism in the economies of Foz do Iguaçu and Puerto Iguazú (Argentina) suggest their potential economic sensitivity to extreme weather and climate events that affect tourist activities, which can lead a reduction of tourism flows to Ciudad del Este.

Capacities to cope and adapt

The results derived from the qualitative indicators related to Coping Capacity suggest, in general terms, low levels of preparedness, response and recovery in Ciudad del Este. There are indications of insufficient levels of preparedness to reduce damages associated with weather and climate 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 weather and climate events, since this does not allow the complete disaster management cycle (Lavell *et al.* 2012). Regarding response factors, emergency medical services were also considered inadequate in PI and CDE. The indi-

Table 6. Economic Attributes Indicators

Sub-dimension	Factor	Indicator	Foz do Iguaçu	Ciudad del Este
Size and diversification	Economic size	Gross domestic product (GDP 2014 – current US$ 1,000)	2,675,248	730,815**
	Economic diversification	Agriculture	0,65%	31.00%
		Industry	48.63%	15.00%
		Services	38.39%	49.00%
		Public	12.34%	6.00%
Public finances	Public accounts	Municipal budget (current US$ 1,000)	204,118	7,829
Business sector	Business vitality	Number of businesses	6,999	15,000
	Business environment	Simplicity to conduct business activities	Medium	Medium

* Current US$ used to covert local currency: 1 USD = R$ 3.26 = 5,595.97 Guaraníes

**GDP for Ciudad del Este was scaled-down using Alto Parana's GDP 2010 based on GDP per capita.

Table 7. Coping Capacity Attributes Indicators

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

Table 8. Adaptive Capacity Indicators

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

cators 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. The results derived from the qualitative indicators related to Coping Capacity suggest, in general terms, low levels of preparedness, response and recovery (Table 7).

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*".

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 and provide 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 other things.

Several organisations were identified throughout the interviews as key agencies in the face of an extreme weather event related disaster. In terms of prevention, Itaipu has an important role by providing early warning systems and offering meteorological 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. Itaipu also grants social assistance through the Fire Brigade by delivering emergency kits, mattresses, food and water. The Volunteer Fire Brigades are independent organisations

that provide support to the community through an emergency phone line when disasters caused by extreme weather events occur. The Red Cross also plays a relevant role in aid delivery efforts. It offers medical attention, helps to evacuate people (depending on the type of event), organises 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*". 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. Other social actors are: the Infantry division, Rotaract, Junior Chamber International, TECHO (youth-led non-profit organisation), Lions Club, CODELESTE (Ciudad del Este's Economic Development Council), Chamber of Commerce, Technology Chamber, and religious organisations. During disasters, these organisations contribute with immediate needs such as clothing and food, but do not offer financial support.

Ciudad del Este has no institutional structure that allows the use of direct financial resources from the Municipal Treasury as financing mechanisms for post-disaster recovery. In addition, our interviews and survey responses mentioned the inexistence of an insurance scheme which covers both households and businesses in the case of extreme weather events. The lack of reconstruction funds and a low dissemination of insurance schemes in Ciudad del Este indicate low capacities for post-disaster performance, compared to Foz do Iguaçu.

Effective institutional networks rely on strong and reliable institutions, operative participation channels, and mechanisms for engaging civil society in government decisions. This represents a necessary basis for the existence of efficient stakeholder networks that enhance the city's adaptive capacity. The results for Ciudad del Este 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 Ciudad del Este (Table 8).

The results in general indicate significant inertia to promote new public policies. Some interviewees indicated that the introduction of new policies usually takes a long time. It was found that Ciudad del Este has greater difficulties to develop and adopt new policies than Foz do Iguaçu. It is worth noting that there is a lack of climate change mitigation and adaptation plans in Ciudad del Este. This shows that climate variations and extreme weather events are still waiting to be integrated into public policy, which highlights the urgency to promote effective climate-resilient development in the city.

CONCLUSION

This work presents a first assessment of the vulnerability of Ciudad del Este to climate variations and extremes. It provides a background to understand the characteristics of this city. It examines their current sensitivity, disaster risk reduction strategies, policies and institutional settings with the aim of assessing its current situation in the face of extreme weather events.

In a nutshell, extreme water-related weather events have caused important problems in Ciudad del Este. Heavy rainfall and flooding have been the most common events affecting this city. 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. This is a worrisome matter if, on the one hand, we consider the future climate projections, which point at an increase in the intensity and frequency of extreme weather events. On the other hand, Ciudad del Este is expected to be among the ten fastest growing cities in Latin America by the year 2030, according to UN urbanisation prospects. Thus, the fact that urban planning and investment in infrastructure have not paired with population growth represents a challenge for Ciudad del Este.

The present assessment found an inadequate urban planning, 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. Investment in tourism infrastructure is also required to capitalise on the large flux of tourists, especially in Ciudad del Este. 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 UHI 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. 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. Solid waste management was also pinpointed as a serious issue. Other problems that were detected are low levels of education and increasing levels of insecurity. In contrast, Ciudad del Este offers a good business environment, although economic diversity needs to increase. Similarly, work needs to be done to support small and medium sized enterprises (SMEs) which are generally the most vulnerable in the private sector, and most importantly the largest number of firms in Ciudad del Este belong to this type of organisations. The agricultural sector in Ciudad del Este accounts for almost a third of its gross domestic product, being an activity that is also sensitive to changes in climate, and it represents an important area for further studies.

In terms of preparedness, Ciudad del Este possesses emergency protocols and contingency plans, although they are informal. Response mechanisms rely on the municipality through different organisations. Civil Defence is the first entity to respond to an emergency and disaster situation in the city. 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 and Itaipu is a key actor in providing early warnings. Results highlight that prevention, preparedness and reco-

very strategies are not enough, and in some cases have proven to be inefficient due to lack of equipment, coordination, and resources. Likewise, planning for climate change adaptation is still incipient. Nevertheless, a strong will to take action was found in this important city of Paraguay.

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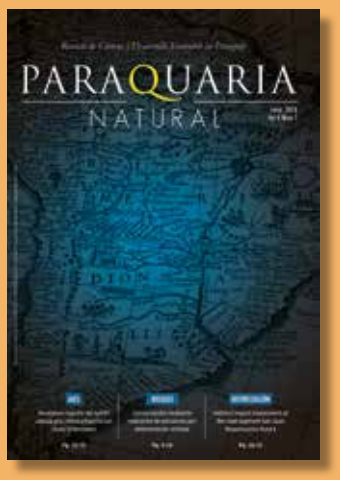

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ASOCIACIÓN GUYRA PARAGUAY
CONSERVACIÓN DE AVES
Parque Ecológico Asunción Verde
Avda. Carlos Bóveda (2km desde la Entrada del Botánico). CC 1132
Asunción, Paraguay
www.guyra.org.py
Tels: (+59521) 223 567, 229 097
Mail: guyra.paraguay@guyra.org.py

CONSULTAS Y ENVÍOS DE ARTÍCULOS
paraquaria.editor@gmail.com
Tels: (+595 21) 223 567, 229 097

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