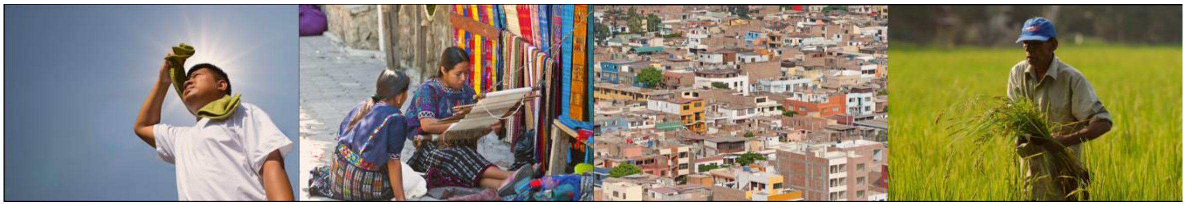

Extreme heat in Central and South America

Technical lead
Marisol Yglesias-González

Consultancy team
Luciana Blanco, José Luis Díaz, Stella Hartinger, Juliana Helo, Romina Lavarello, Yasna Palmeiro, Ivonne Reyes, Luciana Rojas.

Consultancy report

June 30th, 2022

Table of contents

Executive Summary ... *5*

1 Heat risk variability between and within CSA and identifying highest risk areas based on hazard, exposure, and vulnerability ... *8*

1.1 Methodology ... **8**

1.1.1 Literature Review ... 8

1.1.2 Heat Stress: Data Sources and Data Analysis ... 9

1.1.3 Vulnerability: Data Sources and Data Analysis ... 10

1.2 Results ... **11**

1.2.1 Literature Review ... 11

1.2.2 Heat Stress: Spatial Analysis ... 12

1.2.3 Heat Stress: Population Weighted Average Analysis (PWA) ... 14

1.2.4 Vulnerability ... 15

1.2.5 Overall Synthesis ... 16

1.3 Limitations ... **17**

1.4 Conclusions ... **18**

2 Understand the known impacts of extreme heat across countries ... *19*

2.1 Methodology ... **19**

2.1.1 Literature Review ... 19

2.1.2 Key Informant Interviews ... 20

2.2 Results ... **20**

2.2.1 Literature review ... 22

2.2.2 Key Informant Interviews ... 28

2.3 Limitations ... **31**

2.4 Conclusions ... **32**

3 Existing early warning systems for extreme heat in Central and South America ... *33*

3.1 Methodology ... **33**

3.1.1 Gray Literature Review ... 33

3.1.2 Key Informant Interviews ... 33

3.2 Results ... **34**

3.2.1 Gray Literature Review ... 34

3.2.2 Key Informant Interviews ... 39

3.3 Limitations ... **41**

3.4 Conclusions ... **41**

4 Actors and organizations working on extreme heat in Central and South America. ... *43*

4.1 Methodology ... **43**

4.2 Results ... **44**

4.2.1 Type of Actors ... 45

4.2.2 Actor's approach to heat waves ... 45

4.2.3 Geographic coverage of the material produced by the actors and organizations ... 46

4.3 Limitations **47**

4.4 Conclusion **47**

5 Heat wave events in Central and South America, 2017-2021 .... ***48***

5.1 Methodology **48**

5.1.1 Literature Review 48

5.1.2 Heat waves: Data Sources and Data Analysis 49

5.1.3 Known Impacts from Heat Wave Events 49

5.2 Results **49**

5.2.1 Literature Review 49

5.2.2 Heat Wave Events 53

5.2.3 Overall Synthesis 53

5.3 Limitations **54**

5.4 Conclusions **54**

6 Priority gaps in heat risk knowledge in Central and South America for future research agendas ***56***

6.1 Methodology **56**

6.2 Results **56**

6.2.1 Knowledge and Scientific Production 57

6.2.2 Data Generation and Management 65

6.2.3 Knowledge Transfer and Co-creation 67

6.3 Limitations **68**

6.4 Conclusions **68**

7 Priority gaps in emergency heat risk action for future operational considerations ***70***

7.1 Methodology **70**

7.2 Results **70**

7.2.1 Urgency 71

7.2.2 Articulation of Entities 72

7.2.3 Operational Action and Preparedness 73

7.2.4 Distribution of Alerts and Action 76

7.3 Limitations **77**

7.4 Conclusions **77**

8 Recommendations ***78***

Glossary ***84***

References ***86***

9 Appendix ***100***

Appendix 1. List of countries included in the study **100**

Appendix 2. Summary of literature review for objective 1 .... **101**

Appendix 3. Trends of UTCI per country from 2017 to 2021 .... **104**

Appendix 4. Search terms and summary of literature review for objective 2 114
Appendix 5. List of Key Informants 185
Appendix 6. Coding Agenda 186
Appendix 7. Protocol for semi-structured interview 193
Appendix 8. Assessment of EWS in National Adaptation Plans 196
Appendix 9. Heat wave definitions by country 199
Appendix 10. Mapping of actors 201
Appendix 11. Monthly heat wave events from 2017 to 2021 214

Executive Summary

The rise in extreme temperatures due to climate change is generating a direct impact on human health, ranging from dehydration, heat cramps, heat strokes, increased mental illnesses, to renal and cardio-pulmonary diseases, and even premature death (1). Moreover, extreme heat is also generating indirect impacts as *it "can alter human behavior, the transmission of diseases, health service delivery, air quality, and critical social infrastructure such as energy, transport, and water"* (1) affecting labor capacity, productivity, food, and water supply access, among others (2–5). Extreme temperatures exacerbate the population's vulnerabilities, affecting the elderly, children, people with co-morbidities, and those with low incomes more severely (6).

There is already much evidence of the impacts of extreme heat and heat waves in high-income countries (7). However, these countries have different climates, environmental conditions, socioeconomic characteristics, and vulnerabilities than those from Central and South America (CSA). CSA have existing inequalities that make them more prone to the adverse effects of extreme heat, such as high urbanization in poorly planned cities, lack of potable water, lack of sanitation and infrastructure, and high levels of poverty (8). However, the evidence on the health impacts of extreme heat in CSA is still limited.

This report is the result of a multidisciplinary work that aims to address the following objectives: (i) understand how heat risk varies within the region and identify the countries and cities most at risk based on a combination of hazard, exposure, and vulnerability; (ii) recognize the known impacts of extreme heat in all countries; (iii) recognize the coverage of existing early warning systems for extreme heat; (iv) identify actors and organizations that are working on extreme heat in CSA; v) list significant heat wave events in the past (last 5 years); (vi) highlight priority gaps in heat risk knowledge for future research agendas; and (viii) highlight priority gaps in heat risk emergency action for future operational considerations.

Main findings

- CSA is exposed year-round to heat stress, nevertheless not all countries have the same heat risk. In Central America, Guatemala and El Salvador are the countries with the highest heat risk. In South America, Bolivia, Colombia, Ecuador, Guyana, Paraguay, Suriname, and Venezuela have the highest heat risk. These countries do not have clear heat action plans for these events, much less heat Early Warning Systems (EWS).

- Evidence on the risk and impacts of extreme heat and heat waves in CSA is limited to a handful of studies, mainly on health outcomes. Impacts on health care demands, the proliferation of vectors and infectious diseases, agricultural productivity, labor outcomes, occupational income choices, migration decisions, human capital accumulation, conflict, or political stability have not been extensively documented. However, limited evidence suggests that heat and increasing temperatures could affect all these outcomes that impact human well-being in CSA.
- Lack of consensus on the definition of a heat wave, health impacts of heat waves and, in turn, the pressure on the health systems, the identification of structural and social vulnerabilities, the quantification of the additive effects of exposure to simultaneous hazard and the lack of or limited heat EWS in most of the countries of the region are additional research gaps that emerged from key informant interviews.
- There have been important heat wave events from 2017 onwards; however, the region's analysis of impacts on health is unclear.
- There are great challenges in dealing with heat risk emergencies. A major gap is that, in general, there are no multisectoral and articulated national-level emergency heat risk action plans.

Recommendations

- Work with local authorities in the identification of groups that are vulnerable to extreme heat to prioritize preparedness and response measures and to improve adaptive capacity.
- Provide tools to government authorities for capacity building. Contribute to raising awareness in stakeholders about heat as a health risk.
- Conduct and/or support research that tackles the diverse impacts of extreme heat.
- Conduct and/or support research that provide evidence on feasibility, and effectiveness of heat EWS. Work with health authorities to identify supply needs to increase monitoring stations and to protect the most vulnerable during heat wave events.
- Explore the possibilities of undertaking a cross-sectoral collaboration with actors and organizations in CSA.
- Favor multisectoral and articulated action with national authorities to protect human health and wellbeing for all.

The results presented in this report represent novel findings on extreme heat in CSA. To the best of our knowledge, the generated information for this report has not been previously studied or published. This work provides baseline evidence of extreme heat in the region, enhancing the understanding of best practices for heat events, combining quantitative data, scientific and gray literature reviews with narratives from key regional stakeholders.

1 Heat risk variability between and within CSA and identifying highest risk areas based on hazard, exposure, and vulnerability

1.1 Methodology

To achieve this objective, three main steps were followed. First, a general literature review of scientific evidence on heat risk was carried out. Second, an analysis of the Universal Thermal Climate Index (UTCI) [1] was performed to spatially identify areas where heat stress is particularly high.

Additionally, the UTCI was combined with population density data to obtain temporal analysis of population exposure to heat stress by country. The list of countries included in the review were those from CSA (See Appendix 1).

Finally, an overall analysis was conducted integrating the literature review, UTCI data, and vulnerability information by country. Unfortunately, there is no validated indicator of heat stress that includes a standardized index of vulnerability, either social or biological. To complement this analysis, exposure to heat stress was analyzed under two indices that might potentially indicate some degree of vulnerability: the Global Climate Risk Index (GCRI) (10) and the Human Development Index (HDI) (11) .

1.1.1 Literature Review

The literature review was guided by the following research question *"How does heat risk vary between and within Latin American countries?"*.

---

[1] There are several indices that might be used to estimate heat stress; however, not all of them can be directly applied to all regions of the world due to geographical constraints and underlying assumptions (9). The most common indices are the Heat Index (HI), Humidex, Wet-Bulb Globe Temperature (WBGT), and the UTCI. Most of these indices consider heat-balance models using different complexities in their construction with the purpose to better represent human experience to heat.; nevertheless, they do not indicate individual heat risks because they do not include social vulnerability factors that can play an important role in determining the overall risk.

The search strategy was the following*: "heat" AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND "Latin America"*.

The search was performed on Web of Science on 22 May 2022. The references were included in Rayyan and were first screened for selection by title and abstract. The full text of the chosen articles was then analyzed and selected. The screening and study selection was based on the following eligibility criteria: (i) the article was included if information on CSA countries was presented; (ii) the article analyzed any component of heat risk; and (iii) the article analyzed heat risks to human health. Appendix 2 shows a summary of the articles included in the review.

The information from selected papers was extracted using an Excel sheet that covered (i) lead author; (ii) publication year; (iii) country or region under analysis; (iv) brief methods; and (v) key findings. This information was synthesized by country and topic. The focus of key findings was on how heat risk is distributed across CSA countries, quantification of heat risk, and identification of vulnerable populations to heat.

1.1.2 Heat Stress: Data Sources and Data Analysis

Data for analyzing heat stress was based on the UTCI, which is an advanced human biometeorology index that links outdoor environment and human wellbeing. This index was created to describe the human body response to atmospheric conditions (air temperature, humidity, wind, and radiation) by taking into account physiology and clothing adaptation (12–15). One limitation of this index is its complexity because is based on a multi-node model; therefore its calculation using different variables could limit its use (9). However, because of its wide geographical application, it has been calculated worldwide using reanalysis data, allowing spatial comparability.

The UTCI is represented in degree Celsius (°C) with ten categories that represent specific human physiological responses to the thermal environment. The categories are shown in table 1.

UTCI (°C) range	Stress Category
Above +46	Extreme heat stress
+38 to +46	Very strong heat stress

+32 to +38	Strong heat stress
+26 to +32	Moderate heat stress
+9 to +26	No thermal stress
0 to +9	Slight cold stress
-13 to 0	Moderate cold stress
-27 to -13	Strong cold stress
-40 to -27	Very strong cold stress
Below -40	Extreme cold stress

Table 1. Categories of UTCI (16)

The UTCI data was downloaded from the Copernicus platform (16) on 20 May 2022, as NetCDF files considering a spatial resolution of 0.25°×0.25°. The temporal resolution covers hourly information from 2017 to 2021.

To capture a more stable and representative index over time, monthly summaries were obtained considering an average of five years (2017-2021). Monthly summaries were generated by obtaining (i) the daily maximum value of UTCI; (ii) a monthly average of daily maximum value; and (iii) the average for each month considering five years of observations (2017-2021).

To capture an index that represents the degree of exposure and considers where the population live, the UTCI was combined with population distribution datasets. Due to the period under study, the Gridded Population of the World version 4 for 2020 was downloaded from the Socioeconomic Data and Applications Center (SEDAC) website (17). To obtain information country by country, a public shapefile for countries under study was downloaded (18). All analyses were performed in R.

1.1.3 Vulnerability: Data Sources and Data Analysis

Given that there is no validated index that combines heat risk and social vulnerability, an overall analysis of proxies would help understand which country would be at greater heat risk. The proxies taken here are meant to give a general perspective and context of potential heat vulnerability, but they are not combined in one index nor considered as vulnerability indices because of their limited validity and representativeness of them as vulnerability indicators.

The first index is the Global Climate Risk Index (GCRI) and the second index is the Human Development Index (HDI). The GCRI analyses quantified impacts of extreme weather events in terms of fatalities and economic losses by integrating extreme weather events and socioeconomic data . The 2021 GCRI report considered worldwide weather-related events (storms, floods, and mass movements, temperature extremes, including heat waves) collated by MunichRe's NatCatSERVICE (10). Complementary, the HDI is an index that combines the dimensions of health, education, and standard of living (11). This indicator is also a proxy to potential social vulnerability. However, it does not reflect on inequities or poverty; therefore, it should be used carefully for potential climate vulnerability.

1.2 Results

In the following sections, detailed results are described considering the literature review findings on heat risk in the region, key results from the UTCI analysis of heat stress per country, and the review of proxy indicators of vulnerability. An overall synthesis that compiles a regional perspective of risk as a function of exposure and vulnerability is presented.

1.2.1 Literature Review

A total of 49 articles were identified in Web of Science. After screening titles and abstracts, eight articles were included to be fully analyzed. Of these articles, **four covered CSA countries, two were from Brazil, one from Colombia, and one covered low- and middle-income countries**.

In terms of risk and its elements, it is possible to identify that most of the literature is related to the exposure to heat in countries from Central America and Brazil in South America. The literature highlights that these countries are highly exposed to heat risks due to the presence of the climate hazard (heat) and social vulnerabilities.

The vulnerability factors found in the literature are mainly described at the individual level. People over 65 years old (19–21), people with pre-existing co-morbidities (e.g., diabetes, hypertension) (20–22), women (21), people with low socioeconomic level or those living in poverty (19,21–24), people with limited access to healthcare (21), and outdoor workers (24) are the most vulnerable groups to heat stress. Vulnerability factors at the community or societal level were less commonly identified. Some identified factors include areas with less resources to adapt to heat waves (23) and densely populated areas in urban settings (25).

Amongst the most common health outcomes (morbidity and mortality) evaluated in the literature are temperature-related outcomes (e.g., heat stroke, heat exhaustion, heat cramps), cardiovascular and respiratory diseases, and renal failure (19–24).

1.2.2 Heat Stress: Spatial Analysis

The UTCI across all countries in CSA varies by geographical area[2], especially in areas with low or high altitude (Figures 1-4). **Heat stress can be particularly strong in the south of Central America and the north of South America from September to February. In austral summer (December, January, February), most of the countries are under moderate to strong heat stress, particularly Brazil, Colombia, El Salvador, Nicaragua, Paraguay, and Venezuela (Figure 1).**

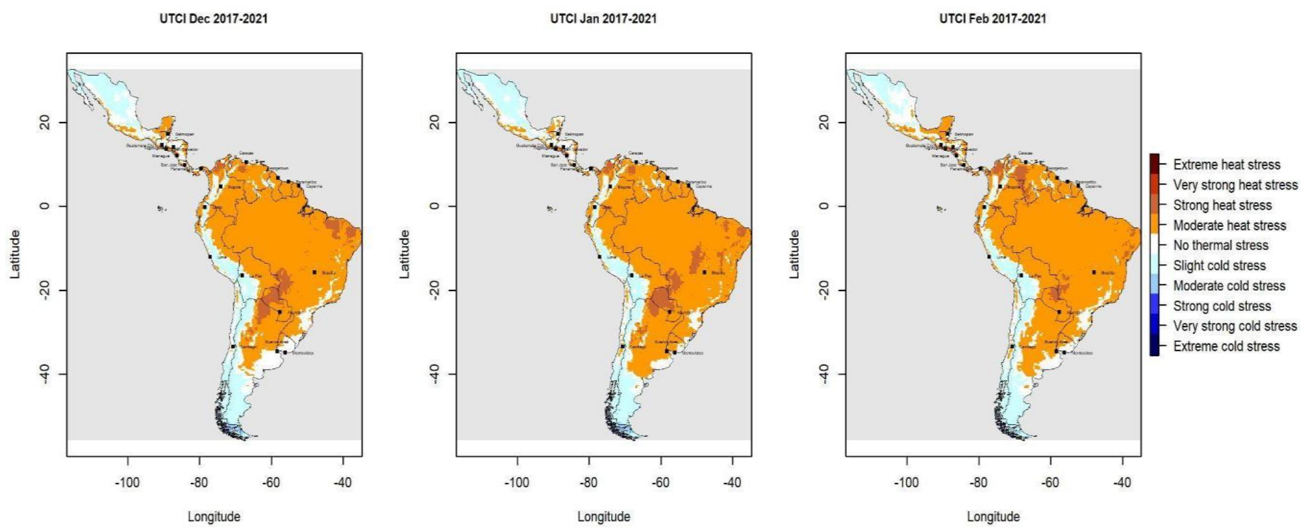

Figure 1. Heat and cold stress in austral summer (December, January, February) for CSA countries.

In austral autumn (March, April, May), moderate heat stress reduces its geographical extension, especially in southern South America (Argentina, Chile, and Uruguay), while increases its

[2] High resolution maps are: All figures can be downloaded from: https://drive.google.com/drive/folders/1DbLlBtTri0V8zNRaeky_aKOajvew-N59?usp=sharing

extension and magnitude in Central America (Figure 2), particularly in El Salvador, Guatemala, and Nicaragua (end of the dry season).

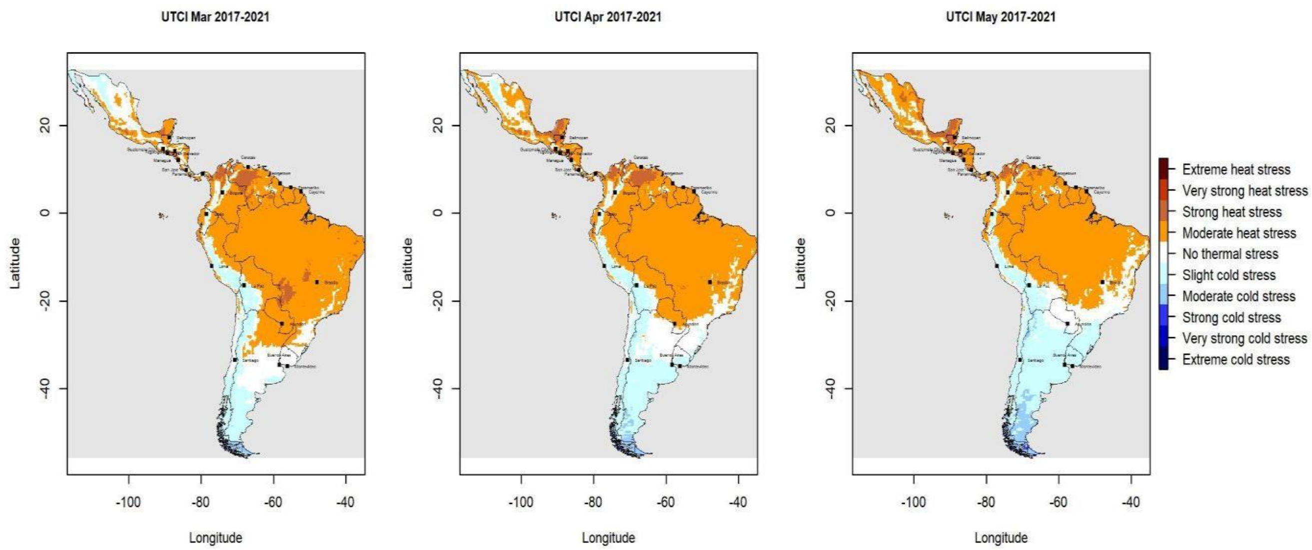

Figure 2. Heat and cold stress in austral autumn (March, April, May) for CSA countries.

From June to August, heat stress is present in most part of Brazil, the north of South America, and Central America (Figure 3).

.

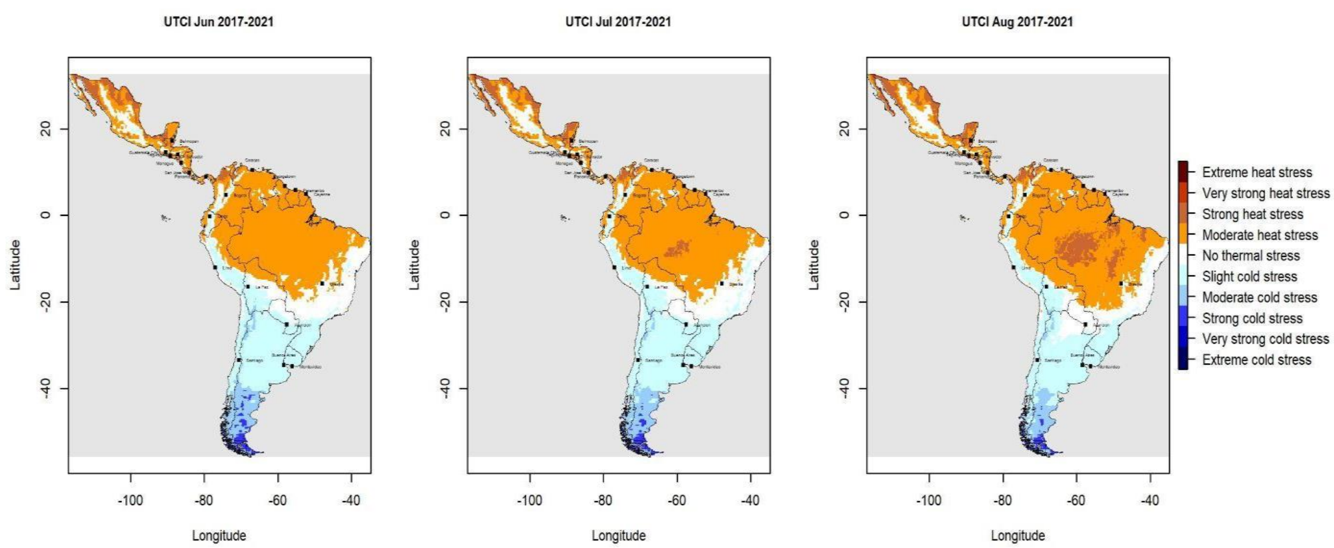

Figure 3. Heat and cold stress in austral winter (June, July, August) for CSA countries

Heat stress from September to November is particularly relevant for South America. The extension of strong heat stress is at its highest extension in Brazil, covering more than 50% of the the country. This situation overlaps with the forest fire season in September, adding risks to population health. In November, heat stress slightly decreases in Central America (Figure 4).

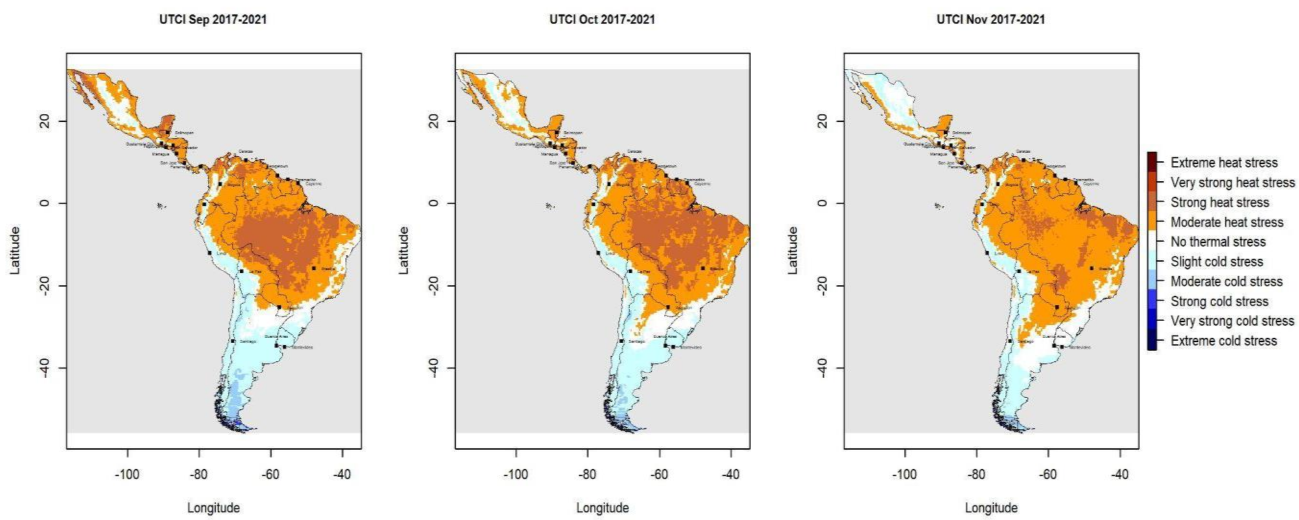

Figure 4. Heat and cold stress in austral spring (September, October, November) for CSA countries.

1.2.3 Heat Stress: Population Weighted Average Analysis (PWA)

Although heat stress could be high in particular geographical areas, it is important to evaluate areas where populations live, such as cities. Figures 5 to 24 (See Appendix 3) show the evolution of monthly thermal stress per country from 2017 to 2021. Population-weighted average of UTCI is shown (solid line) to identify how heat stress is affecting where the population lives.

In Figures 5 to 24 (See Appendix 3) is noticeable that most of the countries were exposed to high levels of heat stress throughout the calendar year from 2017 to 2021. Some countries, such as Chile, Peru, and Uruguay, show lines representing country averages of thermal stress (SA) and PWA thermal stress apart from one another, while Belize shows very similar lines. In Belize, thermal stress is equally distributed across the entire territory, including areas where populations tend to live.

Countries with strong and very strong heat stress exposure over the entire period under study (See Appendix 3) are Belize (Figure 6), Brazil (Figure 8), Guyana (Figure 15),

Honduras (Figure 16), Nicaragua (Figure 17), Paraguay (Figure 19), Suriname (Figure 21), and Venezuela (Figure 23). People in these countries are exposed to heat stress over the entire year. On the other hand, people in Chile (Figure 9), Peru (Figure 20), and Uruguay (Figure 22) are only exposed to heat stress in the summer months.

1.2.4 Vulnerability

Considering GCRI and HDI as proxy parameters to descriptively contextualize heat vulnerability, Table 2 shows the values for GCRI 2000-2019 and HDI 2019 for CSA countries. Both indicators are complementary (see Section 1.1.3) and provide a better understanding on which countries have social vulnerabilities that could be worsen due to climate change. Countries such as Guatemala, Bolivia, El Salvador and Belize are considered to be the most affected by extreme weather events (including heat waves) as they have the lowest GCRI values of CSA, which corresponds to a moderate ranking (range from 21 to 50). Moreover, countries with an HDI between 0.550-0.699 such as Honduras, Nicaragua, Guatemala, El Salvador and Guyana are ranked as having a medium level of HDI. Therefore, **Guatemala and El Salvador appear to have both, the highest climate risk and the lowest Human Development Index score in the region, which could result in higher vulnerability to heat.**

Country	GCRI 2000-2019 (*)	Country	HDI 2019 (**)
Guatemala	37.50	Honduras	0.634
Bolivia	40.17	Nicaragua	0.660
El Salvador	43.67	Guatemala	0.663
Belize	48.67	El Salvador	0.673
Nicaragua	53	Guyana	0.682
Colombia	54.83	Venezuela	0.711
Honduras	57	Belize	0.716
Peru	57.67	Bolivia	0.718
Paraguay	67	Paraguay	0.728
Argentina	77	Suriname	0.738
Brazil	79.5	Ecuador	0.759

Chile	81.33	Brazil	0.765
Costa Rica	84.50	Colombia	0.767
Uruguay	89.83	Peru	0.777
Ecuador	94.17	Costa Rica	0.810
Panama	107	Panama	0.815
Guyana	108.17	Uruguay	0.817
Venezuela	132.5	Argentina	0.845
Suriname	164	Chile	0.851

Table 2. GCRI and HDI for CSA countries under study.

(*) GCRI ranges from 1 to 180, with 1 being the most affected countries and 180 the least affected; the ranks are distributed in the following ranges: 1-10, 11-20, 21-50, 51-100, >100.
(**) HDI ranges from 0 to 1, with 1 representing the highest possible human development, the categories are distributed in the following: Low (< 0.550), Medium (0.550-0.699), High (0.700-0.799), Very high (= 0.800).

1.2.5 Overall Synthesis

Most of the countries in Central America are exposed to heat stress year-round, having critical periods of strong heat stress from March to October. This situation could be worsened in densely populated areas including parts of the Pacific coast of Guatemala, El Salvador, and Nicaragua. At the same time, added risk factors are related to climate and social vulnerability. Guatemala, and El Salvador appear to have the greater climate risk and the lowest Human Development Index score in the region, which could result in higher vulnerability to heat.

In the north of South America, heat stress is also experienced year-round in areas with low elevation. Coastal areas of Colombia, Ecuador, Guyana, Suriname, and Venezuela are exposed to moderate/strong heat stress, which are also the most densely populated. In Colombia, areas in Cordoba, Sucre, Bolivar, Atlántico, and Magdalena are usually exposed to strong heat stress. Although, Venezuela might have low climatic risk and social vulnerability, internal inequities and high levels of poverty could lead to higher vulnerability to heat impacts. Venezuelan states with high levels of heat stress are Aragua, Barinas, Carabobo, Cojedes, Guarico, Lara, Merida, Portuguesa, Trujillo, and Zulia.

The south of South America and the Amazon Basin are constantly exposed to moderate-strong heat stress across the entire year. The area with moderate-strong heat stress expands during spring and summer, reaching all countries in the region. High altitude areas in Bolivia, Chile, and Peru generally are under no thermal heat stress or even slight cold stress year-round. In the Patagonia region of Argentina and Chile, thermal stress is related to cold rather than heat.

In Bolivia, there is a marked difference in thermal stress due to elevation. The most densely populated areas of Cochabamba, La Paz, and Tarija are partially exposed to heat stress during summer months.

Although Brazil appears to have overall low climate risk and social vulnerability, some specific areas would be at high risk of heat because of internal social inequities and high exposure to heat stress. Areas with strong heat stress are concentrated in Mato Grosso do Sul, Ceara, Rio Grande do Norte, Paraiba, Pernambuco, and Goias. However, in some seasons (summer and spring), high levels of heat stress are countrywide.

Paraguay is a country with relative lower climate risk and social vulnerability; however, it is highly exposed to high levels of heat stress, especially during the austral summer (December to February). In particular, areas of Alto Paraguay, Boquerón, Presidente Hayes, Amabay, Concepción, and San Pedro are exposed to very high levels of heat stress. Additionally, people in Paraguay are exposed to a high thermal variability across the year, which means that in summer they are exposed to strong heat stress and in winter to slight cold stress. This variability might imply a need of wide range of social preparedness to climatic factors.

Other countries, such as Argentina, Chile, and Uruguay are affected by heat stress, especially during summer and spring; however, they seem to be less vulnerable to heat and therefore have less heat risk. This situation does not mean that sub-populations in these countries are risk-free.

1.3 Limitations

UTCI is an index with a broad geographic coverage that describes the human body response to atmospheric conditions, nevertheless, it does not cover acclimatization. Additionally, one of the main limitations of this section is the evaluation of vulnerability at different levels. As it was mentioned before, there is no standardized vulnerability indicator that could be integrated to evaluate heat risk. The GCRI and HDI were taken as proxies to contextualize heat vulnerability; however, they do not directly measure vulnerability to heat risk. Several areas of individual and social vulnerability could be considered to obtain a general perspective of heat risk; however, the integration of all these factors should consider public health priorities at local level.

1.4 Conclusions

Overall, heat risk changes country by country. Although some countries have year-round exposure to heat stress, vulnerabilities can alter heat risk. Guatemala, El Salvador, and Nicaragua in Central America have the highest risk to heat. In South America, countries with the highest heat risk cover Bolivia, Colombia, Ecuador, Guyana, Paraguay, Suriname, and Venezuela. It is worth noting that there is an important gap when analyzing the published literature and the heat risk present in the region. There is a lack of information regarding heat risk for the most vulnerable countries, which might affect their preparedness and response capacity to heat.

2 Understand the known impacts of extreme heat across countries

2.1 Methodology

To achieve this objective, two main steps were followed. First, a literature review of scientific and gray literature (reports), was carried out. Second, key informant interviews were performed to complement the evidence collected in the literature review.

2.1.1 Literature Review

The literature review was guided by the following research question: *“What are the known impacts of heat waves in Central and South America?” “What are they known impacts in Colombia, Honduras and Guatemala?” “What are the known impacts in the high-risk countries identified in section 1?”*

The search strategy was performed based on the following impact categories (See Appendix 4): Health, Agriculture, Economy, Infrastructure, Tourisms, Migration, Nature. The search was performed considering Latin America South America Central America and high-risk countries (Guatemala Colombia Honduras El Salvador Nicaragua Bolivia Ecuador Guyana Paraguay Suriname and Venezuela)

The search was performed on Google Scholar, PubMed, Jstor and EBSCO between 23 May 2022 and 25 May 2022. The references were manually filtered, and the studies were screened by title and abstract first. Then full texts were analyzed and selected. Screening and selection was based on the following eligibility criteria: (i) the article was included if information on CSA countries was presented; ii) the article analyzed any impact of heat waves, heat stress, or temperature measure. Broad categories of impacts included health, agriculture, economy, education, behavior, migration, infrastructure, and tourism. Appendix 4 shows a summary of the articles included in the review.

The information was extracted using a form and then synthesized by country and topic. Specifically, the information extracted covered: what are the known impacts (e.g., health, labor market outcomes, human capital accumulation, agriculture, etc.) of extreme heat in CSA?

Papers that related any temperature measurement to the outcomes of interest were included, along with the literature that did not exclusively use the definition or term of heat waves. That is, analysis of estimated impacts from excessively hot days, temperature deviations from the mean, temperature averages, temperature maximums, among any other temperature measures. This strategy was followed to amplify the scope of results.

2.1.2 Key Informant Interviews

To assess the knowledge of the impacts of extreme heat or heat waves in the region, a total of seven key informant interviews were conducted from governmental and non-governmental institutions representing the health, environment, academic, youth, and government sectors from different countries[3]. The interviews were held in Spanish and conducted using the platform Zoom Meetings.

The sessions were recorded, transcribed, and selected quotes were translated into English. Verbal consent to participate and record the video conference was received by all the informants. The interviews were analyzed using qualitative methods, specifically through thematic analysis with an inductive approach on the codification process (See Appendix 6). The software MaxQDA was used to do the qualitative analysis.

In terms of the questions (see Appendix 7), participants were asked about their experience with heat waves and the impacts that they had identified in the field. They were asked questions about health impacts, demands for health services, and economic impacts, including agriculture and labor productivity, migration, human behavior, among others.

2.2 Results

The search strategy yielded 85 documents prioritized by title name. After that, the abstracts were reviewed and 11 were discarded because of their geographical location (outside of CSA),

[3] A list of all the key informants interviewed for this report is available in Appendix 5.

methodology, or relevance. Of the remaining 74, nearly 60% (44 papers) are related to health impacts, nine cover different health-related topics, 27 are specifically related to kidney problems and seven on mortality; three address impacts on agriculture; five within cities and/or infrastructure; five focus on economic outcomes, from which four are specifically related to the labor market; two on migration; seven on specific weather and/or climate analysis; three on nature affairs; one focuses on cooling technology access; and the remaining four are related to other topics.

Geographically, the 85 documents were mostly focused on Latin America (16) and global (13) studies that considered LAC countries. Central (7) and Mesoamerica (4) are more studied than South America (4). Regarding studies for specific countries, Nicaragua (6) is the most studied one, followed by Colombia and Guatemala (5 each), Costa Rica, Brazil and El Salvador (4 each), Argentina and Chile (2 each), and finally Jamaica, Ecuador, Paraguay, and Low- and middle-income countries that consider LAC countries (1 each). The remaining 4 were discarded because they used data from Mexico.

Rising temperatures and extreme heat are expected to affect an array of outcomes, including human health -both physical and mental, decision-making, educational attainment and the ability to learn, agricultural output, labor productivity, economic growth, migration, political stability, human behavior (irritability, violence, intimate partner violence, accidentality, or conflict (26). They are also expected to affect populations differentially by a wide range of characteristics including age, location (urban/rural), income, social vulnerability, social isolation, disability, among others. All of these could translate into increased pressure on health infrastructure, not only because of higher demand for health services from sick patients but also on the ability of equipment to work at high heat.

But most of these impacts have been identified in countries located in higher income countries or in places outside CSA. CSA region differs from others not only in terms of socioeconomic and demographic characteristics, but also in environmental conditions and threats given their closeness to the Equator. These differences in characteristics could trigger differential responses, either stronger or milder in certain aspects, but they have not been extensively studied in CSA.

Evidence on the heat impacts in CSA is limited to a handful of case studies geographically concentrated and centered around health outcomes. Within health outcomes, it has been well documented the relationship between heat stress and Chronic Kidney Disease (CKD) / Chronic Kidney Disease of unknown etiology (CKDu) in Central American agricultural workers.

The remaining literature suggests significant impacts in mortality, increased incidence of infectious and vector-borne diseases, other morbidity outcomes and demands for health care after the occurrence of hot temperature shocks. Beyond health, heat waves appear to affect labor productivity, human capital accumulation and future income; increase losses in the agricultural sector, accidents, and homicides; as well as triggering migration flows.

The following sections describe in detail the known heat impacts in CSA, considering that heat waves are not deemed the main extreme weather-related disaster in the region (27). Health impacts are described first, followed by economic outcomes. The literature review has been complemented with interviews from key informants in the region.

2.2.1 Literature review

Health impacts

Health impacts related to extreme heat have received much of the attention in CSA, especially those related to mortality risk. Increased mortality and morbidity due to respiratory illness, infectious diseases, cardiovascular diseases, heat strokes, dehydration and kidney failure, have been identified as the main mechanisms through which heat stress affects human health in the region. The elderly and agricultural workers have been identified in the available literature for CSA as highly vulnerable to extreme temperature events. More recent evidence suggests that children aged zero to nine years, impacted by the incidence of vector-borne diseases, could be at high-risk.

- Mortality

Mortality at high temperatures has been mostly analyzed or studied in urban cities in South America, located in Brazil, Colombia, Chile, and Peru (21). Higher than average temperatures have been associated with mortality risk in São Paulo and Santiago de Chile (19) , as well as other population centers with over 100,000 inhabitants (28). **Mortality increases has been documented in cities where temperature regularly exceeds 25°C (e.g. Buenos Aires, Mérida, Rio de Janeiro)** (28). Deaths due to respiratory infections and circulatory diseases were correlated to excessive heat (28–30). In these places, the elderly, 65 years or older, and lower income/less educated people with limited means to adapt and protect themselves have been identified as vulnerable populations (19). Within the city, higher mortality rates were also observed in areas with high population density; and with more inequalities (Gini index), pollution levels and fewer green spaces (31).

Heat waves in Argentina during the summer of 2013-2014 were also linked to increased mortality, as well as the risk of dying. As in other settings, mortality risk increased with age with no discernible effects by gender. When analyzing general mortality during that heat wave period in Argentina, respiratory and cardiovascular diseases were reported as the primary causes of death (29).

In **Colombia**, Helo (2022) finds that mortality risk is highest at the endpoints of the temperature distribution (32). An additional day with mean temperature above 27°C increases mortality rates by approximately 0.24 deaths per 100,000, equivalent to 0.7% of monthly death rates. Deaths attributed to infectious diseases (vector-borne diseases) and respiratory illnesses drive this relationship in the hot part of the temperature distribution, mainly affecting children aged zero to nine years, primarily in urban settings.

The relationship between mortality, heat, and climate change has also been explored. Vicedo-Cabrera et al. (2021) found that heat-related mortality per 100,000 people attributed to human-induced climate change between 1991 and 2018 is high with three excess deaths in Paraguay, and between two and three in Brazil, Ecuador, and Peru (33). Global estimations under different climate change scenarios also point to increases in heat-related mortality throughout CSA (34). Under any scenario, South America is particularly vulnerable, especially the Amazon biome and its surroundings (35).

- Morbidity

Morbidity outcomes have been less studied, except for the incidence of CKDu in Central American agricultural workers. Two recent papers document increases in demand for health services after the occurrence of hot temperature shocks, but not specifically on the effect of heat waves. Zhao et al. (2019) found that an increase in 5°C in daily temperature over the period 2000-2015 led to an increase in the risk of hospitalizations in Brazil, affecting the elderly and children, primarily (36).

Helo (2021) documents the relationship between temperature and health services usage in **Colombia** and shows that hospitalization rates increase with temperature (37). Increased hospitalizations due to infectious/vector-borne diseases, pregnancy-related/maternal care, respiratory, circulatory, as well as external factors (accidents and homicides) drive this result. Increase in hospitalizations related to infectious/vector-borne diseases is consistent with evidence showing that the spread of malaria and dengue increases with temperature. These vectors are also migrating to higher elevations in Colombia as they become warmer (38), threatening human health under any scenario of climate change.

Chronic Kidney Disease of unknown etiology (CKDu) or Mesoamerican nephropathy (MeN)

Unlike the mortality literature in South America, which focuses on effects of heat in urban populations, heat waves can be detrimental in countries like Guatemala, El Salvador, Belize, Honduras, and Nicaragua given that rural populations account for more than 45% of the total population (39). **Several papers focus on the incidence of CKD and CKDu, especially in agricultural workers in Mesoamerica (40–42).** Mortality and morbidity due to this disease has been associated with repeated heat stress in sugarcane cultivators, with a stronger association in men than in women (24,43). Research has focused on the sugarcane industry because other agricultural or industrial settings are not as physically demanding (44). However, expected rising temperatures in the future could indicate that other occupations and agricultural sectors may be at risk (45,46). In fact, in 2013, the Pan American Health Organization (PAHO) recognized CKDu as a public health problem in Central America.

In **Guatemala**, sugarcane workers increase their creatinine during work shifts when exposed to heat, which could damage the kidneys. Regular shared rest breaks and hydration were found to be protective (47). Beyond the health dimension, heat effects extend to economic impacts. Sugarcane cutters reduce their working hours, and even quit. Heat exposure is related to lower productivity at the start and the end of production periods because of a reduction in daily tons produced or premature workforce attrition. People with previously impaired kidneys are more likely to leave their job before the end of the harvest season (48). This shows an *"inherent conflict between preserving health and maintaining productivity that workers and employers must address."* (48) Lower agricultural productivity can threaten food security and stable income (48)

In **Nicaragua** sugarcane workers are at moderate or high risk of heat-related illness based on OSHA's heat index-based risk guidelines during a great part of their workdays (49,50). Heterogeneous effects within the sugarcane industry were documented, with cane cutters being more vulnerable because shade is less available at their workplace. In addition, these workers are less educated and have lower income (40,50). Intake of electrolytes and hydration during the workday might protect workers against kidney injury (51).

In **Costa Rica**, the sugarcane industry is characterized by temporary, migrant, and older workers that could have underlying health conditions. Workers are exposed to different levels of heat stress depending on the job (52–54). It is the only country that has a regulation to protect workers that could be working under thermal heat stress, tailored to their specific needs. Crowe et al. (2010) suggests that protection strategies against heat should consider the characteristics of the industry, incentives, and culture (53). On the one hand, if workers are paid based on the amount of sugarcane cut, they have little incentive to take rest periods or drink water (54). Migrant workers often don't seek medical care due to lack of proper identification and documentation (52). One suggestion is to provide water dispensers or break periods in air-conditioned rooms. However, in Costa Rica there is a belief that exposure to dissimilar temperatures could make you sick. Some workers believe the drinking water available at work is contaminated, probably linked to the high incidence of kidney disease in sugarcane workers (52).

Birth Outcomes

Heat exposure has been associated with adverse birth outcomes. Andalón et al. (2016) found that in **Colombia in-utero exposure to extreme heat during the third trimester reduces birth weight and has a negative effect on the Apgar score**, which is a measure that summarizes the newborn's health based on Appearance (skin color), Pulse (heart rate), Grimace (reflexes), Activity (muscle tone), and Respiration (breathing rate and effort) (55). Helo (2021) also found for Colombia, increases in hospitalization rates for pregnant women after a hot temperature shock due to fetus distress (37). Molina and Saldarriaga (2017) document the effects of exposure to temperature variability in Colombia, **Bolivia** and **Peru** (56). Deviations from historical temperature mean reduces birth weight by 20 grams and increase the probability that a child is born with low birth weight (below 2,500 grams). They provide suggestive evidence that food insecurity during pregnancy might explain these results.

- Cities and infrastructure

The phenomenon of heat islands in Latin America, due to the historical inequalities of the cities in the region, recognizes that urban areas are particularly affected by heat waves and heat effects are exacerbated. In Paraguay, for instance, climate change projections are expected to increase overheating rates on buildings, which refers to the heat discomfort of the people living in them, due to higher temperatures (57).

Rising temperatures or temperature shocks increases demand for electricity and the use of cooling technologies. Limited access to such technologies can lead to greater heat exposure and worse health outcomes (58). In Buenos Aires, homeless and people without access to refrigeration/air conditioning are vulnerable, which could deepen existing inequities in Latin American cities (59).

Access to cooling technology, mainly fans and more limited air conditioning, among people has increased in the region, especially in Brazil and Bolivia, and among urban populations (60). Other adaptation measures, such as urban green spaces, have also been considered. The importance of nature in urban infrastructure is key because it creates microclimates that reduce temperature (31). For instance, Medellin has a large cooling effect because of the high proportion of green areas in the city (61).

Economic Impacts

Beyond health, extreme heat impacts have been more elusive and less studied in CSA. However, some papers studied productivity, labor market, migration, or education, which can shed light on the economic impacts across the region.

- Economic Sector and Labor Markets

In terms of productive sectors, the small amount of evidence suggests that the agriculture-silviculture and fishing sectors are negatively impacted by extreme heat (62). The International Labor Organization (ILO) already identified heat exposure as an occupational threat in rice and sugarcane production in Central America (63). Though some specific sub-sectors may benefit from increasing temperatures, extreme heat seems to be problematic in CSA and it will lead to the highest production losses when compared worldwide (64). Casali et al. (2022) found that in South America, specifically in Chaco, Paraguay, maize is highly impacted by heat stress (65). For livestock, Rocha et al. (2019) found that in Colombia cattle with lower adaptability to heat stress have higher presence of tick burden; this relationship is affected by the conditions of the region's environment (66).

Kjellstrom et al. (2009) simulate that labor productivity, across sectors and countries in Latin America and the Caribbean, will be reduced due to increase in temperature by 2080 (67)[4]. The ILO (2019) estimates that by 2030, 0.6% of total working hours will be lost due to heat stress driven by the agricultural and construction sectors in the region (68). This is equivalent to 2.9 million full-time jobs. Specifically, Central America is expected to lose 0.91% of total working hours by 2030 due to heat stress (equivalent to 800,000 full-time jobs), and South America 0.76% of total working hours (equivalent to 1.6 million full-time jobs). Gross Domestic Product (GDP) is expected to fall 0.4% by 2030 on average for ten countries in the Americas.

- Migration

Extreme heat can trigger international migration, domestic displacement, or changes in occupational choices. For the region, two papers were identified. First, Ibañez et al. (2022) find that extreme temperature or temperature shocks in El Salvador reduces agricultural productivity and output (69). This in turn reduces demand for agricultural workers, leading to migration of the workforce and reallocating to other economic sectors. Second, Baez et al. (2017) show that **the increase in heat exposure more than doubles the probability of young unskilled women to migrate to the provincial capital city in Central America and the Caribbean**, because fluctuations in temperature affect industries dominated by women (e.g. seamstresses), leading to loss of income (70).

[4] Depending on the climate change scenario, the percentage of days lost in 2080 goes from 6.7% to 13.2% in the Andean region of Latin America; from 31.5% to 42.4% in the Central region of Latin America; from 0.2% to 0.3% in the South region of Latin America; and from 6% to 8.9% in the Tropical region of Latin America.

- Education

Beyond occupational choices and labor market outcomes, educational performance and human capital accumulation have been shown to react to extreme heat. The evidence in CSA is limited to one study. Fishman et al. (2019) found that in Ecuador, higher temperatures in-utero leads to lower educational attainment and adult earnings (71). An increase of 1°C in average monthly temperature while in-utero translates into a 0.7% decline in adult earnings, with larger effects on women.

2.2.2 Key Informant Interviews

The process of interviews entailed an in-depth discussion with key actors from CSA with both local and regional approaches. The participants provided insights from their experience with known impacts from heat as key actors in the region. The results were categorized according to the different topics where impacts were described. The categories were identified using an inductive approach, which resulted in the following sub-categories (i) health, (ii) labor and (iii) agriculture (See Appendix 6).

Participants identified the health impacts of heat waves and extreme heat, though primarily affected populations differ across settings. In Argentina, for example, where more than 90% of the population is urbanized, urban centers are more vulnerable to heat waves and effects are exacerbated by the heat island effects. The elderly and populations with underlying health conditions are primarily affected.

> *"In a study for Buenos Aires[5]... we quantify excess mortality as 1,877 deaths, out of these only 12 were coded as a consequence of excessive heat. …The elderly is the most affected group, as well as people with chronic diseases. A challenge we face in Argentina is the demographic and epidemiological transition, where the population is expected to live longer, and the amount of vulnerable population will increase…"*
>
> *(Representative from the Ministry of Health of Argentina)*

[5] This study was published and can be seen listed in the references of this report. Reference (29)

In contrast, agricultural workers have been identified as vulnerable in Honduras given their long exposure to high temperatures, sun, and radiation. In many places in Central America, participants are aware of the relationship between heat exposure and CKDu.

"…for agricultural workers, it is common to observe chronic dehydration which translates into health problems such as high blood pressure, kidney failure, and urinary tract infections…. The elderly is also vulnerable to temperature change."
(Representative from The International Federation of Medical Students Associations - Honduras)

Key informants also agreed that health impacts could be exacerbated by the incidence and proliferation of vector-borne and infectious diseases, especially in tropical and subtropical latitudes. Impacts on vectors and disease can be slower to materialize and therefore are not often recorded immediately after the occurrence of the hot temperature shocks, but it would rather take a while to fully translate.

"… on infectious diseases, we are always exposed to dengue, and seasonality is well defined, however, we see that dengue proliferation is related to increases in temperature."
(Representative from The International Federation of Medical Students Associations - Honduras)

"I remember that the chikungunya epidemic coincided with ENSO-El Niño event and with increases in temperature. The Ministry of Health does follow this through epidemiological surveillance and control"
(Representative team from National Unit for Disaster Risk Management - Colombia)

However, some participants also mentioned that heat impacts specific to their setting or country had not been studied in-depth. Most of the knowledge they had was taken from international literature.

"… we have all these global studies that identify impacts, right? So, among the ones that have been known and that we observe in the field, for example, we identify all of the impacts in the health dimension, either because of thermal shock or vector proliferation"
(Representative from the Ministry of Environment and Sustainable Development of Paraguay)

Beyond the health effects previously described, participants identified that heat transcends into the labor productivity of workers.

"The Ministry of Development is worried about absence from work and its relation to climate change. How vector-borne diseases and extreme temperatures can affect absence from work, which in turn translates to economic losses."

(Representative from the Ministry of Health of Argentina)

They also mentioned that firms, specifically those in the agricultural sector, are aware of the health problems of workers after the exposure to extreme heat, and therefore, have designed strategies to cope with lower productivity.

"Some firms modify working conditions, especially when workers perform duties outside… during hotter months and weeks, they adjust working hours or take breaks more frequently. In Mexico, for example, starting hours are modified and shifts stop at midday when temperatures are highest. They resume work after 3:00 or 4:00 p.m. when it's cooler… Costa Rica is the only country in Central America that has regulations for work and exposure to extreme heat, However, there is no enforcement mechanism."

(Representative from La Isla Network and from The Costa Rica Institute of Technology)

In Paraguay, key informants mentioned that forest fires are more likely after the occurrence of high temperatures and droughts. These, in turn, could significantly impact agricultural production and trigger livestock losses. Moreover, particulate matter released from fires affects health outcomes of populations not only in nearby rural areas but also in urban cities.

"...the agricultural sector experienced significant losses triggered by these fires, especially in El Chaco, Paraguay. This is a livestock region, many animals perished, and pastures were lost. This has important economic effects."

(Representative from Health Emergencies WHO/PAHO)

In **Guatemala**, the key informant suggested that excessively high temperatures can affect not only labor productivity of workers, but agricultural yields that threaten food security and income. However, there is no formal evidence that identifies this relationship, and more research is needed.

"Crops are highly affected by heat waves, as well as hydrometeorological events … Effects are mostly related to productivity losses rather than health. Many people depend on their crops, either because they obtain food from them or because they sell them.
So, this is where we are seeing effects in terms of food security"
(Representative from The National Coordination for Disaster Reduction from Guatemala)

Besides health and labor effects previously described, participants were not aware of further impacts of extreme heat. Most participants agreed that it is difficult to separate the effects of heat waves from those associated with droughts or other extreme weather events, which in many cases trigger similar responses in the health and economic dimensions. In fact, some participants mentioned an association between ENSO-El Niño events and the occurrence of extremely hot days, though no evidence on this link and associated impacts were found in this literature review.

"...the Unit does not consider heat waves as a riskful event… however, we are prepared and there is an action plan for El Niño events, for example. During these events, there are guidelines to provide water to affected areas, monitor forest fires and impacts, and everything related to dry conditions."
(Representative team from National Unit for Disaster Risk Management - Colombia)

In contrast to heat waves, many countries in the region are well prepared and aware of climatic risks such as ENSO-El Niño, droughts, excessive rainfall, or storms, all of which are considered more prevalent in the region.

"...in Central America we are more used to damages associated with precipitation and rainfall. This is what we are prepared for, and systems are built for this. Everything is related to landslides, infrastructure, vectors, hurricanes, etc. We know a lot in these areas."
(Representative from La Isla Network and from The Costa Rica Institute of Technology)

2.3 Limitations

The research outlined in this section focuses on the effect of extreme temperatures generally, rather than in the impacts of heat waves. Only a handful of papers in Latin America study heat waves as defined by the number of days with temperature above the 90th percentile. There is no unique definition or metric for heat waves in the literature (59,72), even less in the region where in many countries heat waves are not even defined (See Appendix 9).

It is challenging to separate the effects of extreme temperatures and droughts, given the correlation that exists in the region between these events. Typically, high temperatures are observed simultaneously with periods of droughts or ENSO - El Niño/La Niña climate events. In fact, most of the countries in Latin America do not consider or define heat waves as a main hazard (27). In 2020, temperature increase was ranked third place in hazard types of CSA and the Caribbean, considering that in the last 20 years floods, storms, and droughts accounted for 93% of disasters (73)**.** Much of the knowledge in the region is thus focused on the impacts of droughts, or excessive rainfall.

Much of the literature in CSA focuses on urban centers and metropolitan areas, except for the research of CKDu in agricultural workers. Though heat effects can be exacerbated in urban areas by the heat island effect, it is important to consider health effects beyond urban populations especially in Central America, where in many countries rural populations account for more than 45% of the population (39).

2.4 Conclusions

Evidence on the impacts of extreme heat and heat waves in CSA is limited to a handful of studies, mainly on health outcomes. In Central America, agricultural workers are at risk as an association between heat stress and CKDu has been well documented. In South America, health impacts on urban areas are expected given the population distribution and the heat island effect which exacerbate effects on large metropolitan areas.

Impacts on health care demands, the proliferation of vectors and infectious diseases, agricultural productivity, labor outcomes, and income occupational choices, migration decisions, human capital accumulation, conflict, or political stability have not been extensively documented. However, the small amount of evidence available seems to suggest that heat and increasing temperatures could affect all these outcomes that impact human well-being in CSA.

3 Existing early warning systems for extreme heat in Central and South America

3.1 Methodology

To achieve this objective, two main steps were followed. First, a gray literature review was conducted focusing on (i) the National Adaptation Plans (NAP) and other key documents, and on (ii) information available at the meteorological websites of governments from selected countries (See Appendix 1). Second, key informant interviews were conducted with different actors to complement the literature review.

3.1.1 Gray Literature Review

In the review of gray literature, the analyzed documents included Climate Change Action Plans, National Adaptation Plans and/or, in some cases, sector-specific adaptation plans from CSA countries (See Appendix 8). A “traffic light” technique was used for each country to determine the level progress on early warning systems (EWS). The color selection was based on three key indicators: (i) if the NAP includes information on EWS, (ii) if the existing EWS is for heat waves, and (iii) if the heat EWS has the health sector as a key actor.

On the national meteorological websites, the following data was extracted when available: (i) whether the country had a heat EWS, (ii) the methodology used for the heat EWS , (iii) the spatial coverage and resolution (country, region, city, etc.), (iv) the year of implementation of the heat EWS, (v) the number of stations the heat EWS has, (vi) the frequency of updates, (vii) the trigger indicators (minimum, maximum, average temperature), (viii) the entity that organizes the heat EWS and (ix) the entity that monitors and alerts.

3.1.2 Key Informant Interviews

To complement the understanding on the coverage of heat EWS, a total of four key informant interviews were conducted from governmental and non-governmental institutions representing the health, environment, and government sector from different countries. The interviews were held in Spanish and conducted using the platform Zoom Meetings.

The sessions were recorded, transcribed, and selected quotes were translated into English. Verbal consent to participate and record the video conference was received by all the informants. The interviews were analyzed using qualitative methods, specifically through thematic analysis with an inductive approach on the codification process (See Appendix 6). The software MaxQDA was used to do the qualitative analysis.

In terms of the questions (See Appendix 7), participants were asked about their knowledge on existing heat EWS, the way the heat EWS operates, how the population is alerted and the level of articulation between government entities.

3.2 Results

The following sections describe detailed results, considering the gray literature search on NAPs, other key documents and national meteorological websites, along with the findings from the key informant interviews.

3.2.1 Gray Literature Review

It was found that 13 out of 19 countries from CSA had a publicly available NAP. Countries such as Ecuador, Guyana, and Panama do not have complete NAP. For Bolivia and Venezuela no NAP was found. Out of the 14 countries that have a NAP (Argentina, Belize, Brazil, Colombia, Costa Rica, Chile, El Salvador, Guatemala, Honduras, Nicaragua, Paraguay, Peru, Suriname and Uruguay) (74–87), twelve have included EWS in the document (See results in Appendix 8). However, the information provided in the NAP is not detailed and, in many cases, is considered limited. The results show that countries such as Argentina, Chile, and Uruguay are in the color-code category of “green”. These are countries that already have an operational EWS, which includes heat waves and extreme temperatures, as well as the health sector as a key actor.

Brazil is a country that already has an operational EWS for extreme temperatures but does not include the health sector as a key player, therefore has been color-coded with “light green”. In “yellow”, Peru, Paraguay, and Guatemala, are countries that are considering the development of EWS for extreme temperatures in the future, in which the health sector will be a key player. Colombia, Suriname, Belize, Nicaragua, and Costa Rica have been color-coded in the category of "orange", as they contemplate the development of EWS for extreme temperatures in the future but do not provide information on having the health sector as a key actor. And finally, the countries within the "red" category are **El Salvador and Honduras, as are the only countries with a NAP for climate change, which does not consider EWS of any kind.**

Based on the information extracted from the national meteorological websites, it is found that heat EWS are rarely developed in the CSA regions, despite that all the meteorological institutes of CSA are reporting temperature anomalies. **No humidity or heat index is considered in the three countries that show the trigger indicator to send early warnings; only maximum and minimum temperatures are considered.** In addition, only eight out of 19 countries have a definition of heat wave, yet the used definitions are often unspecific (See Appendix 9). The search in the meteorological websites also shows coherent results with the NAP analysis. **Only four (21.1%) of 19 countries had implemented EWS for temperatures.** For a better understanding, a summary table (See Table 3) has been prepared with basic information on each of the existing heat EWS. Details on the operation of the heat EWS are described below.

Country	Level	Starting year	N° of monitoring stations	Frequency of updates	Trigger Indicator	Coordination entity	Monitoring entity	Reference
Argentina	Regional	2017	71	Daily	Maximum temperature, minimum temperature	National Meteorological Service of Argentina, Ministry of Defense	Argentine National Meteorological Service	(75)
Brazil	Not detailed	2017	Not detailed	Not detailed	Not detailed	Brazilian National Institute of Meteorology	Brazilian National Institute of Meteorology	(86)
Chile	Regional	2020	34	Daily	Maximum temperature, minimum temperature	University of Santiago	Meteorological Directorate of Chile and National Emergency Office, Department of	(80)

							Health Statistics and Information.	
Uruguay	City	2020	Not detailed	Not detailed	Maximum temperature, minimum temperature	Uruguayan Institute of Meteorology	Uruguayan Institute of Meteorology	(83)

Table 3. Description of EWS in CSA

- Argentina

The heat EWS was put into operation in 2017. It was created as a collaboration between the Ministry of Health and the Meteorological Center based on an epidemiological study on the impact of extreme temperatures on mortality among elderly in Buenos Aires. The heat EWS works with 71 weather stations distributed throughout the country's cities, where the necessary conditions to activate the alerts are calculated. Temperature is a continuous variable; therefore, extreme temperatures are spatially homogeneous in Argentina. This makes it possible to extrapolate the weather station alert to the region considered in each case. The heat EWS issues a daily alert at 19:00 hours; this alert is valid for 24 hours.

To define the warnings (trigger indicator), maximum and minimum temperatures observed on the previous days, maximum temperature estimates for the same day, and temperature forecasts for the following three days are used. If there is a heat risk alert (yellow, orange, or red) for the following 24 hours, the Ministry of Security and the Ministry of Health are notified. The Ministry of Health will launch an epidemiological alert and make it public through social media, press agencies, and national media.

The recommendations given by the Ministry of Health are: (i) increase fluid intake without waiting to be thirsty to maintain adequate hydration, (ii) do not expose yourself to the sun in excess or in central hours of the day (between 11 and 17 hours), (iii) avoid alcoholic or very sugary drinks, (iv) avoid very abundant meals, (v) eat vegetables and fruits, (vi) reduce physical activity, (vii) wear light clothing, loose and light colors; (viii) stay in ventilated or conditioned spaces, (ix) remember that there is no pharmacological treatment against heat stroke. Additional recommendations are given if having symptoms of heat stroke (88).

- Brazil

Brazil does not show broad information on the functioning of its heat EWS. However, the evidence on the official website of the National Institute of Meteorology of Brazil (INMET) indicates that it is a multi-threat warning system. There is also evidence that INMET launches alert communications to the population via website. However, it was not possible to find more information on the functioning of its heat EWS in the literature review.

- Chile

This heat EWS started as a monitoring system in 2020. It was created with the help of the University of Santiago de Chile in collaboration with the Meteorological Directorate of Chile, the National Emergency Office, and the Department of Health Statistics and Information. The heat EWS has 34 stations throughout the country's cities. To define the warnings (trigger indicator), maximum temperature estimates for the same day and the temperature forecasts for the following three days are used. The EWS has a public portal that shows real-time monitoring for diurnal and nocturnal heat waves. When a heat wave alert is issued, the meteorology department will call the ministries involved to act. In the case of health, warnings are given to the population in written form.

The alerts include recommendations to act in case of a heatwave, such as (i) drink fluids constantly, (ii) keep food refrigerated and avoid eating foods that decompose quickly with high temperatures, (iii) try to stay indoors with lower temperatures than outside, (iv) monitor body temperature and condition of children and older adults, (v) avoid exposure to the sun during the central hours of the day (11:00 to 17:00 hrs maximum ultraviolet radiation), (vi) rest frequently in the shade and stay hydrated, (vii) wear light, loose-fitting, light-colored clothing and avoid synthetic fabrics, (viii) never leave people or pets inside vehicles, (ix) keep crops, orchards, and vegetation in general hydrated, (x) try to keep in the shade and offer food and water to animals and livestock, (xi) Use fire appropriately and only in authorized areas, (xii) maintain adequate management of waste and garbage, (xiii) monitor the appearance of vectors such as mosquitoes and mice, (xiv) be informed about the appearance of Red Tides since heat waves can favor the concentration of toxic or non-toxic microalgae in bivalve mollusks (mussels, clams, oysters, and clams, among others) (89).

- Uruguay

Uruguay has a multi-event EWS. The system identifies meteorological alert zones through polygons with their corresponding weather alert level (color: yellow, orange, and red) and the nature of the phenomenon (icon: wind, storm, rain, visibility, cold wave, heat wave). In the case of heat waves, the EWS started in 2020 in two departments (Rivera and Montevideo) and the team that generated the heat EWS was formed by members of the Uruguayan Institute of Meteorology and the Ministry of Public Health of Uruguay. To define the warnings (trigger indicator), the heat EWS uses the maximum and minimum temperature of three days.

It should be noted that two different heat wave definitions were found for Uruguay. The Uruguayan Institute of Meteorology refers to it in the line of extreme temperatures using the following definition *“Sustained events of extremely high or extremely low temperature are referred to as a wave. The duration depends on the climate of the place. In Uruguay we speak of a wave when extreme temperatures persist for more than three consecutive days. Temperature thresholds are determined based on the season of the year and these have to be exceeded above or below”* (90). Furthermore, the National Emergency System considers a heat wave *“when high temperatures are recorded for at least three days with minimums above 20° and maximums between 34° and 38°”* (91).

The recommendations given by the Ministry of Health are: (i) avoid physical activity outdoors between 10:00 and 16:00 hours, as well as exposure to the sun's rays at the beach and outdoor spaces, (ii) drink plenty of fluids even if you are not thirsty, offer children more water and fluids than usual, and breastfeed babies on demand. (iii) stay in the coldest place in the house or the shade outdoors, (iv) avoid heavy and hot meals. Prefer light meals based on vegetables and fruits, opting for small portions, (v) Keep food in the refrigerator and take extreme hand hygiene measures before handling and consuming them, (vi) avoid consumption of alcoholic beverages, (vii) take 2 or 3 refreshing showers daily or cool off with wet cloths, (viii) wear loose-fitting, light, dark-colored clothing, a hat, sunglasses, and high-protection sunscreen, (ix) avoid prolonged stay of children, older adults, and animals inside the car, especially when parked, (x) frequently contact elderly, disabled, or chronically ill family members, friends, or neighbors who live alone or stay alone for several hours at home to monitor their health condition. Likewise, it indicates how to identify some of the most frequent symptoms of excess heat to go to a health post (92).

3.2.2 Key Informant Interviews

The process of interviews entailed an in-depth discussion with key actors from CSA with both local and regional approaches. The participants provided insights from their experience in knowledge on heat EWS as key actors in the region. The results were categorized according to the different topics that emerged on heat EWS coverage and operation. The categories were identified using an inductive approach, which resulted in the following categories: (i) competent entity and (ii) alert level. The following section presents a summary with the main points from the discussion, as well as excerpts from the interviews, which exemplify and support the contextual interpretation of the interviews.

In general, it is seen that vulnerable countries, such as Honduras and Guatemala, still have no protocol to follow in the event of a heat wave nor have a heat EWS in place.

"It is planned, it was also included in the Nationally Determined Contribution that has just been updated, but it is not yet being implemented. It is a goal that has been set for a couple of years from now."
(Representative from the National Coordinator for Disaster Reduction of Guatemala)

Specifically, in the case of Honduras, there is no responsible entity addressing heat waves and for the time being, the public is informed about temperature increases through bulletins.

"In Honduras, there is no entity in charge of reviewing the issue of extreme heat waves, in any case it should be the Permanent Contingency Commission (COPECO) which is the official governing body in Emergency Response and Risk Management in the country...There is no established protocol for heat wave emergencies... …Basically, what is done is the publication of an alert bulletin for the population, where they are told what care to take in case of heat waves that are out of the ordinary."
(Representative from World Vision Honduras)

On the other hand, Argentina shows an advanced action plan, which follows previously established protocols in which ministries are articulated. As the key informant indicates, this heat EWS focuses mainly on health impacts.

" In Argentina, we have separate competencies in terms of heat hour actions, the issuance of alerts is generated by the National Meteorological Service, and then there are two other actors, the National System of Integral Risk Management and Prevention, which depends on the Ministry of Security and there is a whole space of articulation with the rest of the ministries and particularly with regard to Health. Health issues recommendations for health care because the alerts generated by the Meteorological Service are designed and built on the basis of health data. So, although it can be applied to other sectors such as energy, animal health, and others, the system has a strong health component and has been built in that sense."

(Representative of the Ministry of Health of Argentina)

For now, there is no heat EWS that alerts rural areas in Argentina. Since 92% of Argentina's population is urban, this heat warning system is mainly aimed at this population.

"We have analyzed it fundamentally in terms of urban population, because in Argentina, nine out of ten people live in urban areas. It is a highly urbanized country, and because in the cities we also have the complexity of heat islands, which enhance the heat wave. Then, and many times, at least in our country, it happens that social vulnerability is more represented in the cities, where there are informal settlements that usually have precarious constructive, weak access to water services, sanitation, waste collection; and also, difficulties in access to the health system. So, all this contributes to increased vulnerability."

(Representative of the Ministry of Health of Argentina)

One key informant indicated that the EWS for Brazil is not national. In Brazil, not all cities have early warnings because there is a lack of capacity at the local level.

"it warns, but it is at city level, and there it depends if each city has or not, but it is not an integrated system. So, this is one of the challenges. Sometimes there are capacities at the local level. But there is no program thought at national level… with local, provincial or state-level meteorological information, it can be done and put together this type of initiative, but identified as national systems, no."

(Expert in Health and Climate Change)

As in Argentina, Chile is making progress in its action plan to alert the population. However, the key informant notes that there are no additional actions done to protect the population. In most cases, the action plan covers only the launch of an alert to the population. Additionally, it is known that starting this year (2022) they will begin monitoring the impacts of extreme temperatures on the health of Chileans.

"If the Meteorological Directorate launches an alert, it calls a technical team of the involved ministries In the case of a heat wave alert, the Ministry of Health, Transport, and Energy will be called, which are key ministries in this... In the case of health, by decree, they really have no incentive other than to take out informative papers to the population."

(Representative from the Chilean Society of Planetary Health)

3.3 Limitations

A general literature search using Elsevier, PubMed and Web of Science was done guided by the research question: *"What is the health impact of early warning systems of extreme heat in Central and South American countries."* The search strategy was the following: *"heat" AND "early warning system" AND "South America" OR "Central America".* **The search showed no results; therefore, it was not included in the report, nevertheless, this is considered a finding itself. In general, the information on heat EWS in CSA is limited as it is a topic that is only recently being taken into consideration.**

In terms of the gray literature review, it was not possible to access the official meteorological websites of Suriname, due to server problems, and not much information could be found on EWS in Brazil as the language (Portuguese) was a limitation. In addition, since the NAP of Venezuela and Bolivia were not found on the Internet, it is unknown if these documents exist. Finally, the findings from the national meteorological websites and NAP analysis should be considered with care, as efforts to develop heat EWS might be in progress in CSA, but not yet published in the revised sources.

3.4 Conclusions

Despite that CSA is exposed year-round to heat stress (See Objective 1) and that temperature anomalies are reported on all the meteorological institutes in the region, heat EWS in CSA is an emerging topic that is only recently being taken into consideration in several countries and, therefore, action plans and information are limited. This is the case of Honduras and El Salvador, in which heat EWS is not present in its NAP despite being countries identified as having higher heat risk (See Objective 1). On the contrary, Argentina, Uruguay, Chile, and Brazil are countries that have heat EWS and issue warnings to the population regarding how heat can affect their health. Despite that heat waves could be accompanied by high humidity (93), none of the existing heat EWS monitors humidity as part of the trigger parameters. Moreover, the key informant interviews have helped to identify that no action goes further on the side of the Ministries of Health. From what has been found, the heat EWS are city-based and do not seem to contemplate rural areas in the alerts.

4 Actors and organizations working on extreme heat in Central and South America.

4.1 Methodology

To achieve this objective, (i) an Internet search was conducted by using Google Search engine to identify actors and organizations, (ii) key informants that participated in interviews for Objectives 2,6 and 7 also shared names of actors and organizations they are aware of, and (iii) a review of the websites of selected organizations was performed to extract information. No restrictions on date or language were used.

Internet search

For the Internet search the following terms were used using different combinations[6]:

- **Heat:** *"extreme heat", "heat wave", "heatwave", "extreme event", "extreme temperature", "heat"*
- **Continente:** *"Latin America", "South America", "Central America"*
- **Country:** *"Argentina," "Bolivia," "Brazil," "Chile," "Colombia," "Ecuador," "Guyana," "Paraguay," "Peru," "Suriname," "Uruguay," "Venezuela," "Belize," "Guatemala," "El Salvador," "Honduras," "Nicaragua," "Costa Rica," and "Panama"*
- **Health:** *"Health"*

Review of websites

Once the websites of actors and organizations were identified through Google Search, they were browsed and examined individually to find more information about their work. Sources of information within their website, such as guides, reports, presentations, fact sheets, and similar records were used. Mentions on heat waves in these sources of information were searched in order to identify the level of predominance and interest of the actors or organizations in the topic .

[6] Please refer to the Excel sheet (Supplementary material) to see the full list of the search strings and Boolean operators.

Data extraction

The following data was extracted from the websites and registered in the Excel sheet: (i) name of actor, (ii) type of actor (i.e., religious organizations, non-governmental organizations, intergovernmental organizations, government entities, companies, community-based organizations, and academic associations of health professionals) (iii) actor's approach to heat waves (it was considered "direct" if the actor had material predominantly focused on heat topics compared to other climate events, and an "indirect" if the actor had material predominantly focused on climate change and less predominantly on heat), (iv) geographic scope of the actor (is the area of influence of the actor or organization; could be global, regional, national, Amazonian, and Andean countries), (vi) geographical coverage (are the areas where the developed materials focus on; it includes countries, and regions considered in the search criteria)[7], and (vii) areas of work (includes policy, research, advocacy, funding, awareness, capacity building, communication, or outreach).

4.2 Results

The following sections describe the main findings on the identification actors and organizations working in extreme heat and/or heat waves (See Appendix 10).

Internet search

The search allowed to identify 95 actors, organizations and/or locations, yet **only one actor was found to work exclusively on the topic: the Global Heat Health Information Network.**

Data extraction

A complete Excel sheet with the extracted data on the identified actors and organizations, along with a dashboard accessible to interact with the data was developed (See Supplementary Material). Below is a summary of the main findings.

[7] In the case where multiple locations are addressed by the actor or organization, all locations were recorded. For three actors (Diálogo Chino, Global Heat Health Information Network, The Lancet Countdown: Health and Climate Change), locations were not specified but they were still included or recorded.

4.2.1 Type of Actors

The types of actors or organizations identified vary widely in style and approach. However, the intergovernmental organizations are the ones that predominate in the results (35%) (See Figure 25).

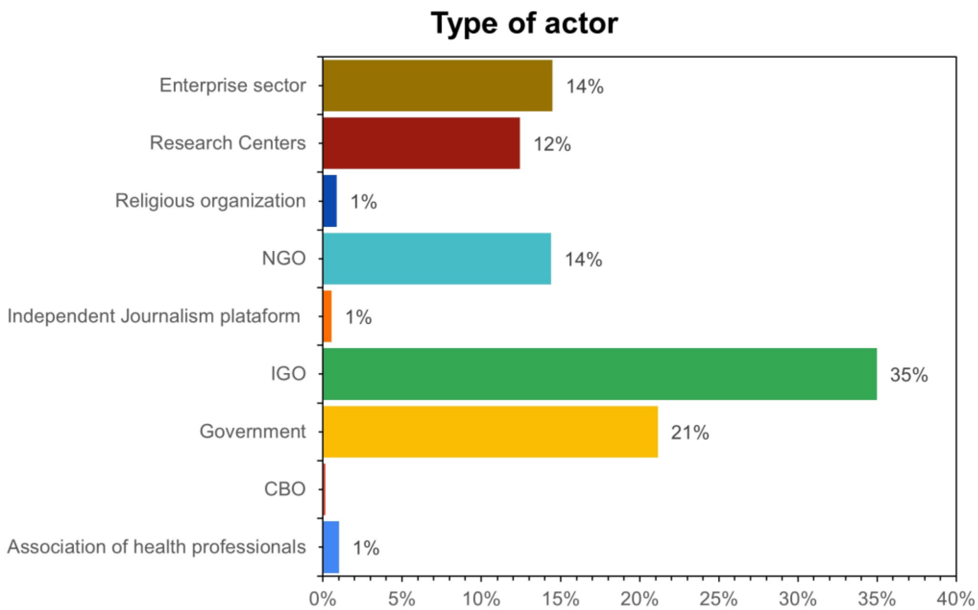

Figure 25. Type of actors or organizations in CSA and the Caribbean[8].

4.2.2 Actor's approach to heat waves

Another assessed aspect is the approach of heat material on the website of the actor or organization on the topic of heat and heat waves (direct or indirect, a s explained in the Methods). This aspect was reviewed to have a better understanding on the potential influence the actors or organizations could have on government policies, procedures, and the management and response to heat wave events (94). In that sense, the results show that heat wave information is addressed directly and indirectly in the same proportion or with slight variation between the different actors.

[8] Caribbean countries were included as their work could be of relevance to Central American countries

4.2.3 Geographic coverage of the material produced by the actors and organizations

As mentioned above, 95 actors or organizations were found and included in the report. The identified material developed by the actors and organizations cover information on 19 countries from CSA. These materials tackle the health impacts of heat waves.

Through this mapping exercise, the geographic coverage of the work done by the actors was identified, but moreover, it was possible to detect which countries had the most mentions on health impacts associated to heat waves. The locations were ranked by level of importance or relevance based on the frequency of mentions on the topic (see Figure 26).

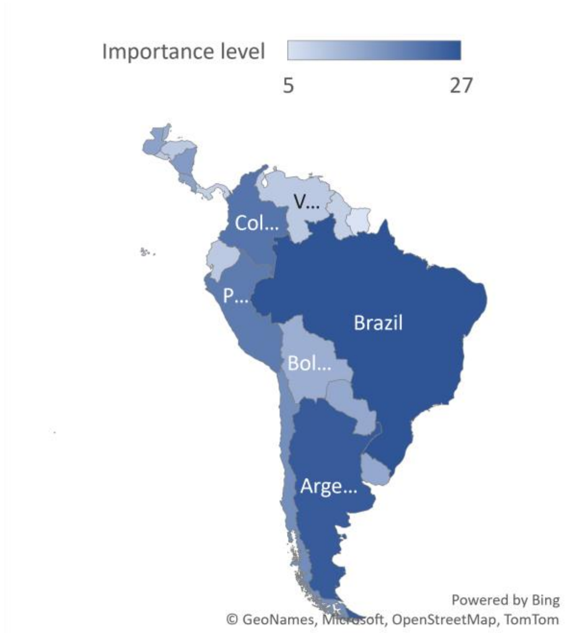

Figure 26. Relevant countries to actors or organizations.

A concentration of information about heat waves and health was apparent in Brazil, Argentina, Colombia, Peru, and Chile. Very little information was found in Suriname. **In general, the proportion of information on South America is twice the information from Central America and most of the information available and mentions are oriented towards outreach and communication activities. Virtually, no information on interventions nor capacity building was found** (See Figure 27).

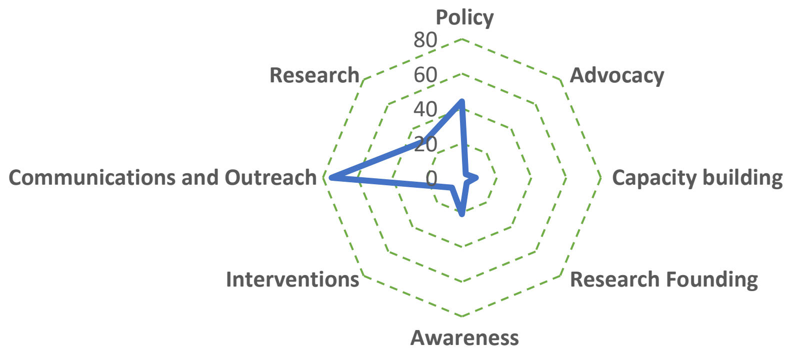

Figure 27. Identified key focus areas

4.3 Limitations

The limitations of this identification of actors and organizations include the use of Google Search, which has a limit of 32 words per search. As a result, some search strategies were not carried out and therefore may not have captured all the information available. On the other hand, the actors or organizations included for this review were chosen subjectively, considering them as the most likely to enable a depth analysis. Furthermore, it is likely that some of the health effects and impacts identified in the search are not supported by scientific evidence but might reflect the perceptions of the stakeholders.

4.4 Conclusion

The analysis reveals gaps in actors and organizations that work on heat waves and extreme heat in countries bordering tropical regions, such as Ecuador, as well as parts of Central America. Most of the actors focus their work and heat wave materials on Brazil, Argentina, Colombia, Peru, and Chile. Although the intergovernmental and government organizations are the ones that have the most information on the subject, only one non-governmental organization with a global reach (Global Heat Health Information Network) is exclusively focused on heat waves and its impacts in different countries that include CSA.

5 Heat wave events in Central and South America, 2017-2021

5.1 Methodology

Impactful past heat waves are understood as heat wave events that had consequences to human health in terms of deaths or hospitalizations. To achieve this objective, three main steps were followed. First, a literature review of scientific evidence and gray literature on past heat waves that occurred in CSA was performed to identify potential impacts from these heat waves. The scientific evidence was retrieved from Web of Science and the gray literature from the websites of each Ministry of Health of each country under study. Second, an analysis of reanalysis data was performed to spatially identify areas where heat waves occurred from 2017 to 2021 in CSA. Finally, an overall analysis was conducted integrating the literature review, identified heat waves, and information from official sources about the known impacts of these heat waves.

5.1.1 Literature Review

The literature review was guided by the following research question *"What impacts associated with heat waves have been recorded in Latin American countries?"*.

The search strategy was the following*: (heat?wave) AND ("impacts" OR "effects") AND "Latin America"*. The search was performed on Web of Science on 22 May 2022. To capture the most current evidence, articles that were published from 2017 onwards were included.

The references were included in Rayyan and selected for selection by title and abstract first. The full text of the selected articles was then analyzed and selected. The screening and study selection was based on the following eligibility criteria: (i) the article was included if information on CSA countries was presented; and (ii) the article analyzed past heat waves and their impacts on human health.

The information from the selected papers was extracted using a form that covered (i) lead author; (ii) publication year; (iii) country or region under analysis; (iv) brief methods; and (v) key findings. This information was then synthesized by country and topic. Specifically, the information to be extracted covered heat waves events, when and where they occurred, and known impacts on human health. Moreover, a gray literature review was conducted by doing searches on official Ministries of Health websites. Every website was searched for *“ola de calor”, “onda de calor”,* or *“heatwave”*.

5.1.2 Heat waves: Data Sources and Data Analysis

Heat wave events are defined as periods of hot weather relative to the expected conditions of the area at the time of year (93). In this study, a heat wave event was identified when the daily maximum temperature was above the 90th percentile (1961-1990) for at least 3 consecutive days (95,96).

Current temperature data from ERA5 dataset was downloaded as NetCDF files from Copernicus platform as a gridded product considering a spatial resolution of 0.25°×0.25°. Temporal resolution covers hourly information from 2017 to 2021. To calculate thresholds, historical data from ERA5 dataset was downloaded as NetCDF files from Copernicus platform (19,20) as a gridded product considering a spatial resolution of 0.25°×0.25°. The temporal resolution considered hourly information from 1961 to 1990.

5.1.3 Known Impacts from Heat Wave Events

Once heat wave events per month were identified, they were matched with information obtained from the scientific and gray literature review.

5.2 Results

In the following sections, detailed results are described considering the literature review, the heat waves analysis, and the overall synthesis of information.

5.2.1 Literature Review

A total of 99 articles were found on Web of Science. After screening titles and abstracts, 23 full-text articles were fully analyzed. Of these articles, nine were included in this study. Three were from Brazil, two from Argentina, one from Chile, and one for several cities in CSA. Table 4 shows a summary of the articles included.

Most of the literature published about heat waves in CSA does not identify health impacts after a heat wave event, and when they do, there is a gap of around five years between the event and the publication. As a result, most of the literature published from 2017 onwards identified and analyzed heat waves that occurred several years before the publication.

In general, the climate hazard, in this case, heat waves, is identified, and characterized in the literature; however, its impacts on population are less clear. From the evidence retrieved from 2017 onwards, the most common impacts are related to overall mortality, overall hospitalizations (29,36,97–99), and medical consultations (26). Only one study interviewed people about the degree of discomfort (100), but it did not include vital registration as a variable.

First author	Publication year	Country / Region	Brief methods	Key findings	Reference
Chesini, F.	2019	Buenos Aires, Argentina	Time series of mortality over 2005-2015 period. Comparison was made against a heat wave in 2013.	Risk of death from natural causes increased by 14% (RR = 1.140; 95%CI: 1.108-1.173) during heat waves when compared to the other days in the hot season. The heat wave in December 2013 showed an increase of 43% (RR = 1.428; 95%CI: 1.399-1.457) in total daily deaths, increasing to 51% in individuals over 84 years (RR = 1.515; 95%CI: 1.372-1.674) and 65% (RR = 1.647; 95%CI: 1.367-1.986) for renal causes.	(29)
Costa, I.	2021	Brazil	Association of biometeorological parameters and hospital admissions in different seasons.	Emergency hospitalizations for heart diseases during extreme weather events occurred on days with thermal discomfort.	(97)

				Hospitalizations per day increases during heat waves and cold waves in comparison to days with no anomalies.	
Flores-Larsen, S.	2021	La Pampa, Argentina	Analysis of heat index, indoor air temperature, and effects on population health.	Heat wave on January 7–12, 2018: lasted 6 days and the maximum temperature reached 38.9 C. Heat wave on January 18–22, 2018: lasted 5 days and the maximum air temperature reached 39.1 C. Among adults, medical consultations increased about 15% during the days immediately after the second hot period, when the relative humidity increased.	(101)
Geirinhas, J.	2019	Metropolitan Region of Rio de Janeiro, Brazil	Analysis of time series of temperature and mortality	During February 2010, an elevated mortality peak occurred during an 8-day period (from 2 to 9 Feb 2010) characterized as a heat wave episode in the Metropolitan Region of Rio de Janeiro. On February 9, a total of 414 deaths were recorded, representing an excess of 151 cases when compared to the expected daily average values of 263 deaths for the area. A total excess of 737 deaths was recorded with the elderly group registering the highest mortality incidence.	(98)

Guo, Y.	2017	Worldwide. It takes some locations in Latin America.	Time series analyses to estimate the community-specific heat wave–mortality relation over lags of 0–10 d.	Heat waves during the period 1997-2011 for Brazil were associated with 1,101,149 deaths. Heat waves during the period 1998-2013 for Colombia were associated with 267,736 deaths.	(99)
Smith, P.	2018	Chillán City, Chile	Analysis of climatic variables and observation of behaviors of people exposed to heat waves.	During heat wave in summer 2016, most people declare discomfort, particularly around 18 hours when the temperature reaches its peak (38 ◦C).	(100)
Zhao, Q.	2019	Brazil	Time series analysis of heat waves (using different thresholds) and hospitalizations in Brazil during 2000-2015.	The risk of hospitalization, in particular for perinatal conditions, was higher during heat waves with high temperatures and long durations than for moderate heat waves	(36)

Table 4. Summary of studies on heat waves events in CSA countries**.**

Searches on official Ministries of Health websites did not show any information related to heat wave events and their impacts on human health. The identified information was related to general information to the public on what to do during a heat wave, but no official documentation on known impacts was found. One presentation from the PAHO in 2019 contained information regarding some impacts of heat waves in four countries.

In 2017, four deaths were associated with heat waves in Nicaragua. In 2018, four deaths were associated with heat waves Paraguay (102). However, no official references were cited or found elsewhere. Handsearching of evidence resulted in several news and unofficial data. However, some local evidence was retrieved. In Brazil, a heat wave during 2019 was associated with increases in hospitalizations due to several causes (103).

5.2.2 Heat Wave Events

From the ERA5 data, it was possible to identify geographical areas that were exposed to heat waves from 2017 to 2021. In general, heat waves are monitored during the summer months. In South America, this period covers December, January, and February. In Central America these changes and higher temperatures can be observed from May to September. Nowadays, with changes in the climate, it is possible to observe heat waves outside the hottest months, although the scientific evidence is not clear about the impacts of these. Figures 28 to 39 in Appendix 11 show the number of monthly heat waves from 2017 to 2021; thus, all events can be assessed throughout the year in different geographical areas.

From the analysis and figures it is possible to observe that several heat wave events happened during the period under study year-round. The areas with higher number of events per month differ, but in general Central America is particularly affected from July to October; however, these territories are affected year-round. Similarly, the north area of South America is also affected year-round. **The central and south part of South America is mainly affected from September to March.** From 2019 to 2021, the number of events per month has increased in the whole region, showing important events in Guatemala, El Salvador, Honduras, Brazil, Argentina, Paraguay, and Colombia.

5.2.3 Overall Synthesis

Overall, there is limited official or formal evidence on known impacts of heat wave events in CSA over the last five years. **Documentation and posterior analysis of hospitalizations or mortality after a heat wave in the region is scarce and it might be related to the capacity of processing data along with the registration system of vital statistics.** In addition, it is not common to code heat as a cause of death, therefore mortality is inferred based on the excess of mortality connected to other conditions, including co-morbidities.

It is expected that evidence on known impacts come from countries with a strong and established system of registration of heat waves and mortality/morbidity data. It is highly probable that countries with a weak health system in terms of registration and update of health outcomes would not show health impacts after a heat wave, not because there were no impacts but because of lack of information.

From the scientific and gray literature, it is possible to identify some known impacts from specific heat wave events (See Table 5); however, there might be other unknown impacts due to poor documentation and updated analyses.

Country	Heat wave event	Known impacts
Argentina	January 2018 Santa Rosa, La Pampa, Argentina	Increment of medical consultations within adult population (*)
Brazil	January 2019 Bauru city	Increase in 56% - 150% in hospitalizations due to cardiovascular diseases in comparison to to the seen hospitalizations in January 2018 (*)
Nicaragua	2017 (no month mentioned)	Four deaths
Paraguay	2018 (no month mentioned)	Four deaths

Table 5. Heat wave events and known impacts in CSA 2017-2021.
(*) These studies do not consider excess of deaths

5.3 Limitations

One of the limitations of this section is the few articles that related health impacts to heat waves within the selected timeframe. Most of the published evidence is for heat waves that occurred more than 5 or 10 years ago. This could be explained due to a lack of priority on the topic, a missing definition of heat waves and consequently identification of them when occurring, difficulty on access data, the slow process to update health registrations, and then the gradual process of analysis. Additionally, 2 of the studies (Brazil, Argentina) did not take into account the excess of deaths, which might under-represent the impacts.

5.4 Conclusions

Overall, there have been important heat wave events from 2017 onwards; however, the analysis of impacts on health is unclear in the region.[9] This scarce information might be explained due to several reasons. One could be associated with low awareness of heat as a health risk and several deaths or hospitalizations are not categorized as temperature related. Another explanation might

[9] All figures can be downloaded from: https://drive.google.com/drive/folders/1DbLlBtTri0V8zNRaeky_aKOajvew-N59?usp=sharing

be the low capacity of timely analyses of climatic events and health outcomes by governmental offices.

6 Priority gaps in heat risk knowledge in Central and South America for future research agendas

6.1 Methodology

To identify the knowledge and gaps in the region in terms of heat risk, a total of nine key informant interviews were conducted from governmental and non-governmental institutions representing the health, environment, academic, youth, and government sectors from different countries. The interviews were held in Spanish and conducted using the platform Zoom Meetings.

The sessions were recorded, transcribed, and selected quotes were translated into English. Verbal consent to participate and record the video conference was received by all the informants. The interviews were analyzed using qualitative methods, specifically through thematic analysis with an inductive approach on the codification process (See Appendix 6). The software MaxQDA was used to do the qualitative analysis.

In terms of the questions (see Appendix 7), participants were asked about the overall knowledge of heat waves and extreme heat in the region and/or in their country of origin, to describe the knowledge gaps on heat risk and the challenges in knowledge transfer.

6.2 Results

The process of interviews entailed an in-depth discussion with key actors from CSA with both local and regional approaches. The participants provided insights from their experience in knowledge production or as key actors in the region. The results were categorized according to the different topics where gaps were described. The categories were identified using an inductive approach, which resulted in the following categories: (i) gaps in the level of knowledge level and scientific production, (ii) gaps in data generation and management, and (iii) gaps in knowledge transfer and co-creation. The following section presents a summary with the main points from the discussion, as well as excerpts from the interviews, which exemplify and support the contextual interpretation of the interviews.

6.2.1 Knowledge and Scientific Production

In comparison with the scientific production on high income countries, research in CSA is still limited and circumscribed to the existing efforts that have come from the academic force of high-income countries. In addition, research occurring in the study area produced by local talent has reduced visibility even though such capacity exists.

"Sometimes the academic work of Latin America is not very visible, less visible because it is published in different languages or for various reasons, but in general the region has a lot of academic capacity".
(Representative from the Inter-American Institute for Global Change Research)

General knowledge about heat risk, extreme heat and health impacts in CSA starts with being able to address the crucial topic of the intersection between health and climate. Tackling this link begins with academic training in universities, which needs to be transferred to students by contextualizing the study of extreme heat to the regional reality. The existing academic trainings in Central America that have a climate change approach tends to address the topic from a risk management perspective supported by literature from studies carried out in countries outside the region, with characteristics very different from those of CSA. In addition, **the lack of awareness and research on the effects of high temperatures on health, creates a barrier in the recognition of this phenomena as a problem in Central America, despite being acknowledged as a key issue in other countries**, mainly those from high-income countries.

"...heat waves, if they were named within the whole career once, it was a lot. And I'm sure that within the Central American curricula, - which I've also had the chance to see the curricula, they are more related to climate change, risks, and risk management. They are named and exemplified as problems of countries in Europe and North America. Not Central American countries. "
(Representative from La Isla Network and from The Costa Rica Institute of Technology)

Looking at a more concrete case, a key informant from Honduras expressed that there is a research gap in health and climate change in this country. As described below, the nonexistent scientific production on this topic seems to be linked to a limited interest on behalf of the health sector along with few funding opportunities for research in this area.

"...if you want to look for a scientific article on climate and health in Honduras, you won't find a single article. So, in fact, there is not much interest from the health sector. There is not much support to be able to finance this type of research".

(Representative from The International Federation of Medical Students Associations – Honduras)

Despite the limited scientific production on climate change and health, including heat risk, the impact of extreme heat is known by both governments and populations. The population is no stranger to this problem, because they are already living and experiencing the effects of extreme heat, particularly those who are in most vulnerability (the elderly, young children, those with co-morbidities and/or with non-communicable diseases).

"I think that at a general level people understand that heat or heat waves have a negative impact on health. We live it, especially the most vulnerable populations, it is obvious, because it is their reality, they live it, it doesn't require a PhD, a study to understand that."

(Representative from the Inter-American Institute for Global Change Research)

However, the issue is not only about what is known about heat, but about what is being done with the knowledge that already exists.

"We already know that heat has an impact on health. We don't have to keep asking these questions. What we have to do is: what are they doing about it?"

(Climate change and health expert)

- Definition of heat waves and event characterization

Another important gap mentioned by the interviewees is the definition of heat waves. Having a universal definition of what a heat wave is, common for all countries, does not seem feasible. This is because the concept of heat wave results from a country's own features, including the meteorological and population´s characteristics (e.g. heat tolerance levels) (104).

"But this is one of the problems of the definition, of the definitions that there are about hot days or heat stress or heat waves... ...I don't know if that will be possible, to make a single definition for all countries."

(Climate change and health expert)

Most countries in CSA do not have their own definition of heat waves, which increases the knowledge gap on heat risk and exacerbates the lack of recognition of the phenomenon. Having local studies so that each country in the region has its own definition of heat wave based on evidence that obeys the country's own characteristics is a fundamental baseline to better characterize the event and be able to conduct subsequent studies on heat risks, including impacts on morbidity and mortality and on key vulnerabilities (104).

The issue becomes particularly difficult for countries in Central America and for some countries in South America where there are no defined seasons and where there are no extreme temperatures, as there are in the North countries or in some other countries of the Southern Cone such as Argentina and Chile, where the phenomenon is particularly recognized during the summer season.

"...the biggest problem is the lack of knowledge of what a heat wave is, that is, in the region it is not a concept that is handled as it is handled, for example in the United States or in Europe, where it is very well identified and is closely related to summer periods... ...In Central America, it may be due to the fact that we do not have seasons and practically what we have is a dry season and a rainy season. This phenomenon has not been identified within the phenomena to which we are exposed".
(Representative from La Isla Network and from The Costa Rica Institute of Technology)

Apart from each country being able to determine what a heat wave is, there is a need to identify the characteristics of heat waves. Being able to develop a diagnosis through models with different scenarios and projections, to better understand the extent of extreme heat in order to explore risk, is one of the research gaps identified in Colombia.

"...well, with a modeling or some kind of estimation and interpolation of peak temperatures.... ...And with that we could have a baseline to "diagnose" the situation of the heat wave problem in the country"
(Representative team from National Unit for Disaster Risk Management – Colombia)

- Adaptation and early warning systems (EWS)

In addition to defining what heat waves are, a research gap identified by the informants has to do with the level of preparedness, resilience, and adaptation of health care facilities in scenarios of extreme heat.

"...we are working on the issue of resilient service, but we could also make a line of whether the service is prepared to have heat waves, with oral rehydration serums, recovery beds, oxygen therapy."
(Representative from Health Emergencies WHO/PAHO)

Continuing with examples of research gaps in adaptation, Argentina's experience with heat EWS shows that the systems may be influencing people's decision making. An analysis of adaptive behaviors in Buenos Aires that was conducted using an indicator on the use of public bicycles during heat wave warnings, led to this conclusion. Conducting a study, for example, on knowledge, attitudes, and practices related to heat risk may be useful to better understand what may be behind the loss of sensitivity to EWS after a few days. It is important to generate evidence on the impact EWS have on health, whether there is indeed a reduction in the effects, whether it affects decision-making and to identify the best strategy for communicating the warnings.

"...I would like to be able to evaluate to some extent the impact of the warning system, to see if it has reduced or not the effects... ...to be able to define how effective the warning system is, how much impact it has on the population's decision making, how the community is informed in order to be able to improve communication strategies".
(Representative from the Ministry of Health of Argentina)

- Implementation Science

Another research gap identified by informants relates to the promotion of research evidence and findings for viable implementation (i.e., Implementation Science). Specifically on the issue of extreme heat, **there are gaps related to the evidence that identify barriers and enablers to implementing measures, particularly on EWS. There are gaps with respect to the feasibility at the economic, technological, human resources and data availability levels.** This type of studies approached from implementation science is from where academics can contribute, hand in hand, with the leadership and commitment of decision makers.

"There is a big gap… on the development of the models, to actually implement an early warning system and all the factors that can facilitate or impede the fact that a government actually adopts, implements and sustains an early warning system. When we did for the IPCC an analysis of early warning systems for health in Central and South America, as part of their analysis, we did a feasibility assessment, but we didn't find any studies directly talking about feasibility".
(Representative from the Inter-American Institute for Global Change Research)

- Correlation studies

A gap indicated by some of the interviewees has to do with the need to be able to carry out studies to establish correlations between exposure, morbidity, and mortality. To achieve that, access to climatological data and records of heat waves is required.

"...it's almost impossible, so to speak, to be able to relate it to a heat wave because there's not even a record of heat waves at the regional level. So, there would be no way that a country could make a correlation between, for example, if we are experiencing a heat wave this week that in 15 or eight days, there are deaths that can be attributed to this heat wave that we are experiencing this week.".
(Representative from La Isla Network and from The Costa Rica Institute of Technology)

Even though **there are no records on heat waves, the need for research on this topic is still relevant to define exposure thresholds and subsequent health impacts through correlations.** These types of studies should be promoted not only from the research agenda, but also in the health sector agenda to be able to act.

"...with the Ministry of Health here in Uruguay… we talked about the fact that there is no information, for example, on how heat waves affect morbidity or mortality in Uruguay... ...it is not contemplated within the monitoring and surveillance systems. Let's say, for example, that there is a heat wave and a couple of days later there is an increase in respiratory, cardiovascular pathologies, etcetera, but there is no way currently, within the systems, to link that and measure that and say "ah, because of such a heat wave there was a 20% increase in cardiovascular problems".

(Representative from the Inter-American Institute for Global Change Research)

According to our informants, these correlation studies are essential. In some cases, as in Paraguay, different databases exist from the National Emergency Secretariat, but they need to be merged with those of the Ministry of Health to generate these analyses.

"...this correlation between the event and the impacts is where we must start working a little bit more... The Ministry of Health already has its own database on the number of cases. So, somehow, we would have to merge that".

(Representative from the Ministry of Environment and Sustainable Development of Paraguay)

It is also important to be able to diagnose patients coming to the health center due to symptoms from heat stress, and to improve the registration and follow up system to have a better understanding of the impact of heat waves on health, vulnerabilities, and risk.

"We would have to review the Health Ministry's information system ...a lot of information remains in the registry. "Reason for consultations: suffocation, fainting." And do a thorough work in a research team in the field."

(Representative from Health Emergencies WHO/PAHO)

- Vulnerability studies

Other research gaps have to do with gaining a better understanding on which areas of a country are most vulnerable to extreme heat by developing vulnerability indices. Colombia has experience developing vulnerability indices, but with a focus on water issues. As of today, they have not conducted heat-related vulnerability studies. However, it is recognized that the experience they already have in this type of measures could be used to develop an indicator on extreme temperature.

"I think that some very key things are that the country has several studies... they have aridity indices and vulnerability indices for water shortages.... However, one could extrapolate this a little to the part we are dealing with.... not so much with water regulation as such, but with temperature issues that could generate a zoning, a prioritization of areas in the country ... to highlight the temperature values".

(Representative team from National Unit for Disaster Risk Management – Colombia)

Another gap is to be able to identify the populations that are vulnerable to extreme heat and heat waves.

"Speaking specifically of the issue of vulnerabilities… …knowing better the social and development dynamics of the population I think could be very helpful… to know how to act and what needs can be covered before such an event"

(Representative from The National Coordination for Disaster Reduction from Guatemala)

Particularly, an analysis of structural vulnerabilities (e.g., poverty levels, presence of informal settlements, limited water access and sanitation) from a social perspective that incorporates the reality that exists in each country is needed. Approaching social vulnerabilities may be overshadowed by the lack of access to first-hand information from the same populations that combine multiple social inequalities.

"We have many social ghettos, we have in Brazil the favelas are super, super relevant in terms of and associated with poverty as well, and they are prepared in a very, very weak way for these elements, because also the State or the Government cannot enter much in that area. So, I think there is an overlap of many risks that we do not see today, not even from the academy, not even from the decision making".

(Representative from the Chilean Society of Planetary Health)

Furthermore, social, and structural vulnerabilities appear to be a sensitive topic in general, even when dealing with extreme heat. **Research in the line of social and structural vulnerabilities offers the opportunity to generate evidence that can assist decision makers about where to invest resources and intervene with greater urgency.**

"...people, they kind of don't want to go to that point, but if we don't work directly on the vulnerabilities of the populations, say the people who live in houses that are not adequate, the suburbs that lack basic services, we are never going to solve the issue... You can have the best early warning system... but if there are people who are still totally forgotten and outside the social system, there are still going to be deaths and illnesses related to heat waves"

(Representative from the Inter-American Institute for Global Change Research)

- Impacts on health

In addition to the need of correlation studies between exposure and health outcomes and vulnerability studies, other research gaps point towards developing studies that look into the impact of heat and CKDu in outdoors workers, since the causes and pathology of this disease are still unclear.

"...that as far as I understand, it is not yet fully defined, the cause, the pathology, is still under investigation."
(Representative from the Inter-American Institute for Global Change Research)

The disease has been mostly investigated in Central America, yet it is not exactly known what is happening in South America, although one key informant reports there is a similar symptom profile to that reported in Central America.

"when we interviewed Nephrologists in Ecuador, the answers were varied, but we did see – and this was not published, but they did tell us – that in rural and agricultural areas they described a pathology, a clinical presentation very similar to what we had heard in Central America".
(Representative from the Inter-American Institute for Global Change Research)

According to a key informant, epidemiological studies with sampling are needed, particularly because there are no early detection activities and because most nephrologists are not in rural areas where these cases might exist.

Apart from CKDu, other key research topics highlighted by the participants include (i) understanding the health effects of extreme heat in combination with other exposures such as air pollution, (ii) to identify the local impacts of extreme heat and (iii) identifying the impacts of extreme heat on children's development.

"...the detail is the combined effects of heat and other factors. So, what other factors are you not taking into consideration besides heat and humidity which is also used for heat waves, but perhaps other components? How can they exacerbate health effects? In the Caribbean, for example, there are

associations between temperatures and Saharan dust, for example. So, it is also difficult to disaggregate the exclusive effect of heat from some components that we are not yet monitoring and that may have a double effect on health.

(Climate change and health expert)

6.2.2 Data Generation and Management

CSA experience challenges with respect to both data generation and capacity for data management and analysis. Regarding data gaps, those identified in the interviews include gaps in health statistics on cases linked to exposure to extreme heat – particularly in Central America – and in recording mortality linked to the lack of International Classification of Diseases (ICD) codes related to extreme heat.

- Health statistics

In Central America, although there is research and cases of people affected by extreme heat, the information is sometimes not generated from the health system, but from the care systems of the firms where activities with exposure to extreme heat occur, leaving any symptom or diagnosis unreported in the health statistics. A key informant shares anecdotally:

"These cases do not reach the health systems because they have care systems within these companies, they have nurses or doctors or small clinics where they give primary care to these people and they are not reported either, neither as incidents nor as illnesses. So, it escapes into the health statistics of the country".

(Representative from La Isla Network and from The Costa Rica Institute of Technology)

Another challenge in terms of data gaps includes the impossibility of identifying mortality caused by extreme heat. Based on the interviews conducted, there is a need to link the ICD codes to heat-related mortality and to CKDu.

"...we found that deaths were not coded as being from exposure to extreme heat, but in general the coding of deaths was by their basic cause and in many cases they were from stroke, ischemic heart disease, renal failure with some renal pathology, diabetes mellitus."

(Representative from the Ministry of Health of Argentina)

However, it should be noted that even if there was a way to record these deaths with ICD codes, the record would not necessarily be timely received to make decisions during the occurrence of the event, as the data itself takes time to be available. Moreover, even if the data was timely, it is not a guarantee that the cause of death will be correct.

"So the idea is to be able to have timely information, because the analysis of mortality is always very delayed. At least in Argentina, the consolidation of mortality databases takes more than a year. So, to be able to analyze mortality a year later, obviously does not allow any decision making".
(Representative from the Ministry of Health of Argentina)

- Data management

On the other hand, it is crucial not only to have the capacity to evaluate, measure, generate data and make it accessible, but also to be able to interpret the findings. There is a gap in scientific production because there are barriers in the management and analysis of data within government entities, including health.

"...the States and governments in our region do not have the capacity to develop research or to develop and manage basic information...
...And it also happens that the States or governments measure, evaluate a lot, a lot, a lot, they take numbers. But there is also no capacity to analyze those numbers".
(Representative from the Chilean Society of Planetary Health)

The need to build technical capacity on data management and analysis has been explicitly mentioned by Caribbean countries, which also have weaknesses and require building those skills. This is particularly a challenge for smaller countries in CSA.

"...from the Caribbean, they indicated to us that their needs and weaknesses were more in analysis, data, geographic information systems, statistics, and informatics "
(Representative from the Inter-American Institute for Global Change Research)

As mentioned by the key informant, even the countries themselves are looking for funding opportunities for data scientist positions, given this need to better understand what is being generated.

"...in some cases, they have asked us for funding, or they have found funding for there to be someone designated within the Ministry of Public Health who can maybe be like a data scientist or someone who is like a point between the climate and health sector, but who works for the government itself."
(Representative from the Inter-American Institute for Global Change Research)

6.2.3 Knowledge Transfer and Co-creation

As mentioned before, Argentina is a case of success in the implementation of heat EWS. A key characteristic to achieve this was the involvement of the academic sector, which worked hand in hand with different ministries. Knowledge transfer from the academics to decision-makers was effective for the political agendas despite the challenges they encountered along the way.

"If these processes are purely from the academic sector, there are often difficulties in the transfer of knowledge generation to the implementation of a policy".
(Representative from the Ministry of Health of Argentina)

For the successful transfer of knowledge, further development of science diplomacy is required. **Strengthen relationships between scientists and decision makers through dialogue, promotes the exchange of perspectives and it's a space from where academics can be voices for those who need representation.** Scientific diplomacy is gaining more prominence among governmental entities. It is necessary in the region to promote these spaces for the co-creation of public policy based on scientific evidence and with the support of scientists, including those from the social sciences.

"...we also heard more about the interest in science diplomacy, that countries and governments are seeing the role of science to support decision making, which is still something new, that there is a lot to strengthen, but we have seen that there is a lot of interest from governments to develop this space.... .... Researchers can come in to help with the process, a process of co-creation, of building spaces for dialogue, of helping to make sure that different perspectives and voices are represented."

(Representative from the Inter-American Institute for Global Change Research)

To this end, it is also important that academia works in such a way as to improve scientific finding communication for decision-makers, and to be able to address the barriers in the process of knowledge transfer.

"In Latin America I think the big problem is that scientists are on one side, politicians are on the other side, there are no instances of communication or participation and that obviously affects everything that is the transfer a posteriori and understanding at different levels."
(Representative from the Chilean Society of Planetary Health)

Also, building trust between actors is key to facilitate the transfer of information and on an ongoing basis, not just for one-offs. Academics have a role in continuing to bring heat risk issues to decision-makers to try to ensure that the topic can be mainstreamed and kept relevant.

"But that also requires building trust and relationships because they are people at the end of the day. So, building that trust and then being able to begin to share information".
(Representative from the Inter-American Institute for Global Change Research)

6.3 Limitations

Given the large list of countries included in the study, it was not possible to obtain the narratives and perceptions of all the countries nor from all the sectors that may be involved in heat risk research (such as agriculture, migration, energy, among others). Therefore, it is considered that the information generated was not saturated due to time constraints, so the results of this objective should be understood considering these limitations.

6.4 Conclusions

The interviews show that the gaps found in the region at the research level respond primarily to gaps linked to (i) timely access to epidemiological data from the Ministry of Health and the country meteorological services, (ii) data management and analysis and (iii) interpretation and communication of results. The key informant interviews confirmed the concern about the lack of research on this topic despite being recognized as an increasing threat due to increasing temperatures in the region. Additional aspects were linked to the lack of consensus on the definition of a heat wave, health impacts of heat waves and in turn, the pressure on the health systems, the identification of structural and social vulnerabilities, the quantification of the additive effects this might have on these communities and finally the lack of or limited heat EWS in most of the countries of the region.

On the other hand, the literature searches carried out for Objectives 1, 2 and 3 show gaps that are in line with the findings of the interviews and suggest more issues that require attention. Apart from those identified in the interviews, there are gaps in the literature in the region, including studies on heat wave events in the last 5 years, on long-term health impacts, heat-related migration, urbanization, economic impact studies, effects on agricultural yields, differential impacts of heat waves on women, as well as impacts on tourism, which is a key economic driver in the region.

7 Priority gaps in emergency heat risk action for future operational considerations

7.1 Methodology

To identify the main gaps in emergency heat risk actions, a total of seven key informant interviews were conducted from governmental and non-governmental institutions representing the health, environment, academia, and government sector from different countries. The interviews were held in Spanish and conducted using the platform Zoom Meetings.

The sessions were recorded, transcribed, and selected quotes were translated into English. Verbal consent to participate and record the video conference was received by all the informants. The interviews were analyzed using qualitative methods, specifically through thematic analysis with an inductive approach on the codification process (See Appendix 6). The software MaxQDA was used to do the qualitative analysis.

In terms of the questions (See Appendix 7), participants were asked about the regional and/or national response to extreme heat events, the level or articulation between government institutions, the existing capacities, and resources to respond, among others.

7.2 Results

The participants contributed their vision from a risk management point of view. The results were categorized according to the different topics where the gaps were described. The categories were identified using an inductive approach, which resulted in the following categories: (i) urgency, (ii) articulation of entities, (iii) lack of operational action, and (iv) distribution of alerts and action. The following section presents a summary as well as excerpts from the interviews, which exemplify and support the contextual interpretation of the interviews.

7.2.1 Urgency

In general, the strengths of the region are oriented towards the experience in risk management of other types that do not involve heat risk. For example, Central America has prioritized issues related to hydro-meteorological events, such as hurricanes, tropical storms, and even geological events such as volcanic eruptions, and is considered to have extensive expertise in these areas.

"...it is not mapped as a priority. For me, from my perspective, it is in hurricanes, the effects related to volcanic eruptions, earthquakes, but not a heat wave. Because it is invisible within the problem of rains and hurricanes"

(Representative from La Isla Network and from The Costa Rica Institute of Technology)

Similarly, in South American countries, such as Paraguay and Colombia, the priority topic has had to do with forest fires, droughts, floods, and the El Niño phenomenon. The perception is that heat is a less tangible and, therefore, a less pressing issue. Other events perceived as more important overshadow heat risk.

"I believe that because it was always focused more on reactivity... when floods or fires occur. There was no focus on the effects of the heat wave itself. So, what is not seen is not studied".

(Representative from Health Emergencies WHO/PAHO)

"As part of the risk management system, I believe that there is a lack of visualization of these phenomena as emergencies as such, let's say, from a risk management perspective. "

(Representative from the National Coordinator for Disaster Reduction of Guatemala)

As mentioned in Objective 3 and 6, in most of CSA, **there is still a lack of knowledge about the impact of heat waves on health and on the health system.** This gap is critical in emergency heat risk actions, as it prevents CSA countries from acknowledging the problem and visualizing the importance extreme heat has, thus hindering the possibilities of timely and adequate response and adaptation planning.

"...to date, there is no established protocol for heat wave emergencies."

(Representative from World Vision Honduras)

To produce and develop evidence-driven risk action plans in response to extreme heat, first it must be determined if heat is a risk priority for the country and public health sector. Based on what the key informants report, a barrier on action in some countries is mainly due to a lack of knowledge and data. To overcome this gap, research is essential—country-level mandates could facilitate data sharing and the commitment from the health and environment sector.

"As long as the Ministry of Public Health does not see it as a priority, the project will not move forward. And that's also why it's so important to have evidence."
(Representative from the Inter-American Institute for Global Change Research)

"...knowing better the social and development dynamics of the population I think could be very helpful... to know how to act and what needs can be covered before such an event"
(Representative from the National Coordinator for Disaster Reduction of Guatemala)

7.2.2 Articulation of Entities

CSA countries have, in general, poor articulation between their ministries. However, the only way to address the challenges posed by climate change is by working and coordinating collaboratively and from a multisectoral perspective.

"Unfortunately, there is no articulation between institutions, since both COPECO[10] and the Secretary of Environment should work together on this issue, but there is no joint work on this issue."
(Representative from World Vision Honduras)

A clear example is with EWS, since multidisciplinary teams and data sources are needed to develop this tool. However, in CSA there is still resistance to working collaboratively across sectors (environment, health, meteorology, etc.).

"In health, perhaps what has happened to us is that decision-makers continue to have a very welfare-based approach. And it is difficult for them to think about how to generate links with other sectors and

[10] COPECO stands for Permanent Commission of Contingencies - Honduras

how other sectors can improve decision making in health. Particularly thinking about the Meteorological Service, perhaps the health authorities found it a little difficult to understand why we had to work in coordination with the meteorological service".

(Representative of the Ministry of Health of Argentina)

In addition, it is observed that collaborative work between governmental entities tends to be specific. And in many cases, it is only limited to sharing data at specific times or in emergencies.

"We have heard "well, we work with climate or meteorology sectors, but only when we ask for data for something specific" But it's not like there's a constant exchange and flow."

(*Representative from the Inter-American Institute for Global Change Research)*

To effectively prepare for these events, it is necessary that governmental entities work articulately, not only between ministries but also with researchers, and not only during emergencies but engaging for long-term collaborations. **It is essential to set up dialogue spaces and work together prior to these events, especially if the objective is to generate climate services such as EWS.** In this area, researchers are a fundamental part, however, it is necessary to understand that although researchers from outside the governmental institutions generate valuable information, it is crucial that for the long term, the own Ministry develops the capacities and has continuity and commitment.

"...it is very important that there is a political and long-term commitment.... This type of collaboration requires a long-term engagement process…"

(*Representative from the Inter-American Institute for Global Change Research)*

7.2.3 Operational Action and Preparedness

In countries where heat waves are already considered a priority and action plans are already in place (e.g., Argentina and Chile), limitations are still observed. The operational actions, in many cases, do not go beyond launching epidemiological alerts or recommendations to the population, as noted in Objective 3 in more detail. Likewise, the key informant indicated that the lack of operationalization is because, generally, the ministries do not have the authority to implement a response

"What happens here is that the Meteorological Directorate collects the information and calls the "technical people" from the involved ministries… In the case of health, by decree, they really have no incentive other than to take out informative papers to the population. That is, they cannot take an action and… they do not have by decree, they do not have those capabilities... … if it is not by decree, they are not going to do it, because the resources and time for them are quite limited. However, it could be that by local initiative, some municipalities make available, for example, these drinking water fountains…or change, for example, some shelters for cooling centers, but that already depends on the will of the mayor … but there is no obligation… or protocol with clear responsibilities."

(Representative from the Chilean Society of Planetary Health)

It is not known whether hospitals increase their staff in the event of extreme events of this type. Therefore, as part of the action plan, considering the increase in health personnel would be necessary. Also, emergency response protocols that consider effective methods to protect vulnerable populations from the effects of heat waves are urgently needed. As recommended in Objective 3, actions must go beyond recommendations and focus on the most disadvantaged sectors. Because government actions are limited by bureaucracy, it is necessary to generate response capacities at the local level together with municipalities, community leaders, and non-governmental organizations.

"I do not believe that change will come from the central level, but rather from the work done at the municipal level"

(Representative from Health Emergencies WHO/PAHO)

"Humanitarian organizations work very closely with the communities and often have a more immediate response capacity than the State, due to its own bureaucratic inertia, which sometimes finds it difficult to respond to extreme phenomena. And in this sense, it seems to me that it is essential to include them in a dialogue and in the generation of response plans".

(Representative of the Ministry of Health of Argentina)

These emergency response capacities at the local level must be lasting and sustainable over time to be effective. In order to achieve that, it is necessary to build and generate local capacities first.

"The subregions need sustainable actions, not just humanitarian-style interventions that we can set up a camp or campaigns and then leave but leave local capacities".
(Representative from Health Emergencies WHO/PAHO)

In addition to the actions taken upon and during an emergency, adaptation and mitigation actions must be undertaken to allow cities to be more resilient to heat. In that sense, better urban planning should be promoted, where less concrete is used and the creation of green spaces, such as parks, green roofs, and vertical green areas, is prioritized. In addition, green spaces could become heat shelters with drinking fountains. Basic services should be prioritized in those areas where they do not yet exist, and where water is rationed.

On the other hand, the population must understand and gain awareness of the impacts of extreme heat on their health, and the additive effects of structural and social vulnerability on their health. This aspect is key for the population, so that they can also be prepared and take individual adaptation actions too. As pointed in Objective 6, the lack of knowledge and address of vulnerabilities in CSA amplifies the consequences of the most vulnerable in the face of an event of this magnitude, increasing the heat risk they are exposed to. Generating compelling and coordinated communications with different actors (Ministry of Health and Environment) is integral to educating the general population so that they can take individual actions.

Health promotion and awareness campaigns focused on the population can be key activities to achieve individual and community engagement. These education activities could be an opportunity for the humanitarian and non-governmental sector to support preparedness. Generating educational campaigns could help mitigate the effects of extreme heat on health and could also strengthen the mechanisms of action taken by the state in the face of these extreme events.

"Reaching the population effectively through face-to-face work with the people, I think it is important. It is a very big problem that there are no government actors in this area. So, humanitarian organizations could make a contribution with more on-the-ground, more operational work."

(Representative from Health Emergencies WHO/PAHO)

7.2.4 Distribution of Alerts and Action

Objective 2 of this report shows that there is limited research identifying which populations are most affected by extreme heat in CSA. According to the findings of that section, the most studied population in the face of extreme heat, and which has been proven to be affected in Central America and some South American countries, are agricultural and construction workers. Despite this evidence and as abovementioned, heat EWS are only aimed at alerting populations in the city.

Although cities have a very high level of complexity towards this type of event due to its high population concentration of vulnerable persons, it is necessary to manage heat in outdoors workers, that in turn increases workers safety and productivity. The requirement for appropriate clothing for this type of work, rest periods, availability of shaded recovery areas, water stations, and changing work schedules to avoid hotter hours, should be mandatory and regulated.

"…They need shade measures, hydration, rest, monitoring, and surveillance of the health status of the workers."

(*Representative from the Inter-American Institute for Global Change Research)*

Furthermore, it is necessary to indicate that another limitation is concerning the dissemination of information. The existing heat warnings are generally made through social media channels, press releases, and some television channels. Since these warnings are focused on a public that uses media, the most vulnerable people (elderly, small children, people with low resources, outdoors workers) are left behind as they normally do not have access to these media sources. For this reason, **it is advisable to use other means of disseminating information so that the transfer of knowledge to those most vulnerable to heat waves is efficient.**

"Because we think that one of the most vulnerable groups are the elderly and if our communication strategy is the social networks, maybe we are not using the best communication strategy. So, we would have to think of other strategies to reach those populations that may not have a good command of the Internet, of the networks. So, we should think about that, about how the different audiences are informed in order to improve the timely arrival of the recommendations."

(Representative of the Ministry of Health of Argentina)

7.3 Limitations

Given the large list of countries included in the study, it was not possible to obtain the narratives and perceptions of all the countries. Moreover, there was limited access to governmental entities that had the time to give an interview, particularly from Central America. At the time this report was made, the region was going through the impacts of several tropical storms and Agatha hurricane, preventing more emergency response entities participating in the interview. It is considered that the information generated did not reach saturation due to these constraints, so the results of this objective should be understood considering these limitations.

7.4 Conclusions

There are great challenges in dealing with heat risk emergencies. A major gap is that, in general, there are no multisectoral and articulated national-level emergency heat risk action plans. There is a need to work hand in hand with municipalities, communities, non-governmental organizations, among others, to have a more effective emergency heat risk response to these events, especially since governments are very often limited in their actions because of bureaucracy. If implemented, heat risk action plans must be sustainable and sustained over time and any efforts to act should consider with care those who are most vulnerable (e.g., people working in rural areas) and expand the scope of action beyond heat EWS exclusive of urban areas.

8 Recommendations

Recommendation 1: Work with local authorities in the identification of groups that are vulnerable to extreme heat to prioritize preparedness and response measures and to improve adaptive capacity.

Gap: The evidence base available on **heat risks** is limited for CSA. This knowledge gap is most noticeable for countries that have a greater climate risk and lowest Human Development Index score (such as Guatemala and El Salvador), which could result in higher vulnerability to heat and therefore, higher heat risk.

Why it matters: Lack of evidence on heat risk in general, but specially, on the most potentially vulnerable countries of Central America, might affect the preparedness and response capacity to heat at national and local level. In turn, this could exacerbate the impacts of extreme heat and heat waves on mortality, morbidity, cities and infrastructure, economy, among others, in a context where temperature projections are estimated to increase about 1.6° to 2.0°C (105).

Opportunity for action: Future work might consider supporting local public health authorities to spatially identify vulnerable people to extreme heat to prioritize preparedness and response measures and to improve adaptive capacity to reduce vulnerabilities. Several areas of individual and social vulnerability could be considered to obtain a general perspective of heat risk. Moreover, using the results on vulnerability factors that are identified by local public health authorities combined and integrated with UTCI should consider public health priorities at local level.

Recommendation 2: Provide tools to government authorities for capacity building. Contribute to raising awareness in stakeholders about heat as a health risk.

Gap: There is a need to increase capacities at government level for proper analysis and data management and generation on climatic events and health outcomes, but also on raising awareness on heat as health risk among governmental organizations, general public, civil society organizations, and healthcare workers

Why it matters: The difficulty of having climatic data that allows determining health impacts in a timely manner poses a barrier for decision-making and efficient preparedness and response capacities upon extreme heat and heat wave events. Moreover, educating stakeholders, including the general population, can encourage behavioral change, empower people, motivate to action and can be a driver for making informed decisions.

Opportunity for action: Future work to build capacity at government level include (i) facilitate training for local governments and public health authorities in epidemiology, data analysis, identification of hazards and vulnerability factors within their communities, (ii) assist in the identification of resources, development of plans and protocol to know what to do in case of extreme heat and heat wave events, (iii) support the public health authorities with weather and climate information and whenever possible liaise between the Ministry of Health and the national meteorological service to accelerate information exchange. Additionally, future work to raise awareness on heat as a health risk could include (i) offering open online courses on health and climate change, (ii) launching social media campaigns, (iii) promoting awareness activities that bring together different stakeholders to foster individual and community engagement.

Recommendation 3: Conduct and/or support research that tackles the diverse impacts of extreme heat.

Gap: The evidence base available on **the impacts of extreme heat and heat waves** in CSA is limited. Much of the literature focuses on the immediate effects of heatwaves (e.g. health outcomes such as dehydration), but more research is required on the long-term effects. For example, on the proliferation of vector-borne diseases and the subsequent effects on health, migration decisions, and occupational choices. The economic implications of heat-related implications are also needed. There is a lack of studies on the economic evaluation of the health impacts of weather-related extreme events covering Central and South America. Nevertheless, economic impacts beyond health for specific countries are also highly important. Most studies rely on simulations and divide the world into regions. They treat Latin America and the Caribbean as a whole and uniform region, ignoring heterogeneous effects within. In agricultural affairs, there is still a big knowledge gap. We don’t know much about the effect of heatwaves on agricultural yields, which could eventually affect the likelihood of many. The differential impact of heat waves on women must also be explored. Even in research related to CKDu, which is the largest to date in the region, further research is needed. Research on the impacts of heat waves on tourism, which is a key economic driver in the region, is absent. Moreover, through the interviews with key informants reported more gaps on the understanding the health effects of extreme heat in combination with other exposures such as air pollution, the local impacts of extreme heat, the effect of heat and children's development and on the need to develop correlation and vulnerability studies.

Why it matters: The literature available worldwide suggests that heat waves and increasing temperatures, which will become more frequent under any climate change scenario, will affect an array of outcomes over the health, economic, and behavioral domains, among others. Though knowledge gaps on the impacts of heat stress were identified, the available literature suggest that even small variations in temperature affect health, proliferation of vector and waterborne diseases, behavior, among others. The literature review and key informant interviews also indicate that the topic has not been widely studied in the CSA region. Even less, when focusing specifically on the effects of heat waves. There is still much uncertainty on the extent and magnitude that heat might pose in the region. Moreover, the region hosts countries with heterogeneous characteristics, and there is a need to understand how they will be differentially impacted. For example, what might be problematic in a highly urbanized country like Argentina, might not necessarily be what causes negative impacts on agricultural workers in Guatemala. Understanding the full impacts of heat and heat waves is therefore important to quantify, prepare, design, and adapt fully populations, health infrastructure, agricultural sectors, labor conditions, among others, to the changing climate conditions according to the specific needs of each country.

Opportunity for action: Conduct and/or support research in the identified topics. Some research questions that could be formulated are: (i) In many places in the CSA region temperatures remain almost constant throughout the year given their closeness to the Equator. How should we define a heat wave in this region? Is it appropriate to focus only on heat waves or on other measures of heat stress? (ii) Are places located in high-altitude vulnerable to heat-stress? Places that were not traditionally warm are becoming warmer due to increasing temperatures. Are populations in these areas prepared to deal with increasing temperatures? Higher than average temperatures can impact them? To what extent? All these questions remain open and could be addressed in future research. (iii)) Are impacts on education, economic growth, conflict, homicides, and other dimensions which have been documented in other regions observed in the CSA region? How does multiple exposures aggravate the health impacts? How do social vulnerabilities and inequalities characteristic of CSA countries exacerbate/mitigate these impacts? Moreover, in many countries in the CSA region, extreme heat events have been associated to ENSO-El Niño but they are not considered a risk on its own. More research on the impacts of extreme heat, temperature variability, and other measures, could indicate whether they should be addressed separately, or if they also occur in times when ENSO is not declared.

Recommendation 4: Conduct and/or support research that provide evidence on feasibility, and effectiveness of heat EWS. Work with health authorities to identify supply needs to increase monitoring stations and to protect the most vulnerable during heat wave events.

Gap: Heat Early Warning Systems (EWS) is an emerging topic and intervention in CSA. There is limited information on **heat EWS** or any topic related with heat action plans. The countries with existing heat EWS are city-based only and use temperature as a trigger and do not take into consideration humidity. Furthermore, when the warnings are issued, no further action is taken on behalf of the Ministries of Health. In many cases, there are no protocols to deal with an event of this magnitude since there still exists a lack of knowledge about the impacts of these extreme events. On the other hand, in countries where EWS exist, no studies demonstrate their effectiveness.

Why does it matter: Heat EWS, which are vastly absent in CSA, are meant to reduce human health impacts with the issue of timely warnings and prevention measures, particularly to the most vulnerable (106). Increases in mortality during heat waves are preventable and based on the findings of this report, CSA has year-round exposure to heat-stress and experience temperature anomalies. The limited investment and implementation of adaptation measures that include heat EWS in a context with historical vulnerabilities such as those of CSA do not protect everyone or save lives.

Opportunity for action: (i) In countries that have not yet planned heat EWS, it is recommended to conduct or support implementation studies that demonstrate the feasibility of undertaking these interventions. Studies such as these are essential for decision-makers to prioritize the topic. (ii) Studies on the effectiveness of heat EWS do not yet exist in CSA countries with implemented EWS. Conducting or collaborating with studies that determine whether the current EWS works or needs to be calibrated are important. (iii) It is advisable to review the coverage of monitoring stations each country has, to determine if there is enough coverage. This includes reviewing the capacity of monitoring humidity to introduce it as a trigger parameter. (iv) Many of the recommendations of the Ministry of Health are made for a more socioeconomically accessible public. Recommendations such as: *"Do not expose yourself to the sun in central hours of the day (between 11 and 17 hours)", "Stay in the coldest place in the house or the shade outdoors",* and

"*Take 2 or 3 refreshing showers daily"*, may be impossible to comply for people with low-income who might have limited access to water and/or need to expose themselves to outdoors work. Therefore, it is recommended to work together with health authorities to identify what are the supplies needed to protect the most disadvantaged sectors. Supporting the community by providing drinking water and equipping spaces that could be used as cooling centers can help minimize the impacts of heatwaves.

Recommendation 5: Explore the possibilities of undertaking a cross-sectoral collaboration with actors and organizations in CSA.

Gap: In CSA there is a gap of actors and organizations working to implement interventions to adapt to extreme heat and mitigate impacts, conduct research, provide funding for research, build capacity and work in advocacy. Moreover, it is unclear why there are few actors or organizations focused on heat and heat waves in the region despite its vulnerability. Finally, the information available of the identified actors and organizations is limited and might not reflect the real scope of their work.

Why it matters: The challenges posed by climate change require cross-sectoral and transdisciplinary collaborations in order to provide enduring and credible projects and solutions. In accordance with the 2030 Agenda, joining efforts on climate action (SDG 13) through the development of partnerships for goals (SDG 17) is an opportunity to achieve Sustainable Development Goals but also to drive change in policy and practice. Fostering collaboration across boundaries in the topic of extreme heat in CSA is an opportunity to create a space for coordinated regional preparedness and response.

Opportunity for action: (i) Through the identification of actors carried out for this report, it is suggested to continue with the elaboration of a stakeholder analysis in order to gain more understanding on the scope of work of each actor and organization has (consider developing interviews with key informant) and to identify possibilities of alignment on goals and plans. (ii) Future work can include also an analysis of future actions to promote collaboration and consensus among the actors and organizations already working in CSA in order to undertake research, capacity building and advocacy. (iii) Building a regional collaboration could also be helpful to co-design and co-create a conceptual framework that optimizes the development of specific interventions that mitigate the impact of extreme heat and heat waves and facilitates adaptive and coping capacity in the region.

Recommendation 6: Favor multisectoral and articulated action with national authorities to protect human health and wellbeing for all

Gap: When managing heat risk emergencies, siloes prevail between national authorities (intersectoral) and other sectors (multisectoral). This lack of coordination with different actors and entities, such as municipalities, communities, non-governmental organizations, among others, hinders effective emergency heat risk response in the case these events happen. In addition to the lack of articulation upon an emergency, there is also a need to also build consistent dialogues between sectors, including academia.

Why is important: Multisectoral collaboration and coordinated action are crucial to protect human health and wellbeing for all. Adequate governance to tackle the diverse social determinants of health go beyond sectoral boundaries, including the preparedness and response to extreme heat and heat waves. Encouraging cross-sectoral articulation, and the inclusion of academic voices, such as researcher and scientists, could facilitate good governance, exchange of information, resources, data and evidence and in general, enable “win-win” situations (107).

Opportunity for action: Future work could entail: (i) providing training and capacity building on how to structure, manage and coordinate multisectoral and intersectoral work, (ii) promote the development of interministerial committees, (iii) facilitate and promote processes of co-design and co-production of heat emergency plans that bring together researchers and decision-makers, (iv) design toolkits for planning, indicators and monitoring tools that allow to measure progress on implementation of coordinated action (107).

Glossary

Early Warning System: The set of technical, financial, and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss (108).

Extreme heat: Summertime temperatures that are much hotter and/or humid than average (109).

Heat action plan: Document designed to act in the event of an extreme heat event. Heat Action Plans aim to provide a framework for implementation, coordination and evaluation of extreme heat response activities that reduces the negative impact of extreme heat (110).

Heat island: Urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas (111)

Heat risk: Heat risk is understood as the risk of negative impacts of heat stress exposure on human health and wellbeing. Risk, as a function of hazard, exposure, and vulnerability (112), might increase or decrease according to the degree of population exposure to heat (hazard) and individual or social vulnerability factors. These factors might increase the risk due to biological susceptibility characteristics of each individual, as well as adaptive capacity factors at different levels (e.g., individual, community, country) (113).

Heat wave: Three or more consecutive days above one of the following: the 90th percentile for maximum temperature (96). Please take note there is no globally accepted definition. This definition has been used for Objective 5.

Thermal stress: Thermal stress includes both heat and cold stress. These conditions arise when temperatures become too extreme for the body to handle and try to compensate for. The body's temperature will decrease in the case of cold stress, causing a potentially life-threatening condition called hypothermia. More commonly, when there is more heat than the body can dissipate, heat stress can occur in various forms. These may include heat rash, heat cramps, heat exhaustion and, most serious of all, heat stroke (114).

Vulnerability: the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (113).

References

1. World Health Organization. Heat and Health [Internet]. 2018 [cited 2022 Jun 30]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

2. Smoyer-Tomic KE, Kuhn R, Hudson A. Heat Wave Hazards: An Overview of Heat Wave Impacts in Canada. Natural Hazards 2003 28:2 [Internet]. 2003;28(2):465–86. Available from: https://link.springer.com/article/10.1023/A:1022946528157

3. Guirguis K, Gershunov A, Tardy A, Basu R. The impact of recent heat waves on human health in California. Journal of Applied Meteorology and Climatology. 2014;53(1):3–19.

4. Brás TA, Seixas J, Carvalhais N, Jagermeyr J. Severity of drought and heatwave crop losses tripled over the last five decades in Europe. Environmental Research Letters [Internet]. 2021 Jun;16(6):065012. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/abf004 https://iopscience.iop.org/article/10.1088/1748-9326/abf004/meta

5. Ioannou LG, Mantzios K, Tsoutsoubi L, Panagiotaki Z, Kapnia AK, Ciuha U, et al. Effect of a Simulated Heat Wave on Physiological Strain and Labour Productivity. International Journal of Environmental Research and Public Health 2021, Vol 18, Page 3011 [Internet]. 2021 Mar;18(6):3011. Available from: https://www.mdpi.com/1660-4601/18/6/3011/htm https://www.mdpi.com/1660-4601/18/6/3011

6. Li X, Ding Y, Yu Z, Mika S, Liu S, Shangguan D, et al. An 80-year summer temperature history from the Xiao Dongkemadi ice core in the central Tibetan Plateau and its association with atmospheric circulation. Journal of Asian Earth Sciences [Internet]. 2015 Feb 1 [cited 2020 Oct 16];98:285–95. Available from: http://www.sciencedirect.com/science/article/pii/S1367912014004386

7. Campbell S, Remenyi TA, White CJ, Johnston FH. Heatwave and health impact research: A global review. Health & Place [Internet]. 2018 Sep 1 [cited 2020 Sep 23];53:210–8. Available from: http://www.sciencedirect.com/science/article/pii/S1353829218301205

8. World Bank. Porverty and equity brief Latin America and the Caribbean [Internet]. World Bank; 2020 p. 40. Available from:

https://databank.worldbank.org/data/download/poverty/33EF03BB-9722-4AE2-ABC7-AA2972D68AFE/Global_POVEQ_LAC.pdf

9. de Freitas CR, Grigorieva EA. A comparison and appraisal of a comprehensive range of human thermal climate indices. International Journal of Biometeorology [Internet]. 2017 Mar 1;61(3):487–512. Available from: https://doi.org/10.1007/s00484-016-1228-6

10. Eckstein D, Künzel V, Schäfer L. Global Climate Risk Index 2021. Who suffers most from extreme weather events? Weather-related loss events in 2019 and 2020-2019. [Internet]. 2021. Available from: www.germanwatch.org

11. UNDP. Regional Human Development Report 2021. Traped: High Inequality and Low Growth in Latin America and The Caribbean. New York; 2021.

12. Jendritzky G, de Dear R, Havenith G. UTCI—Why another thermal index? [Internet]. Vol. 56, International Journal of Biometeorology. 2012. p. 421–8. Available from: https://doi.org/10.1007/s00484-011-0513-7

13. Błażejczyk K, Jendritzky G, Bröde P, Fiala D, Havenith G, Epstein Y, et al. An introduction to the Universal Thermal Climate Index (UTCI) [Internet]. Vol. 86. IGiPZ PAN; 2013. p. 5–10. Available from: http://rcin.org.pl/igipz/dlibra/publication/edition/29010

14. Di Napoli C, Pappenberger F, Cloke HL. Assessing heat-related health risk in Europe via the Universal Thermal Climate Index (UTCI) [Internet]. Vol. 62, International Journal of Biometeorology. 2018. p. 1155–65. Available from: https://doi.org/10.1007/s00484-018-1518-2

15. Di Napoli C, Barnard C, Prudhomme C, Cloke HL, Pappenberger F. ERA5-HEAT: A global gridded historical dataset of human thermal comfort indices from climate reanalysis [Internet]. Vol. 8, Geoscience Data Journal. 2021. p. 2–10. Available from: https://doi.org/10.1002/gdj3.102

16. ECMWF. Thermal comfort indices derived from ERA5 reanalysis. [Internet]. 2020. Available from: https://cds.climate.copernicus.eu

17. University. C for IESINCC. Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11. NASA Socioeconomic Data and Applications Center (SEDAC); 2018.

18. Calil J. Replication data for Calil et al. (2017): LAC Shapefile [Internet]. Harvard Dataverse; 2017. Available from: https://doi.org/10.7910/DVN/OSNGFE

19. Bell ML, O'Neill MS, Ranjit N, Borja-Aburto VH, Cifuentes LA, Gouveia NC. Vulnerability to heat-related mortality in Latin America: a case-crossover study in São Paulo, Brazil, Santiago, Chile and Mexico City, Mexico. International Journal of Epidemiology [Internet]. 2008 Aug [cited 2022 May 23];37(4):796–804. Available from: https://doi.org/10.1093/ije/dyn094

20. Romero-Lankao P, Qin H, Hughes S, Haeffner M, Borbor-Cordova M. Chapter 10 Urban Vulnerability and Adaptation to the Health Impacts of Air Pollution and Climate Extremes in Latin American Cities [Internet]. Holt WG, editor. Urban Areas and Global Climate Change. Emerald Group Publishing Limited; 2012. p. 247–75. (Research in Urban Sociology; vol. 12). Available from: https://doi.org/10.1108/S1047-0042(2012)0000012013

21. Green H, Bailey J, Schwarz L, Vanos J, Ebi K, Benmarhnia T. Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological evidence and considerations for future research. Environmental Research [Internet]. 2019 Apr;171:80–91. Available from: https://www.sciencedirect.com/science/article/pii/S0013935119300106

22. Silveira IH, Oliveira BFA, Cortes TR, Junger WL. The effect of ambient temperature on cardiovascular mortality in 27 Brazilian cities [Internet]. Vol. 691, Science of The Total Environment. 2019. p. 996–1004. Available from: https://www.sciencedirect.com/science/article/pii/S0048969719330669

23. Moreno AR. Climate change and human health in Latin America: drivers, effects, and policies [Internet]. Vol. 6, Regional Environmental Change. 2006. p. 157–64. Available from: https://doi.org/10.1007/s10113-006-0015-z

24. Redmon JH, Levine KE, Lebov J, Harrington J, Kondash AJ. A comparative review: Chronic Kidney Disease of unknown etiology (CKDu) research conducted in Latin America versus Asia. Environmental Research [Internet]. 2021 Jan;192:110270. Available from: https://www.sciencedirect.com/science/article/pii/S0013935120311671

25. Carneiro E, Lopes W, Espindola G. Linking Urban Sprawl and Surface Urban Heat Island in the Teresina–Timon Conurbation Area in Brazil. Vol. 10, Land. 2021.

26. Dell M, Jones BF, Olken BA. What Do We Learn from the Weather? The New Climate-Economy Literature. Journal of Economic Literature [Internet]. 2014;52(3):740–98. Available from: https://www.aeaweb.org/articles?id=10.1257/jel.52.3.740

27. Garlati A. Climate change and extreme weather events in Latin America: An exposure index. IDB Working paper [Internet]. 2013; Available from: https://publications.iadb.org/publications/english/document/Climate-Change-and-Extreme-Weather-Events-in-Latin-America-An-Exposure-Index.pdf

28. Kephart JL, Sánchez BN, Moore J, Schinasi LH, Bakhtsiyarava M, Ju Y, et al. Extreme temperatures and mortality in 326 Latin American cities. medRxiv [Internet]. 2021 Jan;2021.11.16.21266420. Available from: http://medrxiv.org/content/early/2021/11/17/2021.11.16.21266420.abstract

29. Chesini F, Herrera N, Skansi M, González C, Fontán S, Savoy F, et al. Mortality risk during heat waves in the summer 2013-2014 in 18 provinces of Argentina: Ecological study. Ciencia & saude coletiva. :2071–86.

30. Prosdocimi D, Klima K. Health effects of heat vulnerability in Rio de Janeiro: a validation model for policy applications. SN Applied Sciences [Internet]. 2020 Nov;2(12):1948. Available from: https://doi.org/10.1007/s42452-020-03750-7

31. Sera F, Armstrong B, Tobias A, Vicedo-Cabrera AM, Åström C, Bell ML, et al. How urban characteristics affect vulnerability to heat and cold: a multi-country analysis. International Journal of Epidemiology [Internet]. 2019 Aug [cited 2022 May 25];48(4):1101–12. Available from: https://doi.org/10.1093/ije/dyz008

32. Helo J. Into the Tropics: Temperature, Mortality, and Access to Health Care in Colombia. 2022; Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4113821

33. Vicedo-Cabrera AM, Scovronick N, Sera F, Royé D, Schneider R, Tobias A, et al. The burden of heat-related mortality attributable to recent human-induced climate change. Nature Climate Change [Internet]. 2021 Jun 1;11(6):492–500. Available from: https://doi.org/10.1038/s41558-021-01058-x

34. Gasparrini A, Guo Y, Sera F, Vicedo-Cabrera AM, Huber V, Tong S, et al. Projections of temperature-related excess mortality under climate change scenarios. The Lancet Planetary

health [Internet]. 2017 Dec;1(9):e360–7. Available from: https://pubmed.ncbi.nlm.nih.gov/29276803

35. Fan Y, Pei-Syuan L, Im ES, Lo MH. Regional disparities in the exposure to heat-related mortality risk under 1.5 °C and 2 °C global warming. Environmental Research Letters. 2022;17(5).

36. Zhao Q, Li S, Coelho MSZS, Saldiva PHN, Hu K, Huxley RR, et al. The association between heatwaves and risk of hospitalization in Brazil: A nationwide time series study between 2000 and 2015 [Internet]. Vol. 16, PLOS Medicine. 2019. p. e1002753. Available from: https://doi.org/10.1371/journal.pmed.1002753

37. Helo J. Temperature and Morbidity in Colombia. Work in progress [Internet]. 2021; Available from: https://www.dropbox.com/s/epby5wucib42z2m/ClimateMorbidity_JH_v1.pdf?dl=0

38. Siraj AS, Santos-Vega M, Bouma MJ, Yadeta D, Carrascal DR, Pascual M. Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia. Science [Internet]. 2014;343(6175):1154–8. Available from: https://www.science.org/doi/abs/10.1126/science.1244325

39. The World Bank. Rural population (% of total population) - Honduras, Costa Rica, Nicaragua, Guatemala, Panama, El Salvador | Data [Internet]. 2018 [cited 2022 Jun 20]. Available from: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=HN-CR-NI-GT-PA-SV

40. Crowe J, Nilsson M, Kjellstrom T, Wesseling C. Heat-Related symptoms in sugarcane harvesters: Heat-Related Symptoms in Sugarcane Harvesters. American journal of industrial medicine. 2015 May;58:541–8.

41. Jayasumana C, Orantes C, Herrera R, Almaguer M, Lopez L, Silva LC, et al. Chronic interstitial nephritis in agricultural communities: a worldwide epidemic with social, occupational and environmental determinants. Nephrology Dialysis Transplantation [Internet]. 2017 Feb [cited 2022 May 25];32(2):234–41. Available from: https://doi.org/10.1093/ndt/gfw346

42. Ordunez P, Nieto FJ, Martinez R, Soliz P, Giraldo GP, Mott SA, et al. Chronic kidney disease mortality trends in selected Central America countries, 1997–2013: clues to an epidemic of chronic interstitial nephritis of agricultural communities. Journal of Epidemiology and

Community Health [Internet]. 2018 Apr;72(4):280. Available from: http://jech.bmj.com/content/72/4/280.abstract

43. García-Trabanino R, Jarquín E, Wesseling C, Johnson RJ, González-Quiroz M, Weiss I, et al. Heat stress, dehydration, and kidney function in sugarcane cutters in El Salvador – A cross-shift study of workers at risk of Mesoamerican nephropathy. Environmental Research [Internet]. 2015 Oct;142:746–55. Available from: https://www.sciencedirect.com/science/article/pii/S0013935115300281

44. Bodin T, García-Trabanino R, Weiss I, Jarquín E, Glaser J, Jakobsson K, et al. Intervention to reduce heat stress and improve efficiency among sugarcane workers in El Salvador: Phase 1. Occupational and Environmental Medicine [Internet]. 2016 Jun;73(6):409. Available from: http://oem.bmj.com/content/73/6/409.abstract

45. Gallo-Ruiz L, Sennett C, Sánchez-Delgado M, García-Urbina A, Gámez-Altamirano T, Peer K, et al. Prevalence and Risk Factors for CKD Among Brickmaking Workers in La Paz Centro, Nicaragua. American Journal of Kidney Diseases. 2019 Feb;74.

46. Wesseling C, Glaser J, Rodríguez-Guzmán J, Weiss I, Lucas R, Peraza S, et al. Chronic kidney disease of non-traditional origin in Mesoamerica: a disease primarily driven by occupational heat stress. Revista panamericana de salud publica = Pan American journal of public health [Internet]. 2020 Jan;44:e15–e15. Available from: https://pubmed.ncbi.nlm.nih.gov/31998376

47. Butler-Dawson J, Krisher L, Dally M, James KA, Johnson RJ, Jaramillo D, et al. Sugarcane Workweek Study: Risk Factors for Daily Changes in Creatinine. Kidney international reports [Internet]. 2021 Jun;6(9):2404–14. Available from: https://pubmed.ncbi.nlm.nih.gov/34514201

48. Dally M, Butler-Dawson J, Krisher L, Monaghan A, Weitzenkamp D, Sorensen C, et al. The impact of heat and impaired kidney function on productivity of Guatemalan sugarcane workers. PloS one [Internet]. 2018 Oct;13(10):e0205181–e0205181. Available from: https://pubmed.ncbi.nlm.nih.gov/30289894

49. Petropoulos ZE, Ramirez-Rubio O, Scammell MK, Laws RL, Lopez-Pilarte D, Amador JJ, et al. Climate Trends at a Hotspot of Chronic Kidney Disease of Unknown Causes in Nicaragua, 1973-2014. International journal of environmental research and public health [Internet]. 2021 May;18(10):5418. Available from: https://pubmed.ncbi.nlm.nih.gov/34069421

50. Wesseling C, Aragón A, González M, Weiss I, Glaser J, Bobadilla NA, et al. Kidney function in sugarcane cutters in Nicaragua – A longitudinal study of workers at risk of Mesoamerican nephropathy. Environmental Research [Internet]. 2016 May;147:125–32. Available from: https://www.sciencedirect.com/science/article/pii/S0013935116300433

51. Laws R, Brooks D, Amador J, Weiner D, Kaufman J, Ramirez-Rubio O, et al. Biomarkers of Kidney Injury Among Nicaraguan Sugarcane Workers. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2015 Oct;67.

52. Crowe J, van Wendel de Joode B, Wesseling C. A pilot field evaluation on heat stress in sugarcane workers in Costa Rica: What to do next? Global Health Action [Internet]. 2009 Nov;2(1):2062. Available from: https://doi.org/10.3402/gha.v2i0.2062

53. Crowe J, Manuel Moya-Bonilla J, Román-Solano B, Robles-Ramírez A. Heat exposure in sugarcane workers in Costa Rica during the non-harvest season. Global Health Action [Internet]. 2010 Dec;3(1):5619. Available from: https://doi.org/10.3402/gha.v3i0.5619

54. Crowe J, Wesseling C, Solano B, Umaña M, Ramírez A, Kjellstrom T, et al. Heat exposure in sugarcane harvesters in Costa Rica. American journal of industrial medicine. 2013 Oct;56.

55. Andalón M, Azevedo JP, Rodríguez-Castelán C, Sanfelice V, Valderrama-González D. Weather Shocks and Health at Birth in Colombia. World Development [Internet]. 2016 Jun;82:69–82. Available from: https://www.sciencedirect.com/science/article/pii/S0305750X16000139

56. Molina O, Saldarriaga V. The perils of climate change: In utero exposure to temperature variability and birth outcomes in the Andean region. Economics & Human Biology [Internet]. 2017;24:111–24. Available from: https://www.sciencedirect.com/science/article/pii/S1570677X1630212X

57. Silvero F, Lops C, Montelpare S, Rodrigues F. Impact assessment of climate change on buildings in Paraguay—Overheating risk under different future climate scenarios. Building Simulation [Internet]. 2019 Dec 1;12(6):943–60. Available from: https://doi.org/10.1007/s12273-019-0532-6

58. Mettler-Grove J. Impactos en la salud pública y desigualdades frente al cambio climático en América Latina: Una aproximación hacia las consecuencias diferenciales de las inundaciones

y olas de calor en la Cuenca Matanza Riachuelo. [Internet]. Independent Study Project; 2020. Available from: https://digitalcollections.sit.edu/cgi/viewcontent.cgi?article=4328&context=isp_collection

59. Feron S, Cordero RR, Damiani A, Llanillo PJ, Jorquera J, Sepulveda E, et al. Observations and Projections of Heat Waves in South America [Internet]. Vol. 9, Scientific Reports. 2019. p. 8173. Available from: https://doi.org/10.1038/s41598-019-44614-4

60. KIGALI. Chilling prospects. Tracking sustainable cooling for all. 2021 [Internet]. 2021. Available from: https://www.seforall.org/system/files/2021-05/Chilling-Prospects-21-SEforALL.pdf

61. Fletcher DH, Likongwe PJ, Chiotha SS, Nduwayezu G, Mallick D, Uddin Md. N, et al. Using demand mapping to assess the benefits of urban green and blue space in cities from four continents. Science of The Total Environment [Internet]. 2021 Sep;785:147238. Available from: https://www.sciencedirect.com/science/article/pii/S0048969721023093

62. Hernandez K, Madeira C. The impact of climate change on economic output across industries in Chile. PLOS ONE [Internet]. 2022 Apr;17(4):e0266811. Available from: https://doi.org/10.1371/journal.pone.0266811

63. Kjellstrom T, Crowe J. Climate Change, Workplace Heat Exposure, and Occupational Health and Productivity in Central America. International Journal of Occupational and Environmental Health [Internet]. 2011 Jul;17(3):270–81. Available from: https://www.tandfonline.com/doi/abs/10.1179/107735211799041931

64. Marmai N, Franco Villoria M, Guerzoni M. How the Black Swan damages the harvest: Extreme weather events and the fragility of agriculture in development countries. PLOS ONE [Internet]. 2022 Feb;17(2):e0261839. Available from: https://doi.org/10.1371/journal.pone.0261839

65. Casali L, Herrera JM, Rubio G. Resilient soybean and maize production under a varying climate in the semi-arid and sub-humid Chaco. European Journal of Agronomy [Internet]. 2022 Apr;135:126463. Available from: https://www.sciencedirect.com/science/article/pii/S1161030122000119

66. Rocha JF, Martínez R, López-Villalobos N, Morris ST. Tick burden in Bos taurus cattle and its relationship with heat stress in three agroecological zones in the tropics of Colombia.

Parasites & Vectors [Internet]. 2019 Feb;12(1):73. Available from: https://doi.org/10.1186/s13071-019-3319-9

67. Kjellstrom T, Kovats RS, Lloyd SJ, Holt T, Tol RSJ. The Direct Impact of Climate Change on Regional Labor Productivity. Archives of Environmental & Occupational Health [Internet]. 2009 Nov;64(4):217–27. Available from: https://doi.org/10.1080/19338240903352776

68. ILO. Working on a warmer planet. The impact of heat stress on labour productivity and decent work [Internet]. ILO; 2019. Available from: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf

69. Ibañez AM, Quigua J, Romero J, Velásquez A. Responses to Temperature Shocks: Labor Markets and Migration Decisions in El Salvador. IDB Working paper [Internet]. 2022; Available from: https://publications.iadb.org/publications/english/document/Responses-to-Temperature-Shocks-Labor-Markets-and-Migration-Decisions-in-El-Salvador.pdf

70. Baez J, Caruso G, Mueller V, Niu C. Heat Exposure and Youth Migration in Central America and the Caribbean. American Economic Review. 2017 May;107:446–50.

71. Fishman R, Carrillo P, Russ J. Long-term impacts of exposure to high temperatures on human capital and economic productivity. Journal of Environmental Economics and Management. 2019;93:221–38.

72. Marengo JA, Cunha AP, Cuartas LA, Deusdará Leal KR, Broedel E, Seluchi ME, et al. Extreme Drought in the Brazilian Pantanal in 2019–2020: Characterization, Causes, and Impacts. Frontiers in Water [Internet]. 2021 [cited 2022 May 1];3. Available from: https://www.frontiersin.org/article/10.3389/frwa.2021.639204

73. WMO. State of the Climate in Latin America and the Caribbean, 2020 [Internet]. WMO; 2021. Available from: https://reliefweb.int/report/world/state-climate-latin-america-and-caribbean-2020

74. Government of Suriname. Suriname National Adaptation Plan [Internet]. Paramaribo: Government of Suriname; 2019. Available from: http://extwprlegs1.fao.org/docs/pdf/sur204199.pdf

75. Secretaría de Gobierno de Ambiente y Desarrollo Sustentable. Plan Nacional de Adaptación y Mitigación al Cambio Climático de Argentina [Internet]. Buenos Aires; 2019 p. 283. Report No.: 1. Available from: https://www.argentina.gob.ar/sites/default/files/plan_nacional_de_adaptacion_y_mitigacion_al_cambio_climatico_2019.pdf

76. Ministerio del Ambiente. Plan Nacional de Adaptación al Cambio Climático del Perú [Internet]. Lima; 2021. Available from: https://cdn.www.gob.pe/uploads/document/file/1936379/RM. 096-2021-MINAM con anexo Plan Nacional de Adaptaci{\'{o}}n al Cambio Clim{\'{a}}tico del Per{\'{u}}.pdf.pdf

77. Secretaría del Ambiente, Programa de las Naciones Unidas para el Desarrollo, Fondo Mundial para el Medio Ambiente. Plan Nacional de Adaptación al Cambio Climático de Paraguay [Internet]. Asunción: Oficina Nacional de Cambio Climático; 2017. Available from: http://dncc.mades.gov.py/wp-content/uploads/2018/11/Plan-Nacional-de-Adaptaci{\'{o}}n-al-CC-2017.pdf

78. Ministerio de Medio Ambiente y Recursos Naturales. Plan Nacional de Adaptación al Cambio Climático de El Salvador [Internet]. San Salvador: Ministerio de Medio Ambiente y Recursos Naturales (MARN) Kilómetro; 2019 p. 58. Available from: http://rcc.marn.gob.sv/xmlui/bitstream/handle/123456789/371/PlanNacionalAdaptacionCC.pdf?sequence=1&isAllowed=y

79. Departamento Nacional de Planeación, Ministerio de Medio Ambiente y Desarrollo Sostenible, Instituto de Hidrología Meteorología y Estudios Ambientales, Unidad Nacional para la Destión de Riesgo de Desastres. Plan Nacional de Adaptación al Cambio Climático de Colombia [Internet]. Plan Nacional de Adaptación al Cambio Climático. Bogotá; 2016 p. 1–78. Available from: https://www.minambiente.gov.co/wp-content/uploads/2022/01/PNACC-2016-linea-accion-prioritarias.pdf

80. Ministerio del Medio Ambiente. Plan Nacional de Adaptación al Cambio Climático de Chile. Santiago de Chile; 2014.

81. Dirección de Cambio Climático, Ministerio de Ambiente y Energía. Plan Nacional de Adaptación al Cambio Climático 2022-2026 de Costa Rica [Internet]. San José; 2022 p. 204.

Available from: https://cambioclimatico.go.cr/wp-content/uploads/2022/04/NAP_Documento-2022-2026_VC.pdf

82. Secretaría de Recursos Naturales y Ambiente. Plan Nacional de Adaptación al Cambio Climático - Honduras [Internet]. Tegucigalpa; 2018 p. 64. Available from: http://www.miambiente.gob.hn/media/adjuntos/pdf/DNCC/2018-05-10/16%3A35%3A53.282976%2B00%3A00/PNA.pdf

83. Ministerio de Ambiente, Ministerio de Vivienda y Ordenamiento Territorial. Plan Nacional de Adaptación a la Variabilidad y el Cambio Climático en ciudades e infraestructuras de Uruguay [Internet]. Montevideo: Ministerio de Ambiente; 2021. Available from: https://www.gub.uy/ministerio-ambiente/comunicacion/publicaciones/plan-nacional-adaptacion-variabilidad-cambio-climatico-ciudades

84. Ministerio Agropecuario y Forestal. Plan de Adaptación a la variabilidad y el Cambio Climático en el Sector Agropecuario, Forestal y Pesca en Nicaragua. 2015;0–130.

85. Consejo Nacional de Cambio Climático. Plan de acción nacional de cambio climático de Guatemala [Internet]. Ciudad de Guatemala: Segeplán (Secretaría de Planificación y Programación de la Presidencia); 2016 p. 160. Available from: http://sgccc.org.gt/wp-content/uploads/2016/10/Plan-de-Acción-Nacional-de-Cambio-Climático-ver-oct-2016-aprobado-1.pdf

86. Ministry of Environment. National Adaptation Plan to Climate Change of Brazil [Internet]. Brasilia: Ministry of Environment; 2016. Report No.: 1. Available from: https://antigo.mma.gov.br/images/arquivo/80182/BOOK_PNA_Executive Summary v4.pdf

87. Ministry of Forestry Fisheries and Sustainable Development. A National Adaptation Strategy to Address Climate Change in the Agriculture Sector in Belize [Internet]. 2015. Available from: http://www.caribbeanclimate.bz

88. Servicio Meteorologico Nacional de Argentina. Temperaturas extremas [Internet]. [cited 2022 Jun 28]. Available from: https://www.smn.gob.ar/sistema_temp_extremas_calor

89. Ministerio del Interior y Seguridad Pública de Chile. Previene, informate y prepárate: Calor Extremo, Ola de Calor [Internet]. Previene, informate y prepárate: Calor Extremo, Ola de Calor. Available from:

http://repositoriodigital.onemi.gov.cl/bitstream/handle/2012/1822/PrevieneCalorExtremo_Final.pdf?sequence=9

90. Instituto Uruguayo de Meteorología. ¿Qué es una Ola de Calor y una Ola de Frío? [Internet]. [cited 2022 Jun 17]. Available from: https://www.inumet.gub.uy/sala-de-prensa/videos/que-es-una-ola-de-calor-y-una-ola-de-frio

91. Sistema Nacional de Emergencias. Ola de Calor [Internet]. [cited 2022 Jun 17]. Available from: https://www.gub.uy/sistema-nacional-emergencias/politicas-gestion/ola-calor

92. Ministerio de Salud Pública de Uruguay. Recomendaciones del MSP para hacer frente a la ola de calor [Internet]. Ministerio de Salud Pública. [cited 2022 Jun 28]. Available from: https://www.gub.uy/ministerio-salud-publica/comunicacion/noticias/recomendaciones-del-msp-para-hacer-frente-ola-calor

93. Office M. What is a heatwave? [Internet]. Vol. 2022. Met Office; Available from: https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/temperature/heatwave

94. Büchs M. The role of environmental organisations in supporting carbon reduction: comparing direct and indirect involvement. Environmental Politics. 2014 Nov 2;23(6):1003–22.

95. Perkins SE, Alexander LV. On the Measurement of Heat Waves. Journal of Climate [Internet]. 2013;26(13):4500–17. Available from: https://journals.ametsoc.org/view/journals/clim/26/13/jcli-d-12-00383.1.xml

96. World Meteorological Organization. Updated 30-year reference period reflects changing climate [Internet]. 2021 [cited 2022 Jun 21]. Available from: https://public.wmo.int/en/media/news/updated-30-year-reference-period-reflects-changing-climate

97. Costa IT, Wollmann CA, Gobo JP, Ikefuti PV, Shooshtarian S, Matzarakis A. Extreme Weather Conditions and Cardiovascular Hospitalizations in Southern Brazil. Vol. 13, Sustainability. 2021.

98. Geirinhas JL, Trigo RM, Libonati R, Castro LCO, Sousa PM, Coelho CAS, et al. Characterizing the atmospheric conditions during the 2010 heatwave in Rio de Janeiro marked by excessive mortality rates. Vol. 650, Sci Total Environ. 2019. p. 796–808.

99. Guo Y, Gasparrini A, Armstrong Ben G, Tawatsupa B, Tobias A, Lavigne E, et al. Heat Wave and Mortality: A Multicountry, Multicommunity Study [Internet]. Vol. 125, Environmental Health Perspectives. p. 087006. Available from: https://doi.org/10.1289/EHP1026

100. Smith P, Henríquez C. Microclimate Metrics Linked to the Use and Perception of Public Spaces: The Case of Chillán City, Chile. Vol. 9, Atmosphere. 2018.

101. Flores-Larsen S, Filippín C. Energy efficiency, thermal resilience, and health during extreme heat events in low-income housing in Argentina. Energy and Buildings [Internet]. 2021 Jan [cited 2021 Mar 5];231:110576. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0378778820333624

102. Ugarte C. Impacto de las olas de calor en la salud. [Internet]. PAHO; 2019. Available from: https://www.paho.org/sites/default/files/2021-06/2019-phe-impacto-olas-calor-ciro-ugarte.pdf

103. Sarra S, Kronka R. Os impactos da onda de calor de 2019 sobre a saúde da população na cidade de Bauru (Estado de São Paulo -Brasil). Vol. 7, Brazilian Journal of Development. 2021.

104. Chen K, Bi J, Chen J, Chen X, Huang L, Zhou L. Influence of heat wave definitions to the added effect of heat waves on daily mortality in Nanjing, China. Science of The Total Environment [Internet]. 2015 Feb 15 [cited 2022 Jun 14];506–507:18–25. Available from: https://www.sciencedirect.com/science/article/pii/S0048969714015538

105. Imbach P, Chou SC, Lyra A, Rodrigues D, Rodriguez D, Latinovic D, et al. Future climate change scenarios in Central America at high spatial resolution. PLoS One [Internet]. 2018 Apr 25 [cited 2022 Jun 29];13(4):e0193570. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5919078/

106. Lowe D, Ebi KL, Forsberg B. Heatwave Early Warning Systems and Adaptation Advice to Reduce Human Health Consequences of Heatwaves. Int J Environ Res Public Health [Internet]. 2011 Dec [cited 2022 Jun 29];8(12):4623–48. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3290979/

107. World Health Organization. Multisectoral and intersectoral action for improved health and well-being for all: mapping of the WHO European Region [Internet]. Copenhagen: The Regional Office for Europe of the World Health Organization; 2018 p. 100. Available from: https://www.euro.who.int/__data/assets/pdf_file/0005/371435/multisectoral-report-h1720-eng.pdf

108. Intergovermental Panel on Climate Change. Glossary IPCC SR1.5 [Internet]. [cited 2022 Jun 29]. Available from: https://www.ipcc.ch/site/assets/uploads/2018/11/sr15_glossary.pdf

109. Center for Disease Control and Prevention. About Extreme Heat | Natural Disasters and Severe Weather | CDC [Internet]. 2020 [cited 2022 Jun 29]. Available from: https://www.cdc.gov/disasters/extremeheat/heat_guide.html

110. Magotra R, Tyagi A, Shaw M, Raj V. Review of heat action plans [Internet]. IDRC-CRDI; 2020 p. 58. Available from: https://climateandcities.org/wp-content/uploads/2022/01/Review-of-Heat-Action-Plans.pdf

111. US EPA O. Heat Island Effect [Internet]. 2014 [cited 2022 Jun 29]. Available from: https://www.epa.gov/heatislands

112. Intergovermental Panel on Climate Change. The concept of risk in the IPCC Sixth Assessment Report: a summary of cross: Working Group discussions Guidance for IPCC authors [Internet]. 2020 Sep [cited 2022 Jun 29] p. 15. Report No.: AR6. Available from: https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf

113. Intergovermental Panel on Climate Change. Technical Summary IPCC WGII Sixth Assessment Report [Internet]. p. 96. Report No.: AR6. Available from: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_TechnicalSummary.pdf

114. Utah State University. Thermal Stress | Environmental Health and Safety [Internet]. [cited 2022 Jun 29]. Available from: https://research.usu.edu/ehs/thermal-stress

115. Andalon M, Azevedo JP, Rodriguez Castelan C, Sanfelice V, Valderrama Daniel. Weather Shocks and Health at Birth in Colombia. [Internet]. World Bank; 2014. Report No.: Policy Research Working Paper;No. 7081. Available from: https://openknowledge.worldbank.org/handle/10986/20636

9 Appendix

Appendix 1. List of countries included in the study

South America	Central America
Argentina	Belice
Bolivia	Guatemala
Brasil	El Salvador
Chile	Honduras
Colombia	Nicaragua
Ecuador	Costa Rica
Guyana	Panamá
Paraguay	
Perú	
Suriname	
Uruguay	
Venezuela	

Appendix 2. Summary of literature review for objective 1

First author (number of authors)	Publication year	Country / Region	Brief methods	Key findings	Reference
Redmon, JH.	2021	Latin America	Review of articles published from 2015 - 2019 conducted in Latin American and Asian countries with known chronic kidney disease of unknown aetiology (CKDu).	In Latin American countries, heat stress and dehydration are the most common researched topics related to CKDu risk factors. The countries where most of this research has been carried out are Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, and Brazil. Vulnerable population to CKDu due to heat stress are outdoor workers exposed to high temperatures, farmers, and low-income populations.	(24)
Moreno, A.	2006	Latin America	Review of climate hazards and effects on human health.	The most vulnerable population include people living in poverty and areas that lack resources to adapt to heatwaves. High thermal stress along with other environmental factors (e.g., humidity and air pollution) increase the risk of mortality on vulnerable people who are exposed.	(23)
Green, H.	2019	LMIC	Systematic review of epidemiologic studies investigating potential associations between high ambient temperature or heat waves and mortality or morbidity.	Seven articles from Latin American countries were included, covering Brazil, Colombia, Peru, and Argentina. There was a positive association between heat and morbidity/mortality (e.g., heat stroke, respiratory and cardiovascular diseases, renal failure). The identified vulnerable populations included: elderly, women, groups with low socioeconomic level, people with pre-existing cardiovascular or respiratory comorbidities, and people with limited access to healthcare.	(21)

Carneiro, E.	2021	Brazil	Case study focused on Teresina–Timon conurbation in Brazil. By using remote sensing, the effects of urban sprawl were evaluated, including vulnerability to climate change.	Rapid urbanization led to lose of vegetation coverage, increasing the risk of exposure to high air temperatures. People who live in highly urbanized and densely populated areas are exposed to higher risks of climate hazards. In addition to these factors, informal developments in urban areas increase even more the risk of adverse effects on population.	(25)
Silveira IH.	2019	Brazil	Time-series analyses to estimate the relationship between mean temperature and daily cardiovascular mortality and meta-regression to adjust for other variables.	Higher cardiovascular mortality was associated with low and high temperatures in most of the cities. Vulnerable populations included people with pre-existing cardiovascular diseases, those who live in poverty, unemployed people, and unacclimatised people.	(22)
Romero, P.	2012	Latin America: Bogota, Buenos Aires, Mexico City, and Santiago	Quantitative and qualitative analysis to determine whether and under what conditions the people in these Bogota, Buenos Aires, Mexico City, and Santiago are vulnerable to temperature.	Increased health risk of cardiovascular and respiratory mortality from higher temperature during the warm season, but this risk differs by area. Overall, wealthy populations might mitigate some environmental risks, they virtually have the same risk of morbidity/mortality than other socioeconomic groups. Vulnerable populations include the elderly, very young people, and people with pre-existing comorbidities.	(20)
Bell, M.	2008	Latin America: São Paulo, Brazil; Santiago, Chile; Mexico City, Mexico	Case-crossover approach to analyze heat-related mortality.	High temperatures were associated with mortality risk in the Latin American cities studied, although the nature of the association differed by city. There is variation in the role of socio-economic factors in susceptibility, even within the same region of the world. Higher risk of heat-related mortality for older populations, although vulnerability by sex and education differed by city	(19)

Andalón, M.	2014	Colombia	Analysis the impacts of exposure to extreme weather events (temperature shocks) in utero on birth outcomes.	Cold and hot shocks affect birth indicators. Exposure to heatwaves at any point in the pregnancy reduces the share of babies born at full term by 0.5 percentage points.	(115)

LMIC: Low- and Middle-Income Countries

Appendix 3. Trends of UTCI per country from 2017 to 2021

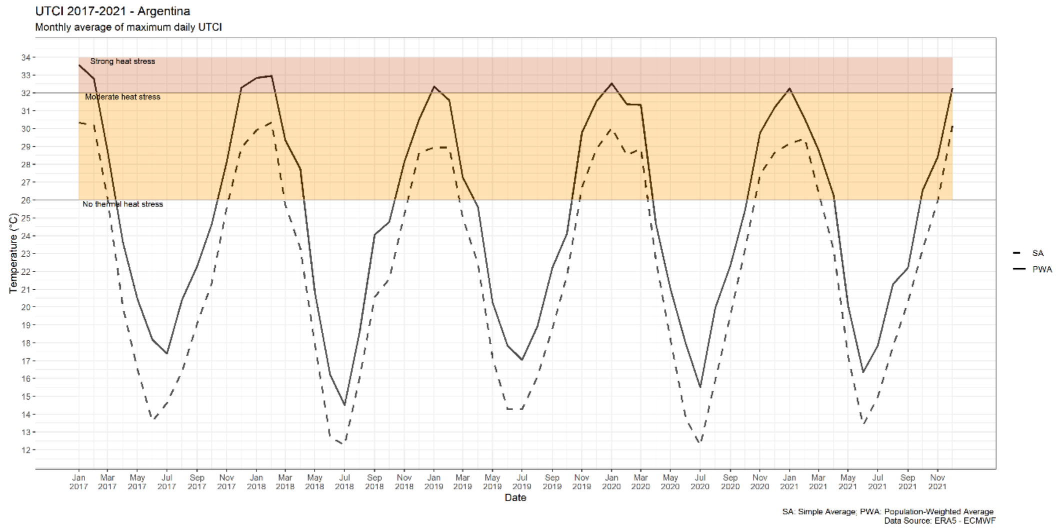

Figure 5. Trend of UCTI from 2017 to 2021 in Argentina. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

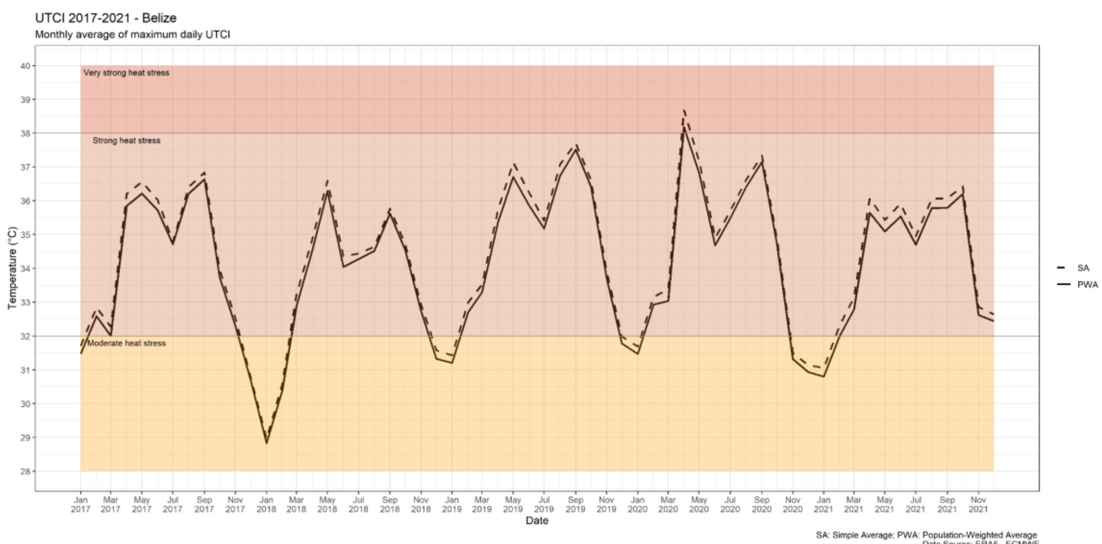

Figure 6. Trend of UCTI from 2017 to 2021 in Belize. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

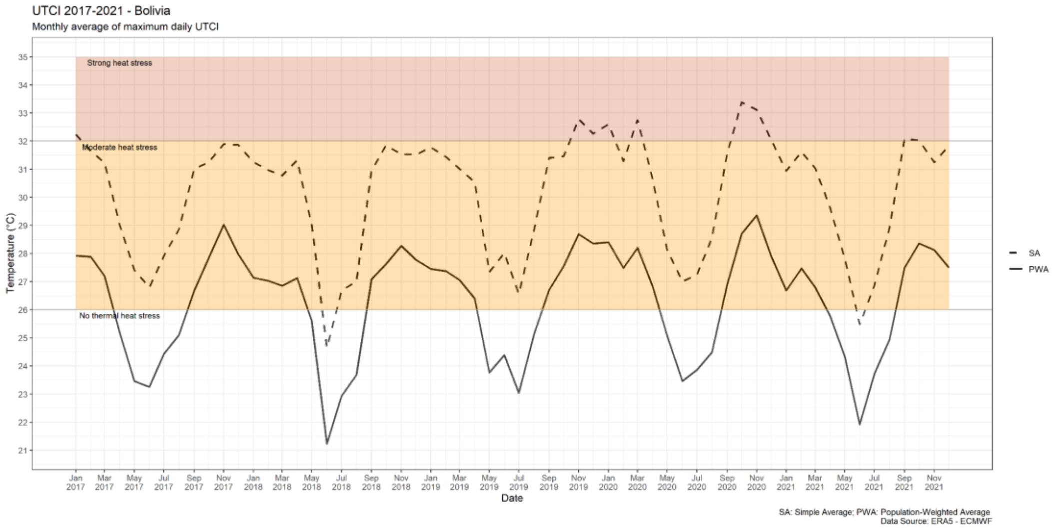

Figure 7. Trend of UCTI from 2017 to 2021 in Bolivia. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

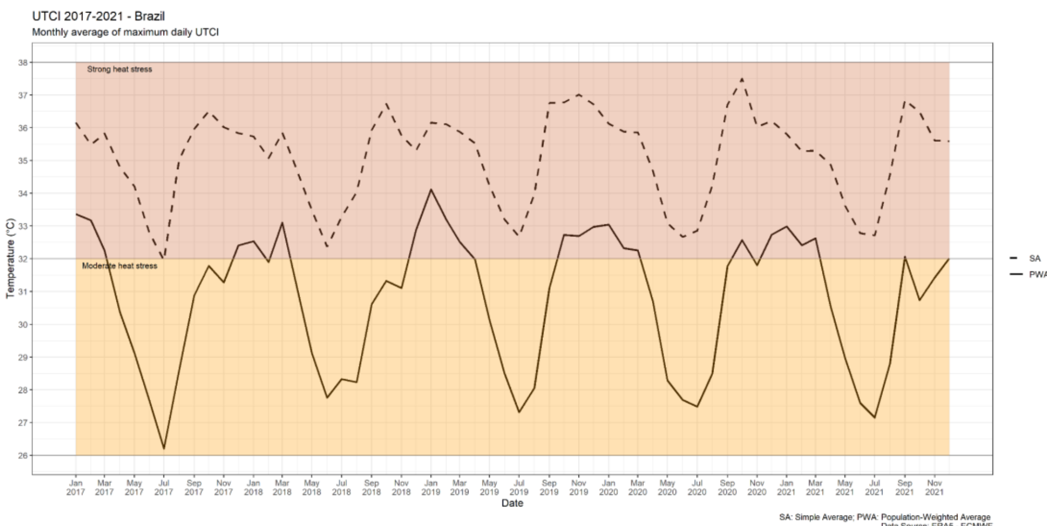

Figure 8. Trend of UCTI from 2017 to 2021 in Brazil. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

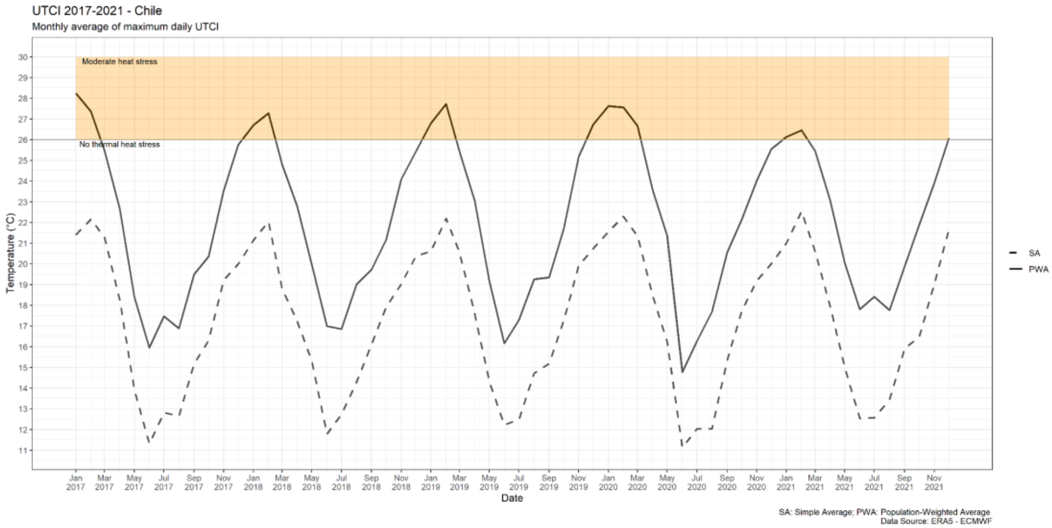

Figure 9. Trend of UCTI from 2017 to 2021 in Chile. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

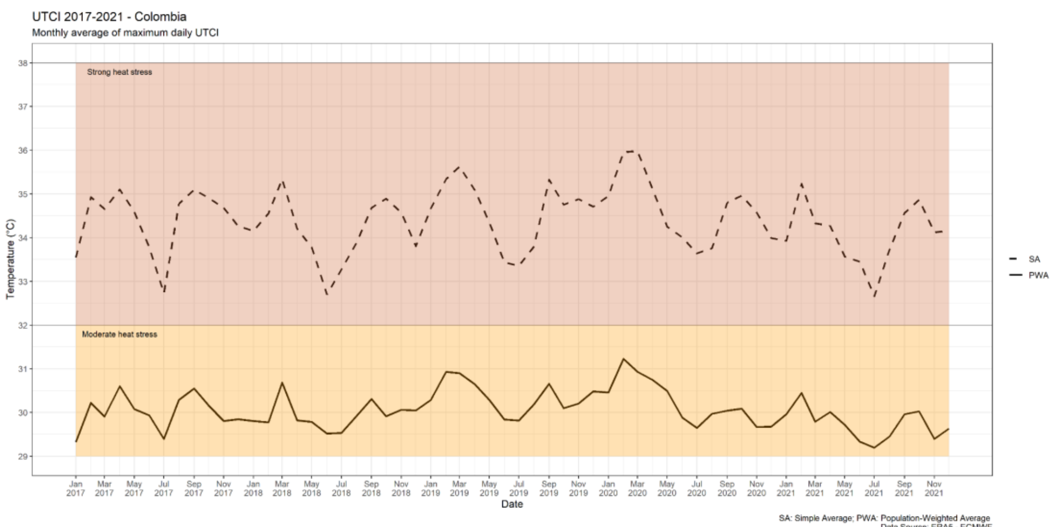

Figure 10. Trend of UCTI from 2017 to 2021 in Colombia. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

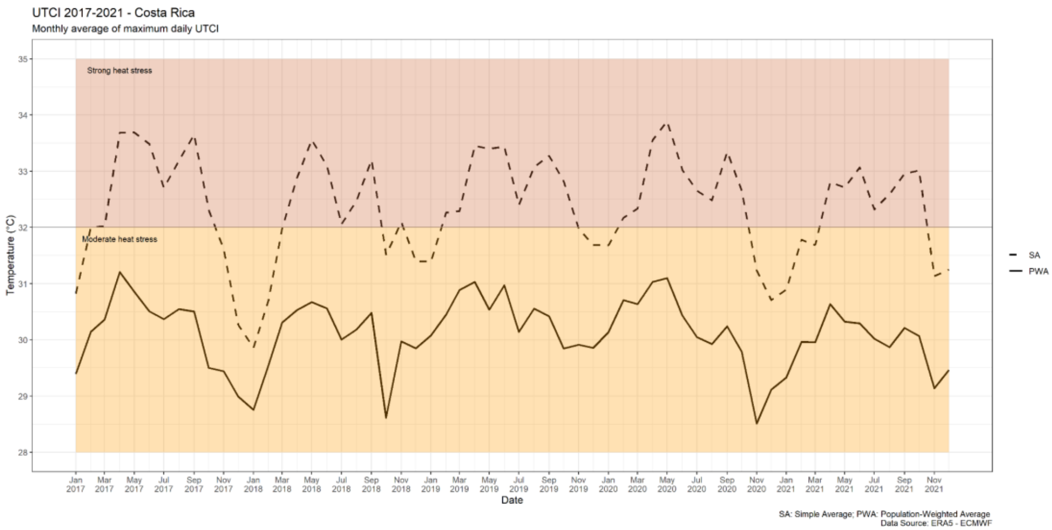

Figure 11. Trend of UCTI from 2017 to 2021 in Costa Rica. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

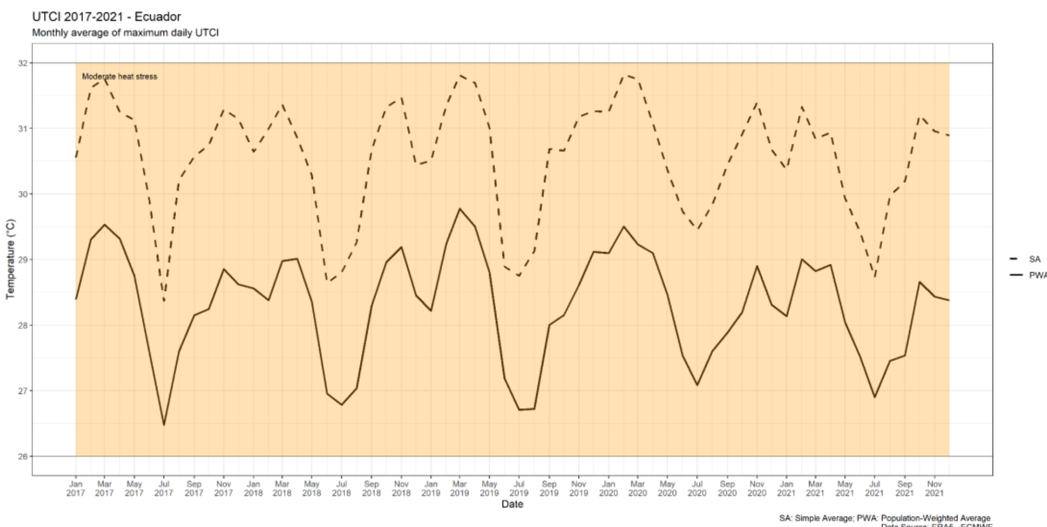

Figure 12. Trend of UCTI from 2017 to 2021 in Ecuador. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

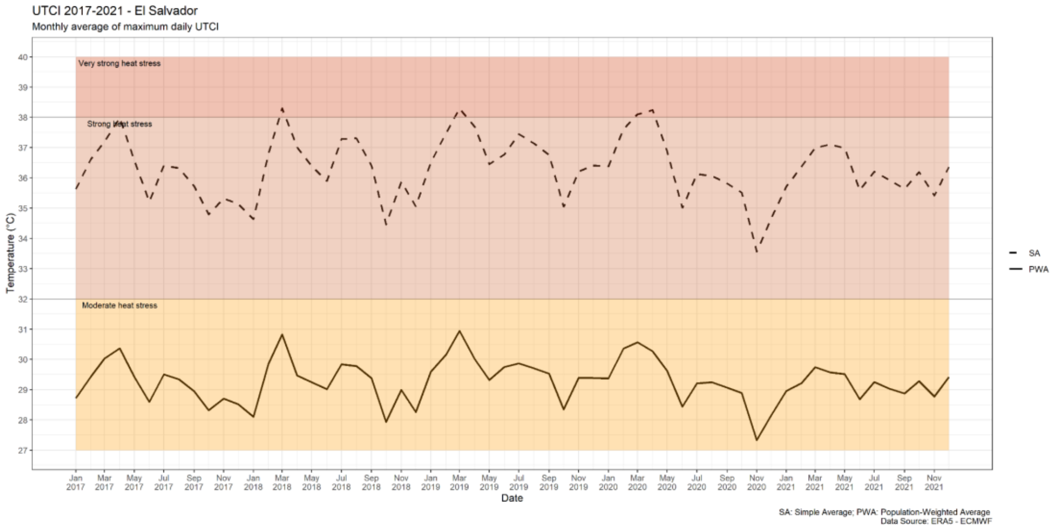

Figure 13. Trend of UCTI from 2017 to 2021 in El Salvador. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

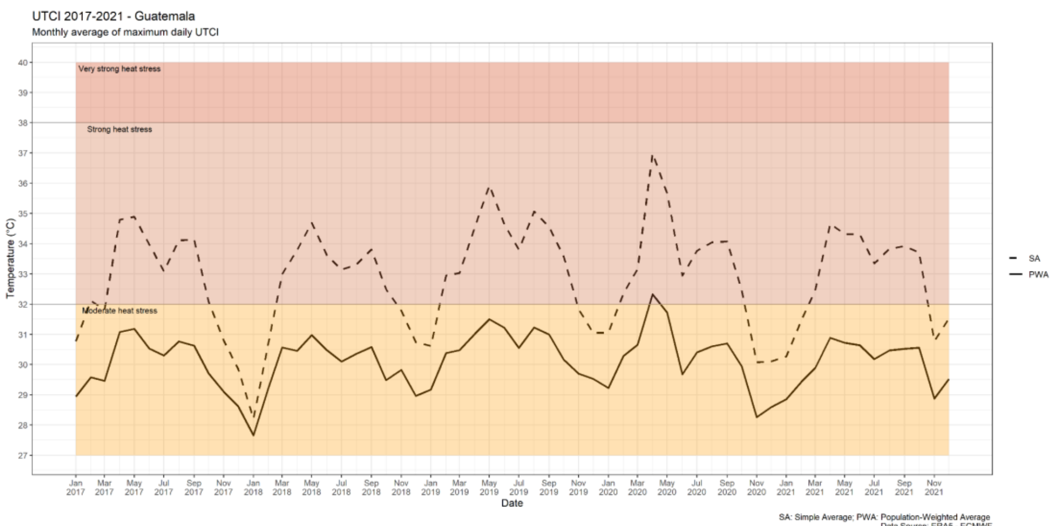

Figure 14. Trend of UCTI from 2017 to 2021 in Guatemala. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

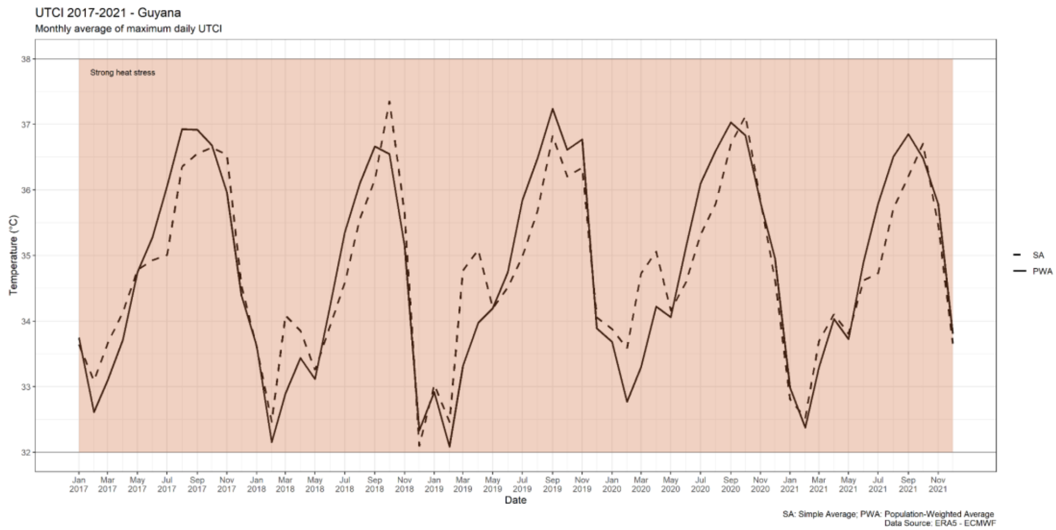

Figure 15. Trend of UCTI from 2017 to 2021 in Guyana. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

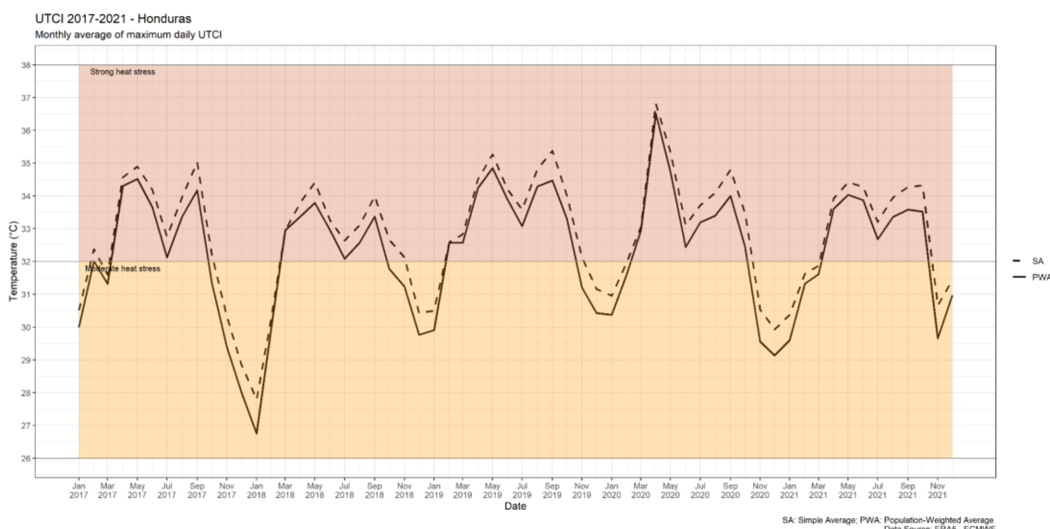

Figure 16. Trend of UCTI from 2017 to 2021 in Honduras. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

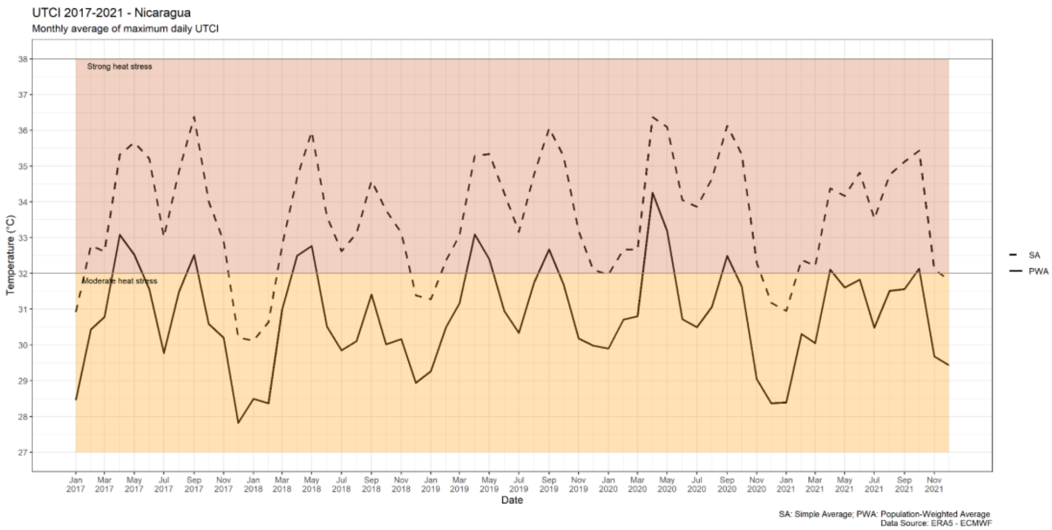

Figure 17. Trend of UCTI from 2017 to 2021 in Nicaragua. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

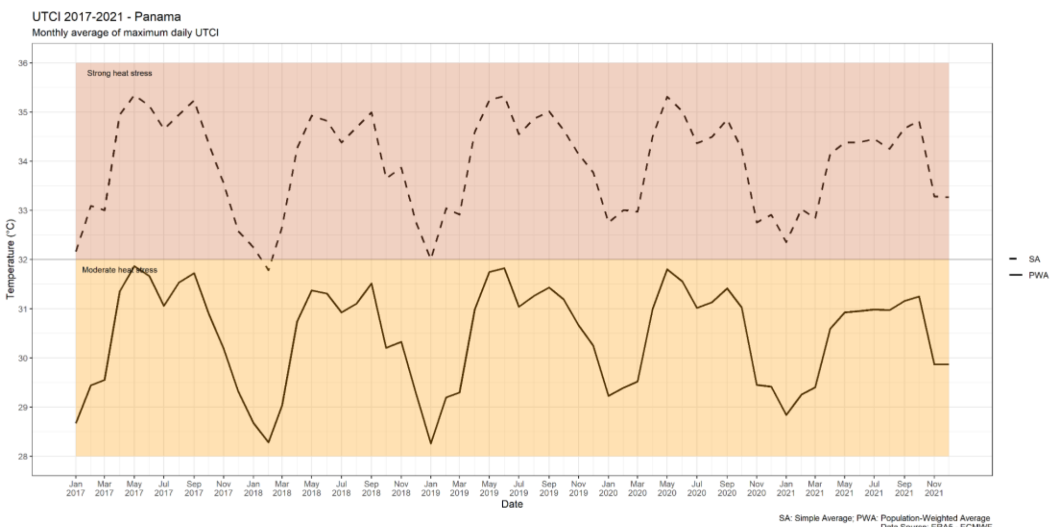

Figure 18. Trend of UCTI from 2017 to 2021 in Panama. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

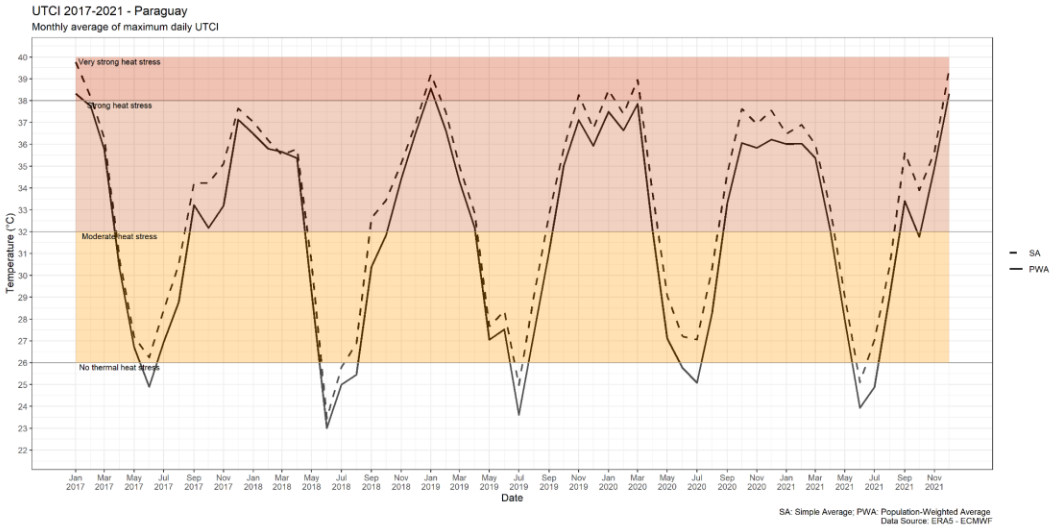

Figure 19. Trend of UCTI from 2017 to 2021 in Paraguay. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

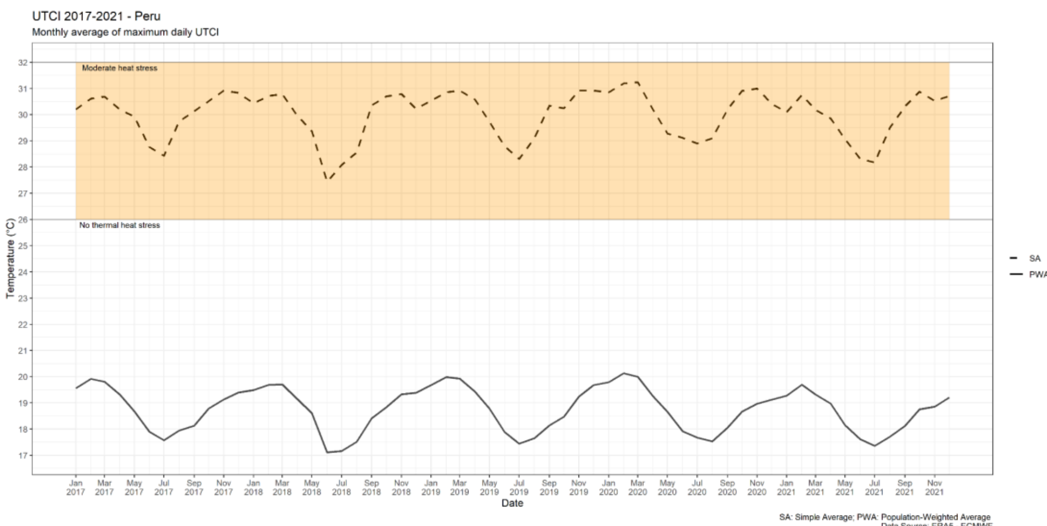

Figure 20. Trend of UCTI from 2017 to 2021 in Peru. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

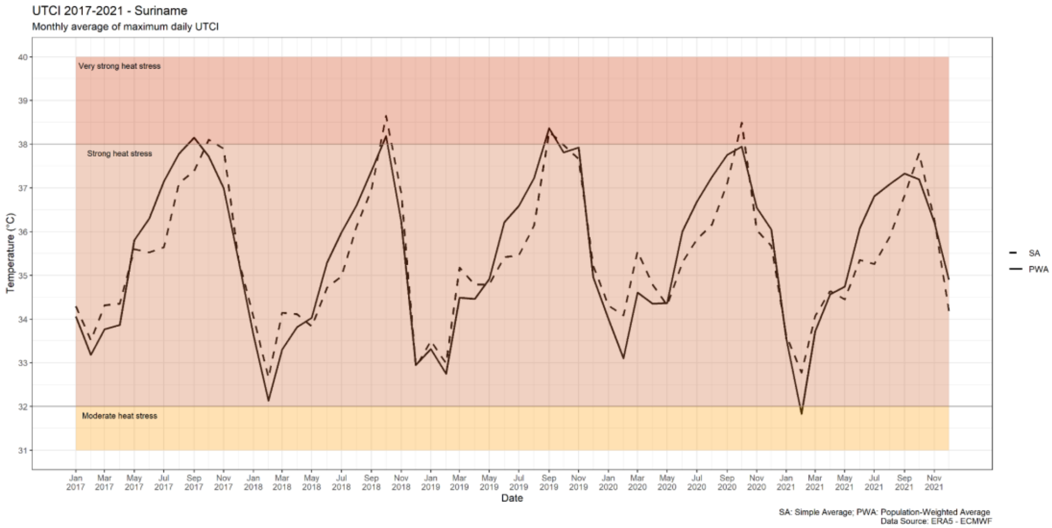

Figure 21. Trend of UCTI from 2017 to 2021 in Suriname The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

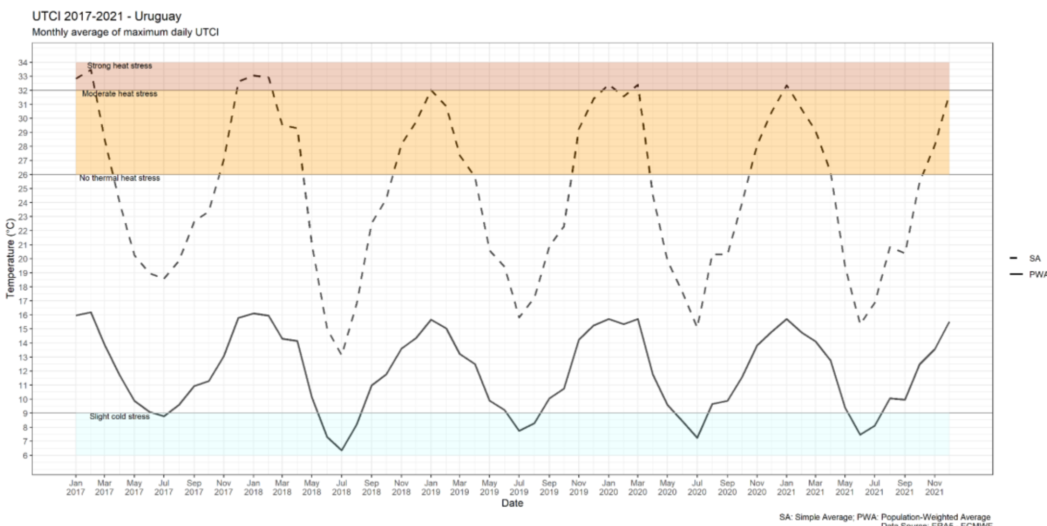

Figure 22. Trend of UCTI from 2017 to 2021 in Uruguay. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

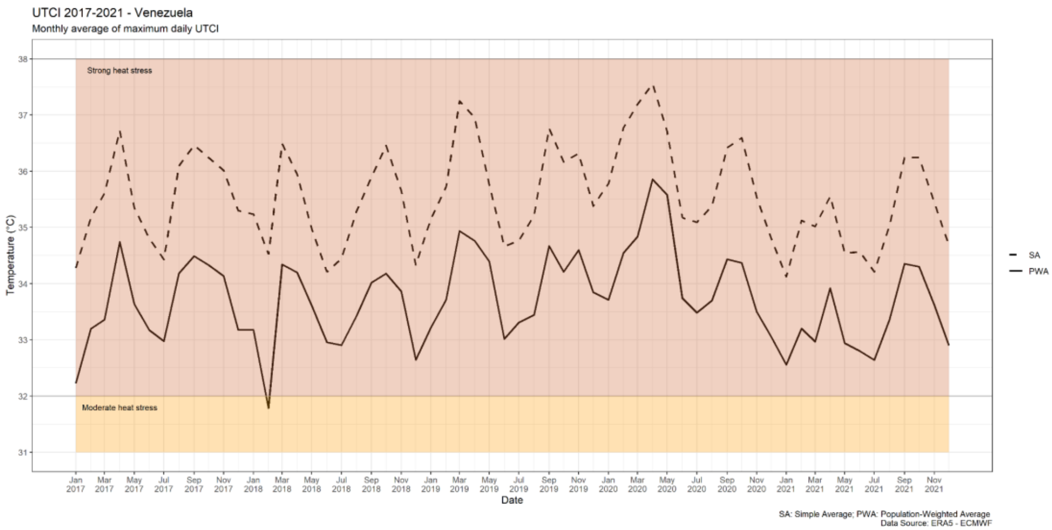

Figure 23. Trend of UCTI from 2017 to 2021 in Venezuela. The solid line represents the population-weighted average, and the dashed line represents the simple average over the country.

Appendix 4. Search terms and summary of literature review for objective 2

The search strategy was performed based on the following impact categories:

- **Health:** *("heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras" OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela") AND ("Health" OR "Respiratory Illness" OR "Mortality" OR "Morbidity" OR "Nutrition" OR "Food safety" OR "Mental health")*
- **Agriculture:** *("heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras" OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela") AND ("Agriculture" OR "Yield" OR "Crops" OR "Food")*
- **Economy: (***"heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras" OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela") AND ("Economy" OR "Consumption" OR "GDP" OR "Income" OR "Productivity" OR "Labor")*
- **Infrastructure: (***"heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela"") AND ("Infrastructure")*
- **Tourism: (***"heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR*

"Honduras OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela"") AND ("Tourism")

- **Migration: (***"heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela"") AND ("Migration")*
- **Nature:** *("heat" OR "heat wave" OR "high temperature" OR "heat stress") AND ("risk" OR "hazard" OR "exposure" OR "vulnerability") AND ("Latin America" OR "South America" OR "Central America" OR "Guatemala" OR "Colombia" OR "Honduras OR "El Salvador" OR "Nicaragua" OR "Bolivia" OR "Ecuador" OR "Guyana" OR "Paraguay" OR "Suriname" OR "Venezuela"") AND ("Nature" OR "Ecosystem" OR "Biodiversity")*

Data was extracted as follows:

Name	Publication year	Country/Region	Key Findings	Methodology
Climate change and extreme weather events in Latin America: an exposure index	2013	Latin America	Development of the Disaster Exposure Index-DEI. Flooding is the most prevalent disaster in the region and Mexico is the most exposed country.	Methodology used to calculate the Human Development Index, from the UNDP.

Observations and Projections of Heat Waves in South America	2019	Latin America	1. "the share of extremely warm DJF [over the period December-January-February] days has at least doubled in recent decades in northern SA; less significant increases were observed in southern SA." 2. RCP4.5 scenario: "by mid-century, the number of HWs per season (HWN) is expected to at least double in southern SA, while they may increase 5–10 times or more in the Atacama Desert and along the coastline of northern SA. Indeed, by mid-century HWN estimates are expected to range from less than 2 in southern SA to more than 3 in northern SA and the Atacama Desert." 3. Geographic differences: "Tropical major cities are expected to be strongly affected by HWs and daily record temperatures." 4. Expected increases in the "share of extremely warm days would exacerbate existing global inequalities, exposing vulnerable and disadvantaged populations (especially in northern SA) to further risks." This implies a major risk considering the countries' vulnerability and limited adaptation capacity.	1. They considered two representative concentration pathways (RCP): RCP4.5 and RCP8.5. 2. They considered a HW the period of "at least 3 consecutive days with the daily maximum temperatures (TMAX) exceeding a defined threshold during the considered season (DJF)." 3. Projections are based on the multi model mean (MMM) of HW metrics.
Vulnerability to heat-related mortality in Latin America: a case-crossover study in São Paulo, Brazil, Santiago, Chile and Mexico City, Mexico	2008	Brazil. Chile. Mexico.	Elevated temperatures are associated with mortality risk in Mexico City, São Paulo, and Santiago de Chile. In São Paulo the elderly were more vulnerable, as well as those with less education and men; this last point was shared with Santiago. ---------- 1. High temperatures are associated with mortality risks, but with different nature of association. Is a paper difficult to follow. They put the following key message: "In three large Latin	1. Case-crossover design to avoid selection bias. 2. Time-stratified approach to select time periods to prevent bias.

			American cities with temperate climates, a higher risk of heat-related mortality was observed among older individuals, although associations in Santiago, Chile were imprecise. Vulnerability to heat-related mortality by sex and education differed by city. These results suggest that adaptation efforts in these cities to respond to the increasing intensity, frequency and duration of heat waves expected under climate change should target older populations, and that other prevention efforts will require tailoring to the unique population vulnerabilities within each community.”	
The heat wave of October 2020 in central South America	2021	Latin America	1. The WSDI showed “warming with longer duration (more than 7 days) at the 90th percentile or more, mostly concentrated in central-western Brazil, northern Argentina, Paraguay, and eastern Bolivia.” 2. Analysis of the heat wave: “this heat wave event happened mostly because of large scale circulation generated by stationary Rossby waves coming from the Indian Ocean region.” 3. Vicious cycle: “The drought is leading to extremely low soil moisture, which is making it easier for “these high-pressure systems to generate extreme heat waves because more of the sun’s energy is going into heating the atmosphere rather than evaporating nonexistent water in the soil. And that is only making things hotter and drier. That is sort of the vicious’ cycle of drought and extreme heat in a warming climate.” 4. There were several areas in South America that suffered from the drought-heat compound. Specifically, “over the southern Peruvian Amazon, northern and eastern Bolivia, northern Argentina, central-western	1. They consider a heat wave as a “period in which both daily maximum and minimum air temperatures exceed the corresponding climatological 90th percentile for three or more consecutive days.” 2. They estimate the warm spell duration index (WSDI), that is the number of days each year which are part of a warm spell. 3. They compute other metrics, such as the drought-heat compound, the integrated drought index, among others.

			Brazil, and Paraguay, covering the Pantanal wetland." 5. The drought-heat compount increase the risk of fires.	
Extreme temperatures and mortality in 326 Latin American cities	2021	Latin America	Analyze mortality at high temperatures in cities in nine countries in Latin America with a population of 100,000 persons or more, find that mortality increased with temperature, mostly in cities where the temperature regularly exceeded approximately 25°C (e.g. Buenos Aires, Mérida, Rio de Janeiro). In addition, people older than 65 years old are more vulnerable to heat-related mortality. Regarding the specific cause of mortality, respiratory infections were highly associated as the cause of death from heat; ----- 1. Temperature and mortality from all cases: "At temperatures below the optimal temperature mortality increased gradually as temperatures dropped, while at temperatures above the optimal temperature mortality increased more steeply as temperatures rose. The sharp increase in mortality with increasing temperatures was most pronounced for cities that regularly exceed approximately 25°C (e.g. Buenos Aires, Mérida, and Rio de Janeiro in Figure 2). However, among cities with temperate or cold climates that rarely (or never) exceeded approximately 25°C (e.g. Lima, Mexico City, and Los Angeles in Figure 2) mortality did not increase or increased only minimally as temperatures increased." 2. Temperature and cause-specific mortality: "In the case of hot temperatures, EDFs for	1. Temperature-mortality association statistics.

			respiratory mortality were slightly higher than for all-cause mortality, but EDFs for cardiovascular mortality were similar to those observed for all-cause mortality. Patterns were similar for deaths at all ages and over 65 years, although the EDFs for over 65 were slightly higher than those for all ages." 3. Respiratory infections were highly associated as cause of death for heat. 4. General conclusion: "a substantial proportion of mortality was attributable to ambient cold and to a lesser extent heat. This mortality burden is larger among older individuals and among deaths from cardiorespiratory causes. Importantly, we found that even small increases in extreme heat can rapidly increase mortality risk." 5. A 1°C increase: "We also observed that the increase in mortality associated with"a 1°C increase in extremely hot temperatures has substantial geographic variation. For example, increases in mortality risk per 1°C increase in extreme heat are particularly steep in the cities of coastal Mexico, northern Argentina, and southern Brazil. Residents of these areas may be particularly vulnerable to extreme heat now and in the near-term under even marginal increases in the frequency of extreme heat from climate change." 6. Adults older than 65 years old are more vulnerable to heat-related mortality. EDFs: Excess Death Fraction	
Heatwave and health impact research: A global review	2018	Global	Research on the impact of heat waves on health is concentrated in regions that are	"A systematic review was undertaken. Four online databases

			projected to experience less extreme heat waves. In this sense, almost no studies covered South and Central America. This could be, among others, because of the lack of funding and data availability in these areas. --------------- 1. Main Result: "When examining the location of heatwave and health impact research worldwide, studies were concentrated on mid-latitude, high-income countries of low- to medium-population density. Regions projected to experience the most extreme heatwaves in the future were not represented. Furthermore, the majority of studies examined mortality as a key indicator of population-wide impact, rather than the more sensitive indicator of morbidity." 2. Almost no studies covered South and Central America. Explanation: "While it is evident that heatwave research is lacking in several regions across the world (for example, Africa and South America), this may be attributable in some part to the lack of research funding in these areas, a dearth of active researchers located within the study areas, and issues with data availability. For example, a lack of resources and infrastructure needed for adequate and robust data collection methods, enabling data of good quality to be available to researchers, may not be paramount in locations where general health infrastructure is poor. To address the paucity of research in areas of high heatwave and health impact risk, emphasis must be placed on developing access to reliable datasets."	were searched for articles examining links between specific historical heatwave events and their impact on mortality or morbidity. The locations of these events were mapped at a global scale, and compared to other known characteristics that influence heat-related illness and death."

Long-Term Effect of Climate Change on Health: Evidence from Heat Waves in Mexico	2014	Mexico		
Half a degree and rapid socioeconomic development matter for heatwave risk	2019	Global	Main result: “Even under the 1.5 °C warming level, the low-human- development countries (representing future populations equal to 25 or 39% of the present global population in the SSP1 and SSP4, respectively) experience exposure levels equal to or greater than the levels for the very high-human-development countries with 2 °C warming. We also find that, in agreement with a recent study8, holding the temperature below 1.5 °C warming yields a large potential to reduce the levels of the heatwave exposure.”	
Mortality by Excessive Natural Heat in Northwest Mexico: Social Conditions Associated with this Cause of Death	2019	Mexico		
Olas de calor y salud: medidas a tomar	2020	Latin America	1. Health risk: “En áreas rurales de países de Centro América (Costa Rica, El Salvador, Guatemala, Nicaragua and Panamá) y México (en áreas delimitadas), se presentó una epidemia de enfermedad renal crónica de causa no tradicional (ERCnt) entre los años 1997 y 2013 que ha causado la muerte de más de 60 000 trabajadores agrícolas (41%<60 años)5. Si bien la etiología de la ERCnt no está definida, se ha asociado a contaminantes en el ambiente (pesticidas, metales pesados y agentes infecciosos), deshidratación crónica, estrés por calor, y largas jornadas de trabajo6 y eventualmente al golpe de calor. Es necesario que las autoridades investiguen más este tema y monitoreen eventuales cambios relacionados con las olas de calor.”	

			2. Health consequences: “La revisión realizada por los autores muestra que en el periodo de 2010 a 2018 las olas de calor afectaron 15 países de la Región (Argentina, Brasil, Bolivia, Canadá, Chile, Colombia, Ecuador, Estados Unidos, Guatemala, Honduras, México, Nicaragua, Paraguay, Perú, y Uruguay). Se estiman al menos 8294 muertes causadas por o asociadas al calor en este periodo en al menos siete países (3030 fallecimientos a partir de reportes de Argentina, Brasil, Canadá y México, y 5264 muertes estimadas para los Estados Unidos en base al promedio de 658 muertes por año12 – complementa las 8081 muertes relacionadas con el calor reportadas en Estados Unidos en el periodo 1999 a 2010. Sin embargo, se considera que estos datos son una subestimación de la realidad, ya que en la mayoría de los países no se cuenta con registros oficiales, ni se han realizado estudios de mortalidad13 asociada a, o causada por las olas de calor."	
Impactos en la salud pública y desigualdades frente al cambio climático en América Latina: Una aproximación hacia las consecuencias diferenciales de las inundaciones y olas de calor en la Cuenca Matanza Riachuelo.	2020	Argentina	The phenomenon of Heat islands recognizes that urban areas are particularly affected by heat waves, most that the rural surrounding areas. This generates an increasing demand for electricity because of a rising use of refrigerators and air conditioning. In Buenos Aires homeless and other people without access to cooling technologies are particularly vulnerable, which represents an inequality problem. This could also lead to health problems through dehydration, low pressure and cramps. -------------------- 1. Interesting conclusion: “Las olas de calor	Public policy analysis

			no afectan a todas las áreas por igual. El fenómeno de la isla urbana de calor (IUC) reconoce que las áreas urbanas se ven especialmente afectadas por las olas de calor y experimentan los impactos más intensos. Por lo tanto, debido al efecto IUC, las ciudades tienden a ser más cálidas que el entorno rural circundante, especialmente durante las noches de verano sin viento y sin nubes, cuando los materiales urbanos retienen el calor de los días y no se enfrían adecuadamente. Esto a su vez generará una mayor demanda de electricidad (aire acondicionado y refrigeración) y generará más problemas de salud relacionados con el calor en la población (Secretaría de Ambiente y Desarrollo Sustentable de la Nación, 2015, p. 26).” 2. Inequality - conclusion: “En el caso de las olas de calor, las poblaciones sin hogar en la ciudad de Buenos Aires, donde el efecto de isla de calor urbano se siente con mayor fuerza, así como aquellos sin acceso al aire acondicionado tanto en la ciudad como en las viviendas de los asentamientos, estarán entre los que más directamente experimenten efectos y problemas de salud correlacionados. En el caso de las inundaciones, nuevamente entre los más expuestos estarán las personas sin hogar y los que viven en asentamientos y viviendas informales cerca del río. Las disparidades económicas ya están presentes en esta región, ya que los recursos económicos se concentran desproporcionadamente en CABA en comparación con el resto la CMR y el GBA. De esta manera, se predice que el cambio climático profundizará aún más las desigualdades existentes a través de amenazas de salud correlacionadas a las	

			próximas olas de calor extremas e inundaciones.”	
Islas de calor, impactos y respuestas: El caso del cantón de Curridabat	2019	Costa Rica		
The burden of heat-related mortality attributable to recent human-induced climate change	2021	Global		1. Time series regressions. 2. Computation of the heat-related mortality between 1991 and 2018 under two climate change scenarios.
Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological evidence and considerations for future research	2019	Low and middle income countries	Literature about the link between heat waves and health is short in low and middle income countries because, among others, complexities in data collection and financial resources. They found studies in Colombia (3), Peru (1), Brazil (10) , Chile (2). ------- Conclusion: “While the link between heat waves and health is well established in the literature, there is a knowledge gap in studying this relationship in LMICs. There are many challenges associated with the collection and analysis of heat-health related data sources, which are especially difficult in certain low income contexts that lack human and financial resources to implement these projects.”	Literature review
An ecological study of chronic kidney disease in five Mesoamerican countries: associations with crop and heat	2021	Mesoamerica	Differences in reported CKD burden within 124merica124ura124 countries is partially explained by differences in heat and crop cultivation. Repeated heat stress is a cause of CKDnt in sugarcane cultivators, with stronger association in men than in women, suggesting that it happens for environmental exposure and not occupational risk. Nevertheless, there are also biological differences that could influence. ---------	1. Statistical computations to homogenize the data. 2. Modelled age-standardized CKD mortality rate using Poisson regression. Spetial computations had to be done with Nicaragua and El Salvador. 3. Bayasian spatial regression model to mapp the distribution of CKD burden. 4. Regression modelling to

			1. Spatial variation of CKD throughout mesoametica: is higher along the Pacific coast. This result is importance because of its high resolution data, and data from Nicaragua and Mexico. 2. Association between CKD burden and intense sugarcane cultivation in heat is presented. Stronger association is presented in men than in women, suggesting that it happens for environmental exposure and not occupational risk. Nevertheless, there are also biological differences that could influence. 3. The results support that repeated heat stress is a cause of CKDnt. 4. Other crops: "The lack of consistent associations between cultivation of banana, coffee, or rice, and CKD imply that work practices or agrochemicals used primarily for cultivation of these crops are not key causal factors for CKDnt initiation or progression. Thus, future studies exploring the differences in occupational exposures and living conditions in communities near these crops and sugarcane could point to important causal mechanisms." 5. There are differences in the spatial distribution between CKD and CKDnt. 6. Conclusion: differences in reported CKD burden within Mesoamerican countries is partially explained by differences in heat and crop cultivation.	understand the relation between crop cultivation density, heat, and CKD.
Economic Evaluations of the Health Impacts of Weather-	2016	Global	No studies about the economic evaluation of the health impacts of weather-related	Literature review

Related Extreme Events: A Scoping Review			extreme events covered Central and Latin America. --------------- 1. Regarding studies about the economic evaluation of the health impacts of weather-related extreme events: "An analysis of the distribution of the pool of identified studies according to their primary environmental hazard and geographical region of focus (Table 2) shows that some parts of the world are clearly under-represented. Most studies have been undertaken in the U.S. (nine studies out of 20) or Asia (seven studies out of 20), whereas no study has covered Central and Latin America, the Middle East nor Africa. This imbalance also explains that most studies (13 studies out of 20) pertained to high or middle-income countries; however, only one study was based in Europe (Spain)."	
The impact of heat and impaired kidney function on productivity of Guatemalan sugarcane workers	2018	Guatemala	In Guatemala's sugarcane workers, heat exposure is related to lower productivity at the start and the end of production periods because of a reduction in daily tons produced or premature workforce attrition. Regarding people with previously impaired kidneys, they were more likely to leave the job before the end of the harvest season. This shows an "inherent conflict between preserving health and maintaining productivity that workers and employers must address." In addition, there is a possible relationship between daily maximum WBGT and lower productivity in the next 5 days, mainly in people with impaired kidneys. However, more research is needed to understand how chronic health conditions affect worker productivity during heat waves. Finally, lower agricultural productivity implies a challenge for food security purposes.	1. Study design in southwest Guatemala from November 2015 to may 2016. Note that all cane cutters who met the inclusion criteria were male. 2. They model the relationship between temperature and health.

			---------- 1. Main result: “Periods of lower productivity occurred at the start of the season during the acclimatization phase, as well as the end of the season when production is wrapping up. These natural periods of lower productivity corresponded with increased temperatures” 2.Reasoning: “Productivity can be adversely affected in two ways: reduced daily tons produced and premature workforce attrition. We observed a notable difference in job attrition between those with impaired kidney function and those with functioning kidneys (...) Workers who started the season with kidney impairment were more likely to leave the workforce before the harvest season was over, even after controlling for age. There was no effect of kidney function on attrition prior to week 11. However, kidney function was related to attrition on or after week 11. The likelihood of leaving the workforce during week 11 or later for those with impaired kidney function was 2.92 (95% CI: 1.88, 4.32) the likelihood for those with functioning kidneys after adjusting for age.” 3. Evidence that provides: “While not definitive, our analyses suggest that increases in daily maximum WBGT negatively affected productivity over the next five days. This was more apparent in the impaired kidney function group, although not statistically significant, when compared to those with an Egfr > 60 ml/min/1.73 m2 at the start of the harvest. This study provides initial field evidence for the link between impaired kidney function, increased heat exposure,	

			and agricultural worker productivity." 4. Additional evidence: "productivity of workers with impaired kidney function may be more greatly impacted by exposure to increase heat extremes. It is important to consider the role of acute and chronic health conditions on worker productivity in future projections of climate's effect on worker productivity. Additionally, we have shown that workers with impaired kidney function have more than twice the risk of not finishing a harvest, resulting in fewer days worked (...) Thus, our data illustrate the inherent conflict between preserving health and maintaining productivity that workers and employers must address [14]. This challenge is particularly urgent in the case of CKDu, in light of evidence implicating high energy expenditure during temperature extremes as a potential contributor to kidney insufficiency (...) Our data provide initial empirical support that climate can directly impact commodity production. Taken together, published models and our data suggest that the extent of food insecurity is being underestimated when climate models of our world's food supply neglect heat's effect on worker health and workforce sustainability."	
Heat-related symptoms in sugarcane harvesters	2015	Central America	Not all sugarcane workers have the same risk. In general, there are ""differences in self-reported heat and dehydration-related symptoms between harvesters and non-harvesters." Harvesters experience some degree of heat exhaustion in a large part of the season. The higher risk of harvesters implies an inequality problem, considering that they are commonly poorer, not living in their own homes, with less education.	1. Heat-exposed participants were subcontracted sugarcane harvesters. Non-harvesters were non-heat exposed workers during daytime in offices; part of the processing plant, machinery shop, storage, cafeteria. 2. Data was collected for 2 months,

			----------- 1. There are clear differences "differences in self-reported heat and dehydration-related symptoms between harvesters and non-harvesters and a trend of increasing symptoms with increasing heat exposure across job categories" 2. Inequaility: the harvesters were commonly poorer, not living in their own homes, with less education. 3. Conclusion: "This study indicates a large percentage of harvesters are experiencing some degree of heat exhaustion on a continual basis throughout the harvest season. This is worrisome since heat exposure in agricultural workers is a serious risk that can be fatal even in non-tropical environments.	starting in February 2020, through surveys.
Evaluation of heat stress and cumulative incidence of acute kidney injury in sugarcane workers in Guatemala	2019	Guatemala	Guatemala's sugarcane cutter workers decreased their shift hours when WBGT increased, which is why some research doesn't find a direct association between WBGT and acute kidney injury (AKI). Nevertheless, 81% of the sugarcane workers presented at least one AKI during the study period even if they were well-hydrated. Nevertheless, the higher electrolyte was found to be protective. --------- 1. Main result: "surprisingly high incidence of cross-shift AKI even when workers were well hydrated. Despite appropriate hydration in the field, increasing post-shift specific gravity was observed to be a risk factor for AKI and higher	Longitudinal cohort study during 2017. They estimated different associations using logistic regression and correlation analysis.

			electrolyte solution intake was found to be protective. The fact that 81% of these sugarcane workers demonstrated evidence of at least one AKI during the study period demonstrates a higher vulnerability" 2. Heat role: "While the present study did not fnd a direct association between increasing WBGT and AKI, heat stress cannot be ignored, since WBGT was over 30 °C on almost all study days with little variation. As expected, we observed that as WBGT increased, cane cutters shift hours decreased. This may explain why increasing WBGT was not associated with AKI."	
Climate change, workplace heat exposure, and occupational health and productivity in Central America	2011	Central America	1. General result: "the limited available analysis of heat effects on working populations in Central America supports the basic physiological and ergonomic evidence about how the health and work capacity of working people can be affected by heat. More detailed occupational epidemiology research is needed to quantify the impacts in different locations and occupational groups. Such quantification is crucial for improving the estimates" 2. Costa Rican case: "In Costa Rica, road-repair workers, particularly those working in the northern region of the country, were found to be working under heat stress conditions.56 Some of these workers were at risk of excess water loss due to a high sweat rate." 3. Regional cases: "Chronic kidney disease in El Salvador57–59 is surprisingly common (prevalence = 12.7% among adult coastland farmers in the García-Trabanino study) despite the fact that the usual risk factors (e.g., diabetes and hypertension) were only present among one-third of the patients.	Analysis of likely occupational heat exposure.

			Exposures to pesticides and alcohol did not appear to be important risk factors. Unusually high prevalence of kidney disease has also been documented in Nicaragua, particularly in men.60,61 Specific causes remain unidentified, but occupational and/or environmental exposures are suspected including repeated daily dehydration caused by heavy labor; work undertaken in very hot temperatures; profuse sweating; insufficient access to drinking water; and consumption of contaminated drinking water. Indoor workers in Central America are also exposed to heat. For example, "maquilas" (factories for the production of products such as textiles and electronics) employ an estimated 500,000 people in the region with the vast majority (80%) being women. Heat is a documented occupational risk in these work places.48,62 In Nicaragua, the food, beverage, and tobacco industry, as well as the metallurgy and metal product sectors, have been shown to represent high heat exposure risks.48" 4. ILO identified risks: "The International Labour Organization (ILO) has identified heat exposure as an occupational health threat in sectors such as rice and sugarcane production in Central America.49,50 There has been some documentation of general risks in the sugarcane industry (including heat)49,51–53 and the need for studies on heat exposure has been highlighted.53,54 In Nicaragua, one intervention study of hydration for sugar harvesters has been published, reporting that hydration programs improved productivity.55"	
Projections of temperature-related excess mortality	2017	Global	In central and south America, heat-related mortality increases in all climate change scenarios according to projections.	1. Estimation of location-specific associations "using observed data on outdoor temperature and mortality."

under climate change scenarios			-------- 11. General result for America: "areas dominated by hotter climates, such as Central and South America, southern Europe, and southeast Asia, show a different pattern and an increased impact of climate change. These regions are currently characterised by relatively higher heat-related impacts, in the order of 0·6–1·7% in 2010–19. The excesses are projected to rise considerably by the end of the century under RCP8.5, reaching 10·5% (95% eCI 5·6 to 17·3) in southern Europe and 16·7% (−1·7 to 33·2) in southeast Asia." 2. The trend in heat-related mortality in Central and South America increases in all climate change scenarios. But clearly mostly in RCP 8.5 than in RCP 2.6 and RCP 4.5	2. Computation of future effects under different climate change scenarios. They use modelled climate and mortality projections. 3. Estimation of exposure-response relationships. 4. Projection of impact on mortality.
A comparative review: Chronic Kidney Disease of unknown etiology (CKDu) research conducted in Latin America versus Asia	2021	Latin America	In a literature review they found 65 studies about risk factors around CKDu in Latin America, where heat stress is the most common studied risk factor, followed by agrochemical use, and traditional epidemiologic research methods are mostly used. In general, sex, family history of CKDu, water intake, and latitude with MeN prevalence have been significantly associated with CKDu. Although the use of agrochemicals have been studied, there are not significant conclusions for it to be considered a risk factor related with CKDu. ----------- 1. 65 studies were found in Latin America: “(Nicaragua—18 studies, El Salvador—11 studies, Mexico—5 studies, Guatemala—5	Literature review

			studies, Costa Rica, and Brazil—1 study each). Central America as a region was discussed in an additional 24 papers." 2. Type of data: "Studies analyzing human blood (26 in Asia, 33 in Latin America) and urine (24 in Asia, 32 in Latin America) were reported more frequently than other sample types." 3. Risk factors considered: "in Latin America, heat stress/dehydration (N = 36) was the most commonly studied risk factor, followed by agrochemical product usage (N = 18), with heavy metals (N = 8) and drinking water contamination (N = 5) less frequently studied. Fig. 4 shows how these risk factors compare between the two regions and by study type." 4. LatAm conclusion: "In Latin America, heat stress research eclipses all other searches for a causative risk factor. Studies in this region have used more traditional epidemiologic research methods, such as case-control and cohort study designs. The summary below highlights the fact that research in these regions is focused on looking at a subset of potential risk factors. MeN/CKDu in Latin America. In Latin America, heat stress and dehydration are the most researched topics related to CKDu risk factors. Several comprehensive literature reviews of MeN in Latin America have examined multiple exposure pathways and found that correlations of sex, family history of CKDu, water intake, and latitude with MeN prevalence have high odds ratios, and were significantly associated with CKDu, while other commonly cited risk factors such as pesticide exposure, alcohol consumption, and	

			NSAIDs did not (Gonzalez-Quiroz et al., 2018a; Herath et al., 2018a; Madero et al., 2017). Other risk factors such as the use of agrochemicals (Campese, 2016; Orantes Navarro et al., 2015) and contaminated water (Campese, 2017) have been mentioned as potential risk factors, although only one study reported collection of environmental samples. Genetic and developmental issues (Friedman and Luyckx, 2019; Perez-Gomez et al., 2018) and Leptospirosis (Riefkohl et al., 2017; Yang, 2018; Yang et al., 2015; Yih et al., 2019) have also been researched in this region. Some studies evaluated heat stress and dehydration interventions in Central America (Caplin et al., 2017; Gonzalez-Quiroz et al., 2017; Wright, 2018) in an effort to reduce acute kidney injury (Bodin et al., 2016; Butler-Dawson et al., 2019). One study provided shade, breaks, and greater drinking water access to sugarcane workers, which decreased self-reported dehydration and heat stress (Bodin et al., 2016). Another intervention study found acute kidney injury despite decreased dehydration, suggesting a multifaceted CKDu etiology(Butler-Dawson et al., 2019). Although mouse model studies were limited, treatment of increased levels of uric acid in blood using allopurinol in one mouse study showed protection of kidney function when exposed to heat stress, laying the groundwork for potential clinical trials in humans (Roncal–Jimenez et al., 2018)."	
Investigating Possible Infectious Causes of Chronic Kidney Disease of Unknown Etiology in a Nicaraguan Mining Community	2019	Nicaragua	1. Main result: "this study of 112 MeN cases and 176 controls in a mining area of Nicaragua, we found a high rate of Leptospira seropositivity among study participants but did not find a positive association between Leptospira seropositivity and MeN (...)	1. Case-control study in a gold-mining area, with 300 subjects. 2. They used logistic regression modeling for risk 134merica134.

			Although we found no evidence of Leptospira or hantavirus seropositivity being risk factors for MeN, the limitations of serology for detecting past infections, especially by Leptospira, and our collection of biological specimens at only a Single point in time preclude us from definitively ruling out these infections as MeN risk factors on the basis of this study."	
Heat exposure in sugarcane harvesters in Costa Rica	2013	Costa Rica	It is important to consider that "harvesters tend to be physically fit and acclimatized to hot weather and therefore may be less vulnerable than the average worker that threshold limits try to protect." A vast part of the workers are migrants of advanced age, which means that they could have former health conditions. Considering that workers are paid based on the sugarcane cut, workers have little incentives to take rest periods or drink water. ----------- 1. Water result: "that water breaks do not necessarily provide time and conditions for core body temperature to decrease." 2. General result: "that harvesters are working long periods over internationally recognized safety limits. It is possible that harvesters tend to be physically fit and acclimatized to hot weather and therefore may be less vulnerable than the average worker that threshold limits try to protect. On the other hand, the low socio-economic status and migrant status of the majority of workers as well as the advanced age of some mean that they likely	Computation of the WBGT, metabolic rate, threshold limit for heat stress risk.

			have underlying health and/or nutrition complications, thereby making stricter protective measures appropriate. A partial explanation for the sustained work efforts of the harvesters in this study is that they do pause to sharpen their machetes, talk to co-workers or supervisors, and drink water. These activities may be a form of self-pacing and provide some of the rest periods that OSHA recommends, thereby helping prevent overheating. It must be pointed out, however, that when choices about resting, drinking water or eating are left up to the individual worker, they cannot be relied upon as protection measures when the workers are not paid for their rest time, or when productivity incentives, such as being paid by the amount of sugarcane cut, exist (...) Another reason that workers should not be allowed to decide when to leave the field is that workers who are in an advanced state of heat illness may exhibit confusion and those on the verge of heat exhaustion can suffer confusion or loss of judgment [United States Air Force, 2002] and may even become resistant to advice from co-workers who suggest taking a break."	
Climate Change and the Emergent Epidemic of CKD from Heat Stress in Rural Communities: The Case for Heat Stress Nephropathy	2016	Latin America	Although it has been reported that women are also affected by CKD, but in a lesser extent, as well as the possible risk of children, further research is needed. ----------- 1. Brazil research: "AKI has also been reported in sugarcane workers in Brazil (34), and population-based studies are being planned in Brazil to better understand the clinical and epidemiologic situation on the	Literature review

			ground." 2. Nephropahy in Mesoamerica- a summary: first reported in 2002 in El Salvador. "The disease typically presents in male sugarcane workers from the Pacific coast of Central America, but has since been reported with less frequency in other occupations, including in construction workers, corn and rice farmers, cotton plantation workers, and miners (32,36–38). In the affected areas women also have an increased prevalence of CKD, although to a much lesser extent, and there is some preliminary evidence that children from these regions may also be at risk (36,39,40). Clinically, the subjects are usually discovered with an asymptomatic rise in serum creatinine, in association with low grade or absent proteinuria, occasionally with microhematuria (36,37). Mild anemia, hypokalemia, and hyperuricemia are common (41–43). Renal biopsies show interstitial fibrosis, low grade inflammation, tubular atrophy, and extensive glomerulosclerosis with signs of glomerular ischemia but only mild vascular lesions (42,44). Progression to ESRD occurs over several years and is higher in those who work more harvests (32). Since chronic renal replacement programs are rarely available in the affected regions, many thousands have died (25). Initial concerns were that Mesoamerican nephropathy might be due to a toxin, for example, from exposure to agrochemicals (such as glyphosate), heavy metals (such as from lead, cadmium, or arsenic), or infectious agents (such as leptospirosis) (24,45,46). The theory that this was a result of direct exposure to pesticides in the fields, however, is weakened by the presence of the disease in occupations not	

			involving farming, by reports that there is a greater risk for renal injury in the sugarcane fields among the cane cutters as opposed to the pesticide applicators, and because the frequency of the disease is lower in sugarcane cutters working at higher altitudes where it is significantly cooler than at lower altitudes, despite similar agrochemical exposure (32,36,47). Nevertheless, it remains possible that toxins, for example, could be concentrating in well water that could affect the populations as a whole. There is also minimal evidence for heavy metal poisoning, such as from lead or cadmium (29). Nonsteroidal agent use is also common among the sugarcane workers and could be an additive factor, but several studies could not identify nonsteroidal anti-inflammatory drugs as an independent risk factor for CKD in this population (32,36,48). Infections, such as leptospirosis, remain a possible cause (49) but there is minimal evidence for this disease as a primary driver of this epidemic, and certainly some manifestations of leptospirosis, such as liver involvement, are not observed." 3. "Evidence that heat stress and recurrent dehydration may be the cause of Mesoamerican nephropathy is emerging."	
Biomarkers of Kidney Injury Among Nicaraguan Sugarcane Workers	2016	Nicaragua	In Nicaraguan sugarcane workers biomarkers of kidney injury varied according to the type of job and increased during the harvest season, especially in cane cutting workers, that were found to be the more vulnerable but that if they intake electrolytes and hydrate during the workday, it might protect them against kidney injury.	Study design in northwestern Nicaragua

			---------- Main result: “In a population of Nicaraguan sugarcane workers at risk for Mesoamerican Nephropathy, urinary levels of NGAL and IL-18, both biomarkers of kidney injury, increased during the harvest season in certain job tasks relative to others. These findings suggest that subclinical kidney injury is occurring in these workers during one harvest season, and the differences by job provide evidence that occupational exposures play a role. We found associations between increases in NGAL and NAG levels and decreases in eGFRs. Finally, we found evidence that electrolyte solution consumption may reduce levels of biomarkers of kidney injury among individuals working high-risk jobs. Our results indicate that of the 7 jobs studied, cane cutters are at highest risk for kidney injury during the harvest.” Complement result: “for the most high-risk jobs such as cane cutting, electrolyte solution intake for rehydration during the workday might protect against kidney injury.” Gender result: “We found that at both pre- and late-harvest, men had NGAL and IL-18 levels that were about one-third those of women regardless of normalization for urine creatinine level, but that the change in these biomarker levels during the harvest was not different by sex.” General result: “in this population of Nicaraguan sugarcane workers, we found that levels of biomarkers of kidney injury varied by job and increased during the harvest season, most notably among cane cutters. These findings suggest that	

			occupational heat stress and volume depletion may play a role in Mesoamerican Nephropathy, and future studies that quantify these exposures are needed. Our results are consistent with tubular injury and support the hypothesis that in these workers, repeated subclinical kidney damage may lead to clinically apparent CKD over time. Our findings suggest that for high-risk jobs such as cane cutting, using electrolyte solutions for rehydration during the workday may protect against kidney injury. This should be evaluated with more quantitative measures of fluid balance in future studies."	
Chronic kidney disease of non-traditional origin in Mesoamerica: a disease primarily driven by occupational heat stress	2020	Mesoamerica	They make a great literature review and conclude that although more research is needed to understand the determinants of CKDnt, heat stress is the strongest factor. The evidence so far is sufficient to consider CKDnt in Mesoamerica as work-driven, since non-occupation or environmental toxicants have explained the epidemic. Although currently, sugarcane cutters have been the ones with the attention, increasing temperatures in the future could indicate that other occupations may be at risk. Longer studies are needed to understand the progression of the disease. ------------ Conclusion: "Studies have documented that CDKnt in Mesoamerica is an occupational disease associated with heavy manual work in hot, often agricultural, regions along the Pacific coast. Importantly, no study has provided evidence against an occupational nature of CKDnt (41). Of all potential risk factors, heat stress appears to be the	Policy 140merica140

			strongest, although much is still needed to better understand determinants of CKDnt onset. Improved exposure assessment and longer follow-up will be important in understanding disease progression. Early research shows benefit of water-rest-shade programs to prevent kidney dysfunction. To date no specific occupational or environmental toxicants have been identified that can adequately explain the epidemic. Non-occupational risk factors have not been consistently associated with CKDnt, and no factor emerged suspect as a primary driver. The evidence for occupational heat stress is sufficiently strong that it requires primary prevention, with evaluation of the components and effectiveness of implementation of the interventions. Future studies should also focus on disease initiation, progression and secondary prevention. In summary, we consider the evidence sufficient that work is the main driver of the epidemic of CKDnt in Mesoamerica. Occupational heat stress is the single factor shown to lead to kidney dysfunction in affected populations. Sugarcane cutters could be viewed as a sentinel occupational population. With increasing environmental temperatures, risk may extend to other occupations with lesser physical demands and other regions as they warm. Action must be taken now while we continue to refine understanding."	
Intervention to reduce heat stress and improve efficiency among sugarcane workers in El Salvador: Phase 1	2016	El Salvador	Although further research is needed, Water-Rest-Shade programs, with cutting efficiency guidelines, have been found to be positive for increasing productivity and reducing heat stress conditions.	Intervention where two groups of cane cutters were invited with similar cane cutting but in two distinct environments.

			------ 1. Main conclusion: “it is possible to implement a focused WRS programme for manual sugarcane cutters in conjunction with an efficiency training programme [through cutting experts guidelines]. Although economic analysis is needed to draw cost–benefit conclusions, we found increased productivity and improved work satisfaction that benefits workers and the mill. It was possible to accomplish a repeated and extensive monitoring of work and environmental conditions and biological sampling in the field.” 2. Perceptions of change: “workers and worker families responded positively to the intervention. The caporal and the workers reported that working conditions had changed. They had believed that the poor working conditions were inevitable, but during the intervention came to realize that conditions could be modified so that, even with the harsh weather circumstances, the work could be improved.”	
Increase of core temperature affected the progression of kidney injury by repeated heat stress exposure	2019			
A pilot field evaluation on heat stress in sugarcane workers in Costa Rica: What to do next?	2009	Costa Rica	The design of measures has also been studied, finding that the measures to promote must consider culture, since a common solution is to provide water dispensers or break periods in air-conditioned rooms. However, in Costa Rica there is a belief that moving across temperatures could make you sick, or precautions with the drinking water	Qualitative assessment through interviews. Questions were about productivity, health, importance of the research, among others.

			--- 1. Interesting about culture importance when designing the necessary measures: “Although some potential solutions are already in place within some companies, such as providing water dispensers inside sugar mills, their effectiveness has not been studied. One potential solution that has been suggested is providing break periods in air-conditioned rooms. Interestingly, this solution may present cultural barriers, and therefore may require a holistic interdisciplinary and participatory approach to research. In particular, there is a strongly held belief in Costa Rica that moving from hot to cold temperatures will cause one to become sick (for example, catch a cold or develop arthritis). Similar beliefs exist about drinking water or other liquids that are cold. There have been no studies to investigate the viability of rest chambers or the provision of cold drinks in terms of the tendency of Costa Ricans to avoid temperature extremes. Other strategies implemented by workers at the individual level may be having negative effects (for example taking caffeinated aspirin pills) or be positive initiatives (for example cooling water in the field by wrapping water jugs in wet cloth, or cooling feet by placing them in cool water while wearing rubber boots) that could be encouraged on a larger scale.” 2. Water solution-culture problem: “Hydration is another example of a commonly used approach already in place within the sugar mills to decrease potential negative effects of	

			heat exposure. However, health and safety personnel indicated that they believe factors such as nutrition and electrolyte levels should be incorporated into hydration programmes in order to make them more effective. Although companies have expressed interest in a more integral nutrition-based approach to hydration as a means of combating heat stress, there have been no studies to explore the dietary and hydration habits already in place or the possibility of implementing hydration programmes in the sugarcane industry. Particularly in Guanacaste, hydration is complicated by what appears to be a widespread belief that the water is unsafe and can lead to kidney problems. This possibility warrants an integrated research model that includes testing the drinking water for nephrotoxins.”	
Heat exposure in sugarcane workers in Costa Rica during the non-harvest season	2010	Costa Rica	1. Main conclusion for us: “This study demonstrates the need to work toward strategies to protect workers from the negative health and productivity effects of heat exposure under current conditions. The non-harvest season is generally considered the less intensive for workers and the companies where this study took place have some of the most favorable (coolest) climatic conditions compared to other sugarcane growing areas in the country. If, as predicted, temperatures rise in Costa Rica and elsewhere in the tropics, there is a pressing need to get strategies in place before conditions, which are already dangerous for workers, become worse (...) This study demonstrated a clear risk of heat stress for workers in non-harvest season tasks in three companies in Costa Rica.”	Qualitative assessment through participatory methods.

Sugarcane Workweek Study: Risk Factors for Daily Changes in Creatinine	2021	Guatemala	Guatemala's sugarcane workers increase their creatine during work shifts when exposed to heat, which could damage the kidneys, and rest breaks were found to be protective. Therefore, it is key to understand better how heat stress, rest, and fluid intake relate to renal problems. --------- 2 main findings: 1. "heat exposure contributes to increases in creatinine across the work shift as well as protective factors in which individual workers can protect themselves under hot conditions."; 2. "workers under these conditions who consumed artesian well water experienced more severe increases in creatinine across the work shift." 1. Heat-related result: "it is necessary to understand the roles of heat stress, rest, and adequate fluid intake in the mitigation of renal stress. We observed that heat exposure plays a role in the daily increase in creatinine. Studies have shown biochemical evidence of heat induced kidney injury.23,24,27,59 which can be induced with increases in serum and urine uric acid and extracellular volume depletion.53 In addition, rest breaks were found to be protective against severe increases in creatinine and a nonsignificant trend that increasing USG was associated with increases in creatinine."	Study conducted between 2017 and 2018
Exposure to air pollutants and heat stress among resource-poor women entrepreneurs in small-scale cassava processing	2019	Nigeria		

Chronic interstitial nephritis in agricultural communities: a worldwide epidemic with social, occupational and environmental determinants	2017	Central America	The difference of CKD prevalence on patients exposed to similar environmental conditions and risks supports the hypothesis that there is no single factor that explains CINAC, including social determinants. Then, heat is a key variable, but not the only one that triggers CINAC. --------- They have a comparison table of CINAC in Sri Lanka and Central America. It is a really good table to understand more about CINAC Key conclusion: "The differences in the incidence of CKD among patients exposed to similar environmental conditions and risk factors further support that a single agent is unlikely to be responsible for CINAC. It is more likely that a complex interaction among the proposed risk factors contributes to the eventual development of the disease. To that cascade of events are added other factors such as social determinants that make them particularly vulnerable to prior kidney damage, such as low birth weight, malaria, diabetes, hypertension, obesity, smoking, excessive alcohol consumption, and use of non-steroidal anti-inflammatory drugs and nephrotoxic medicinal plants [45]." Then, heat is a key variable, but not the only one that triggers CINAC.	Literature review
Tick burden in Bos taurus cattle and its relationship with heat stress in three agroecological zones in the tropics of Colombia	2019	Colombia	Cattle experience heat stress much faster than other livestock species, which leads to higher tick burden. --------- 1. Main result related to tick burn: "The higher tick burden found in SM and ROMO animals	1. The study was developed in three experimental stations of Agrosavia in the departments of Antioquia and Meta. 2. A statistical analysis through a regression was performed

			with an AI > 2 would indicate that cattle with a state of lower adaptability, expressed by the experience of a thermal discomfort, have a higher susceptibility to be infested by ticks. The better thermal adaptation of some animals (with an AI < 2) might be explained by having a particular phenotype for some of the traits discussed above (shorter hair, lighter/brighter coat, smooth coat). However, the ability of cattle to dissipate heat load by sweating and panting is compromised in hot and humid conditions making cattle experience heat stress much faster than other livestock species such as swine [9]. Therefore, the aforementioned adaptation-related traits would be particularly important for cattle located in the tropics, since humidity levels are higher in this region throughout the whole year compared with other latitudes.”	
Chronic kidney disease mortality trends in selected Central America countries, 1997-2013: clues to an epidemic of chronic interstitial nephritis of agricultural communities	2018	Central America	confirms clear elevated pattern of CKD-N18 premature mortality in El Salvador and Nicaragua. The authors find an excess in CKD-N18 mortality related with the chronic interstitial nephritis of agricultural communities (CINAC) that leads to the conclusion that heat-stress and dehydration hypothesis cannot fully explain the epidemic, for which agricultural and environmental factors must be considered. Then, the epidemic could have multiple sources. --------- 1. The study confirms clear elevated pattern of CKD-N18 premature mortality in El Salvador and Nicaragua. 2. Gender approach: “expand mortality	1. WGO/PAHO recommended method for correcting data. 2. Linear and exponential regressions.

			analyses conducted previously to cover a longer period of time and capture more cases, with particular attention to women and adolescents and children, and to better characterize the pattern of this CKD epidemic (...) The mortality pattern observed in our study and concurrent research findings in this context suggest an exposure gradient or a dose–response effect that may explain disparities by sex in the case of the CINAC epidemic." 3. Epidemic timeline: "we estimate that the onset of the epidemic of CINAC may have occurred around mid-1970s, a period which coincided with important changes in agricultural production in this region. The beginning of the epidemic (1975– 1990) run in tandem with the growth of cotton cultivation in Nicaragua and El Salvador. In addition, sugar cane production grew 1.4-fold and 2.0-fold between 2000 and 2013 in Nicaragua and El Salvador, respectively." 4. Multisource: "It is important to point out that the toxic and the heat dehydration hypotheses are not incompatible, but rather complementary. Taken together, the existing evidence points to the biological plausibility of synergism, that is, a more comprehensive multideterminant model of causation, where organ damage results from multiple risk factors, acute and chronic, acting simultaneously or sequentially over the life course amplifying the effect of each other. In others words, in Central America, as in many others high-intensity agricultural areas, the work and temperature stresses and the contaminated environment might lead to an	

			accelerated loss of nephrons and a relative depletion of kidney mass relatively early in life, after reaching working age, particularly among males. This might be exacerbated in especially vulnerable persons, for example, those with nutritional deficiency."	
Chronic kidney disease in Central American agricultural communities: challenges for epidemiology and public health	2014	Central America	In this topic is highly important to investigate further on the causal factor related to heat stress and dehydration (including electrolyte imbalances)	Literature review
Prevalence and Risk Factors for CKD Among Brickmaking Workers in La Paz Centro, Nicaragua	2019	Nicaragua	In Nicaragua, CKD is also prevalent in brick workers, which implies that CKD is not limited to agricultural workers. In fact, brick workers could have a higher prevalence of CKD. This could be happening because brick workers are comparatively informal workers in comparison with sugarcane workers and the protection that these last ones use. However, both workers share some characteristics such as low education, living in rural areas ------------- NOTE: This is a key paper because it concludes that the prevalence of CKD is high in brick workers, so the CKD epidemic could be happening not just in agricultural workers. 1. Difference between agricultural workers and brickmakers: "One reason that we observed a higher prevalence of stage 5 CKD in this sector may be due to the difference in worker protection and screening. Within the formal sector of the sugarcane industry in the region, employers often conduct a pre-employment health screening that includes Scr measurement, as described by Laws et al. in 2015. Workers who have elevated Scr levels are often not hired. Given that	Study design with 257 brick workers from 45 brickmaking facilities, randomly selected. Baseline assessment was carried out through questionnaires and medical samples.

			brickmaking is comparatively informal relative to the sugarcane industry in this region, it is likely that more brick workers with kidney damage are occupationally active." 2. Similarities between sectors: "Our results indicate that brick workers have a high prevalence of CKD and share risk factors for CKDnt that are similar to those observed among agricultural workers in the region, including occupation and low education. In the present study, a medical history of hypertension or diabetes was infrequent, and neither was associated with CKD, consistent with the presentation of CKDnt in the region. Sugarcane and brick makers in this region of Nicaragua live in predominantly rural areas, where their respective industries are the primary economic activity and as such define the lifestyle of the surrounding communities. This may include less emphasis on or opportunity for formal education. (...) Insufficient hydration and volume depletion events may also be risk factors shared by these populations." 2. Inequality relationship: "oven work and lack of formal education were predictive of having CKD." 3. Women perspective: "it is notable that the same proportion of women performed oven work at both visits as men, and none had CKD; the effect of oven work at both visits on kidney function was only observed among men."	
The direct impact of climate change on regional labor productivity	2009	Latin America	Models estimate reductions in labor productivity in a warmer world by 2080 in Andean and Central America, as well as in the	Statistical estimations and GIS

			Caribbean In addition, in tropical Latin America climate change, through an increase in the temperature, leads to losses in working days ------------- 1. Main result- productivity: “Climate change is associated with a shift in the distribution of daily temperatures to include more hot days, and more days with WBGT exceeding the threshold for heat tolerance in individuals. Assuming trends towards less labor-intense work and no specific adaptation of workplace conditions to climate change, our model shows significant reductions in labor productivity due to climate warming in a number of regions, particularly in Africa (Table 2). In terms of absolute change in labor productivity (hence reflecting both current and future climate patterns) by the 2080s, the greatest losses (11.4% to 26.9%) are seen under A2 in Southeast Asia, Andean and Central America, Eastern Sub-Saharan Africa, and the Caribbean. Under the A2 scenario, Eastern and Western Europe and Southern Latin America have the smallest losses (0.1% to 0.2%), with a gain seen in Tropical Latin America (3.0%). Under B2, the combined effects of less warming and greater wealth (meaning more people work in less labor-intense jobs) result in considerably smaller impacts in all regions (the greatest loss being 16% in Central America), and labor productivity gains in some regions (up to 6%).” 2. Main result- losses of working days: “climate change creates losses of working days in all regions, which is expected	

			because the temperature will go up everywhere. The impacts of assumed labor force changes vary between the regions, but all such changes reduce the workplace heat impacts. The impacts of the projected shifts of the workforce from agriculture to industry and services in 5 regions are particularly large (between 8.3% and 21.6%, Southeast Asia, Oceania, Western Sub-Saharan Africa, Central Sub-Saharan Africa, tropical Latin America). Thus, additional shifts of the working population from highly heat exposed to less heat exposed occupations can be an effective way of reducing this climate change impact in an area."	
Using demand mapping to assess the benefits of urban green and blue space in cities from four continents	2021	Colombia	Among Dhaka, Kigali, Leicester, Medellin, and Zomba, Medellin has the largest cooling effect from urban green and blue space because of the proportion of high green areas in the city. --------- 1. Main result: "Medellin saw the largest cooling effect from urban green and blue space, of the five cities [Dhaka, Kigali, Leicester, Medellin, and Zomba]. This is because Medellin has a significantly higher proportion of the most effective land cover class for cooling (high green) relative to the other cities (...) When looking only at high green space, differences are more apparent. In Medellin, over 50% of the urban footprint population and 54% of the total urban footprint have access to high green, whereas the figure for the other cities lies between 17% and 25%."	They make estimations for land cover classification, urban footprint, urbanization- related pressures, socio-economic data, and quantification of ecosystem services provided by urban green and blue space.
Heat Exposure and Youth Migration in Central America and the Caribbean	2017	Latin America	The increase in heat exposure more than doubles the probability of young unskilled women to migrate to the capital because fluctuations in temperature could affect	Difference-in-Difference.

			industries dominated by women, leading to losses in the income. ---------- 1. Main temperature result: “positive and statistically significant effect on the migration of women to a provincial capital. The tendency of women to migrate in response to temperature variability is consistent with recent evidence in South America (Thiede, Gray, and Mueller 2016).” 2. Temperature result on unskill: “A 1 standard deviation increase in heat exposure more than doubles (quadruples) the probability of a young (ages 15–25), unskilled woman migrating to a provincial (national) capital. Restricting the focus to the unskilled also introduces a positive and significant effect on the provincial capital migration of women ages 26–35, and a positive and significant effect on the provincial capital migration of young men.” 2. Reasoning: “income losses caused by fluctuations in temperature may affect the demand for goods and services provided by female-dominated industries (e.g., seamstresses).”	
Associations of Urban Environment Features with Hypertension and Blood Pressure across 230 Latin American Cities	2022	Latin America		
Health-related vulnerability to climate extremes in homoclimatic zones of	2021	Brazil	Through a multidimensional extreme climate vulnerability index find that high temperatures play a key role in explaining the vulnerability of certain areas in Brazil.	1. Grade of Membership (GoM) method to model the degree of “unobserved heterogeneity at the mesoregion level.”

Amazonia and Northeast region of Brazil			------ Main result for us: High temperatures play a key role in explaining the vulnerability of the ED-HT zone [Extreme Drought and High Temperature mesoregion]. Vulnerability as a multidimensional index that considers climatic, sociodemographic and socioeconomic variables. NOTE: High temperatures play a key role within the index to understand the vulnerability of the area.	2. Computationn of the Extreme climate vulnerability index (ECVI) through the Alkire-Foster method.
How the Black Swan damages the harvest: Extreme weather events and the fragility of agriculture in development countries	2022	Latin America	The changing climate in LAC leads to mixed effects of rising temperature on agriculture. Nevertheless, extreme high temperature leads to the highest production losses in the region. ---------- 1. Main result for our region of interest: “Central America & Caribbean exhibits the highest conditional probabilities due to weather extremes for rice and maize, whereas South America shows it for barley and soybean which are among the most important staple crops in the regions. Weather patterns are diverse in Latin America. Whereas South America experiences rising temperature and changing precipitation patterns leading to mixed effects on agriculture, an increase in temperature severely damages agricultural output in Central America. Moreover, even though Central America is marked by a decline in precipitation, floods remain among the most frequent extreme weather events [46]. The estimated conditional probabilities suggest that in Central America & Caribbean maize production reacts mainly to extremes in high	Statistical model

			precipitation and temperature and rice production reacts to extreme low precipitation. In South America, barley and soybean production losses are likely to increase with extremes in temperature and low precipitation respectively.” 2. Yield loss in our region: “In Central America & Caribbean, South America, Eastern Africa and Middle & Southern Africa, extreme high temperature is the condition that leads to the highest production losses. Whereas in the African regions, the associated crop is sorghum, the associated crop is maize in Central America & Caribbean and barley in South America.”	
Chilling Prospects. Tracking Sustainable Cooling for All. 2021.	2021	Global	Access to cooling tools: “In Latin America and the Caribbean, the number of those at highest risk in six countries high-impact countries for access to sustainable cooling grew slightly from 47.6 million people in 2020, to 48.8 million people in 2021. Of those at highest risk, the vast majority are the urban poor, which increased by 500,000 people compared to the previous year. Within the region, the most significant growth in the urban poor category was observed in Brazil (299,000 people) and Bolivia (55,000 people). Among the rural poor, each country experienced growth between 12 and 14 percent, increasing the total number of people living in rural settings who are at high risk of a lack of access to cooling by approximately 700,000. Among the six high-impact countries identified in the region, Paraguay and the Dominican Republic saw the largest declines in their lower-middle income populations, by 12 and 5 percent respectively, though the size	

			of the middle-income population in each country remained relatively stable.”	
Mortality risk during heat waves in the summer 2013-2014 in 18 provinces of Argentina: Ecological study	2022	Argentina	During summer 2013-14 Argentina suffered three heat waves that covered almost all the country. This period was characterized with mortality increases in absolute and relative values, as well as the risk of dying. Nevertheless, risk of dying could not be ‘undoubtedly’ linked to just one variable. Regarding gender, there was no clear association between sex and mortality rate, but the risk of dying was higher with age. In addition, heat waves had incidence on respiratory and cardiovascular disease mortality ----------- 1. General result: “The summer 2013-2014 was particularly hot with three HWs that covered most of the country, which has been related with a growing number of days with minimal temperature above historical values rather than with changes in maximal temperatures, although regional differences make it difficult to establish a homogeneous pattern.” 2. Mortality result: “Overall mortality during the HWs of summer of 2013-2014 showed heterogeneous behavior in provinces, yet increases in absolute and relative values were observed in relation to the three previous summer’s reference period. In absolute terms there were 1.877 excess deaths, as well as significantly increased risk of dying in 11 of the 18 provinces reached by HWs and in 15 out of the 37 provincial events." Nevertheless, risk of dying could not be ‘undoubtfully’ linked to just one variable.	Ecological study

			3. Gender: there was "no clear association between sex and mortality rates or RR of dying could be drawn." This is different to some studies in Brazil and Europe that women are more sensitive to HW. 4. Age: "the risk of dying significantly increased in four jurisdictions for the 60-79 years old group and in six jurisdictions for those 80 years old and over, taking together all HWs of the summer 2013-2014." 5. Health preconditions: "Exposure to extreme heat conditions for long periods can exacerbate a wide range of pre-existing conditions by triggering the chain of pathological events that lead directly to death. The highest RR in causes of death was recorded for pneumonia; which also had the highest frequency (seven jurisdictions with significantly increased risk). The accumulated cases of respiratory diseases (pneumonia and lower respiratory diseases) were responsible for 457 deaths, only in those jurisdictions where the risk was significantly increased. The incidence of HWs on respiratory disease mortality is consistent with other studies. Cardiovascular disease accounted for 48% of the total causes of death at significantly increased risk observed in five jurisdictions. From these analyses, it would seem that public health programs to prevent heat-related mortality would best be directed at the elderly and those persons with cardiovascular and respiratory diseases."	
Health effects of heat vulnerability in Rio de	2020	Brazil	In Brazil heat waves are "correlated with excess deaths of certain types of circulatory diseases."	Regressions & difference in difference

Janeiro: a validation model for policy applications			-------- 1. “heat waves are correlated with excess deaths of certain types of circulatory diseases.” 2. Heat waves vulnerability: “reducing heat vulnerability might add up to the many benefits of urbanizing favelas and slum areas. In developing countries, urbanization is likely more effective and responsive in the short term. For example, urbanization policies such as paving streets, building proper sanitary sewer and arborizing favelas will reduce the vulnerability of the population living there.” 3. They develop a methodology to improve heat vulnerability indices	
Deforestation and climate change are projected to increase heat stress risk in the Brazilian Amazon	2021	Brazil	Deforestation of the Amazon will affect the risk of extreme heat on local and regional scales, mainly vulnerable regions, affecting health, economic and social spheres. In addition, heat stress due to deforestation is comparable to some climate change scenarios. ----------- Main result: “large-scale deforestation of the Amazon rainforest will greatly magnify the risk of exposure to extreme heat associated with climate change on local and regional scales. These heat levels, which will be physiologically intolerable to the human body, will profoundly affect highly vulnerable regions. The heat extreme conditions induced by deforestation could have negative and significantly long-lasting effects on human health, including decreased workability and increased heat-related morbimortality associated with cardiovascular disease, psychological outcomes and acute kidney	1. Wet-bulb globe temperature estimations. 2. Model simulations to make historical and global warming experiments. 3. Amazon Basin savannization simulations.

			diseases. In Brazil, the combined effects of deforestation and climate change are already being reported based on observational data, with the most extreme warming values reported in large deforested areas from 2003 to 2018." Key literature: "Additionally, increased heat stress exposure might impact several areas of the economy via effects on labor productivity, as workers will be exposed to fatal thermal conditions. In Brazil, outdoor workers are already exposed to heat stress, and the projections indicate increasing high-risk exposure over the next decades34,35. The 1.5 °C increase in the global average temperature based on the projections of HadGEM2 and GFDL-ESM2M climate models could represent 0.84% of losses in working hours by 2030, the equivalent of 850,000 full-time jobs, especially in the agricultural and construction sectors36. Particularly in agriculture, the high risk associated with intense work and thermal overload has already been observed among Brazilian sugarcane cutters37,38."	
Climate change impacts in Latin America and the Caribbean and their implications for development	2015	Latin America		Literature analysis
State of the Climate in Latin America and the Caribbean, 2020	2021	Latin America	1. Heatwaves in Argentina: in Cuyo region on 18-28 January with temperature of 36-43 °C 2. Heatwave in Paraguay: in Mariscal Estigarribia, on 8 March, with temperature of 42.5°C. 3. Heatwave in Peru: "On 20 and 21 February, temperatures above the 90th percentile were recorded in the department of San Martín, in	Data analysis

			the northern Amazonia of Peru. 4. Heatwave in Chile: in Valparaiso, on April 17-22, with temperatures of 28.8 °C. In addition, “In May, record temperatures were observed in Chile during the three episodes of heatwaves between Arica and Santiago, with temperatures of 35.5 °C in Rodelillo, 30.6 °C in Santo Domingo and 28.8 °C in Calama on 25–28 April, the highest since the late 1960s.” 5. Regional heatwave: “Between 29 September and 15 October, a major heatwave affected central South America. Some locations experienced warming of about 10 °C above normal, and some even had temperatures above 40 °C several days in a row (Figure 18). Maximum temperatures at some stations showed record-breaking values, with temperatures up to 10 °C above normal. October maximum temperature in Asunción (Paraguay) reached 42.3 °C, a new historical record. In the city of São Paulo (Brazil), the maximum temperature reached 37.5 °C on 2 October (compared with the long-term mean of 28.8 °C), and on three occasions temperatures surpassed 37.4 °C (Figure 18). In the Plurinational State of Bolivia, the heatwave produced record-breaking temperatures in October in four cities, and the highest temperature ever recorded in San José de Chiquitos of 43.4 °C.” 6. November is a very hoy month in several places, such as Bolivia, the northern Amazon, , Brazil. IMPACT ON SECTORS 1. “Hydrometeorological events, such as floods, storms, droughts and heatwaves, account for 93% of all disasters that took	

			place over the last 20 years." In South America, the hazard types of highest concern: Temperature increase is on third place in both, South America, & Central America and the Caribbean 2. Damage to crops affected by heatwaves is of high concern.	
Working on a warmer planet. The impact of heat stress on labour productivity and decent work	2019	Global	By the end of the century, it is expected an "increase in mean temperature varying between 1.6°C and 4°C in Central America and between 1.7°C and 6.7°C in South America by the end of the century" Historically, the impact of heat stress on labor productivity was low in comparison to other regions; in 1995 just 0.3% of the total number of working hours in the region were lost to heat stress. Nevertheless, the impact of heat stress is expected to increase. By 2030 it is expected that 0.6% of total working hours will be lost due to heat stress driven by the agricultural and construction sectors; this is equivalent to 2.9 million full-time jobs. On Annex 6 there are tables of working hours lost to heat stress by sector and country in 1995 and 2030 (projections) in Central America, South America, and the Caribbean Central America is the subregion most affected in the Americas and it is expected to lose 0.91% of total working hours by 2030 due to heat stress; equivalent to 800,000 full-time jobs. South America is expected to lose 0.76% of total working hours by 2030 due to heat stress; equivalent to 1.6 million full-time jobs. Colombia is in the top 3 of the most affected countries in this subregion. In Latin America the share of GDP lost due to heat stress is expected to increase between 1995 and 2030,	Policy analysis

			A graph of the percentage of GDP lost to heat stress under a 1.5°C global warming scenario is available in Annex 7. The GDP loss due to impact on heat stress is above 1% in large part of the Latin American Region -------- 1. Historical temperature increase: “As for Latin America and the Caribbean, a temperature increase of around 0.7°C to 1°C has been observed throughout Central America and South America over the last 40 years. The only exception is the Chilean coast, which experienced a cooling of approximately 1°C during the same period. Moreover, increases in temperature extremes have been identified in Central America, and also in most parts of the tropical and subtropical areas of South America. Looking forward, projections indicate an increase in mean temperature varying between 1.6°C and 4°C in Central America and between 1.7°C and 6.7°C in South America by the end of the century” NOTE: They have a map on page 42 of the incidence of heat stress during the hottest month in the America, 1995 and 2030 (projections) 2. Impact of heat exposure on labor markets: “The impact of heat stress on labour productivity can already be observed, but it is low compared with other regions of the world because agricultural employment is relatively less widespread. In 1995, around 0.3 per cent of the total number of working hours in the region were lost to heat stress, the equivalent	

			of more than 948,000 full-time jobs. Our analysis shows that 55 per cent of this loss was concentrated in the agricultural sector. The impact of heat stress is expected to intensify in the future. In particular, projections suggest that 0.6 per cent of total working hours will be lost to heat stress in 2030 – the equivalent of around 2.9 million full-time jobs. In line with the lower prevalence of agricultural employment in the region, the agricultural sector's share of this productivity loss is projected to decrease from 55 per cent in 1995 to 39 per cent in 2030, while the construction sector's share is projected to increase from 19 per cent in 1995 to 26 per cent in 2030." NOTE: They have a table of working hours lost to heat stress by sector and country. 1995 and 2030 (projections) on pages 44 and 45. 3. Subregional analysis of heat events and labor- Central America: "Central America is the subregion most affected by heat stress in the Americas, which is due, in part, to its proximity to the tropical zone. Indeed, the subregion lost a total of 0.61 per cent of total working hours (the equivalent of 272,000 full-time jobs) as a result of heat stress in 1995. In 2030, the impact of heat stress on labour productivity is expected to be even more pronounced, with up to 0.91 per cent of total working hours being lost (the equivalent of 800,000 full-time jobs) (...) the percentage of working hours lost in 1995 ranged from 0.42 per cent in Guatemala to 0.69 per cent in Nicaragua, while projections for 2030 range from 0.65 per cent in Costa Rica to 1.2 per cent in Panama." 4. Subregional analysis of heat events and labor- South America: "Labour productivity in South America is also impaired by heat stress	

			(table 4.3). Thus, rising temperatures reduced working hours by 0.37 per cent in 1995 (equivalent to 481,000 full-time jobs), and this productivity loss is expected to reach 0.76 per cent in 2030 (equivalent to 1.6 million full-time jobs). However, the impact varies considerably within the subregion. In 1995, the countries with the highest losses included Guyana (1.56 per cent), Suriname (0.64 per cent) and Colombia (0.55 per cent); other countries, such as Uruguay, Argentina and Peru, exhibited much lower rates. Although the estimated share of working hours lost in Brazil was 0.44 per cent in 1995, its sizeable population means that this productivity loss translated into an equivalent of 314,000 full-time jobs, accounting for more than half of the loss incurred by the subregion. As a result of climate change, the productivity loss in terms of working hours is expected to increase in practically all countries in South America." NOTE: They have a figure of the percentage of GDP lost to heat stress under a 1.5°C on page 27. 5. GDP and heat stress: "In all ten countries, which are located in Central and South America, the share of GDP lost as a result of heat stress is projected to increase between 1995 and 2030. Guyana is the country hardest hit: it lost 1.6 per cent of GDP to heat stress in 1995 and is expected to lose 3 per cent of GDP in 2030. Our analysis also points to a significant impact of heat stress on other Central and South American countries, with GDP losses increasing to more than 1 per cent in 2030 in all ten countries shown in figure 4.3. The GDP losses due to the impact of heat stress on labor productivity are projected to almost triple in Suriname and Ecuador between 1995 and 2030, rising from	

			0.7 to 2 per cent and from 0.3 to 1.1 per cent, respectively. Tropical countries with a large share of agricultural employment such as Honduras, El Salvador, Nicaragua and Guatemala are also among the most affected by heat stress in the region. The estimated regional average GDP loss was 0.2 per cent in 1995. This is projected to reach 0.4 per cent in 2030, which points to a growing trend of adverse heat stress impacts but at the same time also reflects the small effect that heat stress is expected to have on the northern part of the region."	
How urban characteristics affect vulnerability to heat and cold: a multi-country analysis	2019	Global	Global study that considers cities in Colombia, Brazil, and Chile, finds that cities with higher GDP, life expectancy and educational level are characterized by higher mortality from heat. Higher mortality rates because of heat are also present in cities with high population density, inequalities, pollution levels and fewer green spaces. ------------ 1. Main result: "Our findings suggest that more developed cities are perhaps surprisingly characterized by higher mortality attributable to heat, as indicated by the significant association with GDP, life expectancy and educational level. Furthermore, a second pattern emerged, with higher impact of heat on mortality in cities characterized by high population density, inequalities, pollution levels and fewer green spaces." 2. Infraestructure and heat impact: "The nature of urban infrastructure creates microclimates that affect temperature; the urban heat island effect is an example, where cities are warmer than their surrounding	1. Time-series analysis. 2. City-specific heat and cold attributable fraction.

			hinterlands due to the thermal storage capacity of the built environment.33 In our results, urban density is associated with an increased heat effect, which is also shown in other contextual studies." 3. Heat and inequality: "we found a positive association between the Gini index of the city's region (an indicator of inequality) and heat impact. This result is consistent with those observed in contextual and individual studies showing a higher heat effect on communities or subjects with lower socio-economic status." 4. Economy, heat, infrastructure and inequality: "heat-related impacts are higher in cities with a higher economic development characterized by a higher GDP, productivity, educational level and life expectancy. Using GDP as an indicator, Anderson and Bell observed a similar positive contextual association in 107 US urban communities, whereas Hajat and Kosatk found a negative association with GDP when meta-regressing heat coefficients across studies internationally. No association was observed at a contextual level in three other studies. The increased impacts of heat on cities with higher GDP, educational level and life expectancy are not necessarily due to those cities being more unequal, as the correlation of those indicators with Gini is low. One explanation might be an association between economic development with features of urbanization such as the urban heat island, but further studies, including individual-level socio-economic indicators, are needed to clarify this."	

Urban poverty and vulnerability to climate change in Latin America	2009	Latin America	1. From the analysis: “Most low-income groups live in housing without air-conditioning or adequate insulation, and during heat waves, the very young, the elderly and people in poor health are particularly at risk.(41) In northern Mexico, heat waves have been correlated with increases in mortality rates; in Buenos Aires, 10 per cent of summer deaths are associated with heat strain; and records show increases in the incidence of diarrhea in Peru.(42) Cold spells are also becoming more frequent, and without proper heating and housing insulation they are also difficult to cope with. In July 2007, it snowed in Buenos Aires for the first time in almost 100 years. There are no available data, however, on death tolls and health impacts related to unusual and extreme temperatures.”	
Green Infrastructure Planning to Tackle Climate Change in Latin American Cities	2019	Latin America		
Heat resilient cities. Measuring benefits of urban heat adaptation	2021	Colombia		
Climate-resilient infraestructure	2018	Global		
Long-term impacts of exposure to high temperatures on human capital and economic productivity	2019	Ecuador	Higher temperatures in-utero lead to less education and significantly lower earnings as adults. For instance, a 1°C increase in average monthly temperature in-utero leads to a decrease of 0.7% in the earnings as an adult in men and women, but with a larger effect on women. --------- Main finding: “higher temperatures in-utero lead to significantly lower adult earnings, with	Regression analysis

			a 1 C increase in average monthly temperature in-utero leading to about a 0.7% decrease in adult earnings of both men and women, even though the effects on women are somewhat larger (0.9% vs. 0.6%). In contrast, the temperature in the corresponding 9-month period after birth shows no impact on adult earnings.”	
Climate Trends at a Hotspot of Chronic Kidney Disease of Unknown Causes in Nicaragua, 1973-2014	2021	Nicaragua	Sugarcane workers in Nicaragua are at moderate or high risk of heat-related illness based on OSHA’s heat index-based risk guidelines during a great part of their workdays. -------- 1. Weather result: “the average daily maximum temperature at ISA, especially during the harvesting months, was higher than in other parts of Nicaragua, and that it increased during the period between 1973 and 1990.” 2. Labor consequences: “We also estimated that workers at this sugarcane facility were at a high or very high risk of heat-related illness on 20–88% (depending on the heat index estimates used) of the working days during the harvesting seasons between 2000 and 2014 (based on OSHA guidance), which might have had adverse health effects on these workers, including renal damage” OSHA has some guidelines for heat risks. 3. Climate change role: “If heat stress does play a key role in the CKDu epidemic in Mesoamerica as hypothesized, the at-risk population will continue to grow, with predicted increases in both mean ambient	1. Statistical analysis. 2. Computation of a Heat Index.

			temperature and weather extremes (i.e., heat waves) due to climate change" 4. Conclusion: "We found that the average daily maximum temperatures at a sugar company with high rates of CKDu in northwestern Nicaragua were higher than in other parts of Nicaragua and that temperatures increased during the period between 1973 and 1990. On a majority of work days during the harvest season, workers were at a moderate or high risk of heat-related illness based on OSHA's heat index-based risk guidelines. While we cannot draw any causal conclusions from this research, we believe these findings add important context to ongoing research on the role of heat stress in the development of CKDu."	
Workplace Screening Identifies Clinically Significant and Potentially Reversible Kidney Injury in Heat-Exposed Sugarcane Workers	2020	Guatemala	In a longitudinal study of Guatemalan sugarcane workers find that early detection of CKDu and "intervention may either prevent or at least delay progression and warrants further study. Given the current scale of the epidemic, earlier identification of patients at risk of disease is critical." Key interventions include increase consumption of electrolytes, water, emphasis in education. And clinical monitoring. ------------ Intervention result: "Mid-season screening proved valuable in identifying the subgroups that had progressed to RKF and AKF (...) our interventions included an increased focus on consumption of electrolyte solution as well as water, educational emphasis on reducing heat stress and on the recognition and avoidance of nephrotoxins, as well as enhanced clinical monitoring for workers	They worked with a parent study conducted between 2016 and 2017 with 517 field workers employed by a sugarcane agribusiness in Guatemala. After this, they made their own methodology, assigning workers to different categories based on certain health characteristics. Latter, the statistical analysis was performed with mixed effects linear regressions.

			identified with abnormal kidney function during the season. Contrary to the commonly held belief that CKDu progresses inexorably to end stage renal disease, this study suggests that early detection and intervention may either prevent or at least delay progression and warrants further study. Given the current scale of the epidemic, earlier identification of patients at risk of disease is critical. Some worker appeared to improve their kidney function throughout intervention period, however it is not clear if this actually represents a possible reversal of disease.”	
Heat stress, dehydration, and kidney function in sugarcane cutters in El Salvador–A cross-shift study of workers at risk of Mesoamerican nephropathy	2015	El Salvador	Heat stress and recurrent dehydration are key factors of MeN prevalence in sugarcane workers. ----------- 1. Heat-related result: “The present study provides the first detailed data showing the extent of heat stress in sugarcane workers in a region with high prevalence of MeN. The concentrated post-shift urine suggests a repeated heavy load on renal tubular reabsorption. This may be compatible with histopathological findings of tubular atrophy and interstitial fibrosis in cases of MeN (Wijkstrom et al., 2013; López- Marín et al. 2014). The redistribution of blood to muscles and skin indicates that renal blood flow is much reduced during work, as also supported by cross-shift increase of serum creatinine and urea nitrogen, indicating reduced GFR during work. This may be one factor behind glomerulosclerosis found in MeN kidney biopsies (Wijkstrom et al., 2013; Lopez-Marín et al., 2014). Another factor could be the increase of serum uric acid; animal studies	Study developed in 3 groups of sugarcane cutters. The study design was cross-sectional (in March/April 2014, at the end of the 6 months sugarcane cutting season), Differences between groups were tested with variance analysis Differences between pre and post shift characteristics were tested with Wilcoxons signed rank, and association between variables through multiple linear regressions.

			have shown that hyperuricemia can cause renal arteriolar constriction, and eventually glomerular hypertension (Kang et al., 2002, San-chez-Lozada et al., 2005). Acidification of urine, and relatively high prevalence of urate crystals in the sediments, support the hypothesis that urate microcrystals could be a causative factor in MeN." 2. General conclusion: "the present study demonstrates the very hot environment for El Salvadoran sugarcane cutters, and substantial cross-shift changes indicating a heavy load on the kidney to counteract dehydration. There is a strong need for preventive measures, which may be as simple as the provision of water, rest, and shade."	
Heat Stress Nephropathy From Exercise-Induced Uric Acid Crystalluria: A Perspective on Mesoamerican Nephropathy	2016	Mesoamerica		
Association of Copeptin, a Surrogate Marker of Arginine Vasopressin, with Decreased Kidney Function in Sugarcane Workers in Guatemala	2020	Guatemala	In Guatemalan male sugarcane workers, research find preliminary evidence that copeptin may be an early marker of kidney dysfunction. ----------- Main findings: "1) a reduction of urine concentration (through higher fluid intake) was associated with a reduced concentration of copeptin, a surrogate marker of vasopressin; and 2) a reduction of copeptin concentration was associated with an improvement in markers of kidney function. Our findings indicate that plasma copeptin concentrations may be predictive of kidney function decline over several months."	Study developed between 2016-17 with male sugarcane field workers

			General conclusion: "our study provides preliminary evidence that copeptin may be an early marker of kidney dysfunction in agricultural workers at high risk for heat stress. Potential clinical and workplace interventions that mitigate this form of injury should be examined in the face of increasing heat extremes. Further research is warranted to understand the contribution of vasopressin to renal injury."	
Kidney function in sugarcane cutters in Nicaragua–A longitudinal study of workers at risk of Mesoamerican nephropathy	2016	Nicaragua	In Nicaragua glomerular kidney function decreases by 10% after just 9 weeks of harvest, which is an important factor in the emergence of chronic kidney disease.	Longitudinal study conducted in 2012-13 with 29 sugarcane cutters, and 25 office workers in the reference group. Differences between groups were tested.
Resolving the enigma of the 172merica172ura172 nephropathy: a research workshop summary	2014	Mesoamerica	Among researchers specializing in Mesoamerican Nephropathy, there is consensus that repeated heat exposure, and water and solute loss, are essential cofactors of MeN.	
Decreased kidney function among agricultural workers in El Salvador	2012	El Salvador	In communities from different agricultural and service-oriented economies. Sugarcane and cotton workers, both men and woman, were found with more prevalence of decreased kidney function ---- 1. Heat result: "establish the prevalence of decreased kidney function measured by serum creatinine (SCr) and estimated glomerular filtration rate (Egfr) in men and women aged 20-60 years of 5 communities in El Salvador, with different economic activities and at different altitudes, as surrogates for occupational and environmental exposures and heat stress (...) establish the prevalence of decreased kidney function measured by	Study design with sugarcane workers. Regression analysis was performed.

			serum creatinine (SCr) and estimated glomerular filtration rate (Egfr) in men and women aged 20-60 years of 5 communities in El Salvador, with different economic activities and at different altitudes, as surrogates for occupational and environmental exposures and heat stress." 2. Conclusion: "If heat stress is a causal factor for CKD, this disease will be an added health risk related to climate change."	
Pesticide exposures and chronic kidney disease of unknown etiology: an epidemiologic review	2017	Central America	So far there is no research examining the relation between heat and pesticide exposure and their relation with CKDu. Therefore, the role of agrochemicals in the CKDu epidemic cannot be adequately evaluated. --------- They have a good summary of the studies that consider the relationship between pesticides and CKD in Mesoamerica. Key gap for us: "up to today, no research has been conducted in CKDu endemic areas with a strong design and examining the role of lifetime exposures to specific pesticides or chemical groups with similar toxicological actions, especially not in combination with heat exposure or other major risk factors. Therefore, a role of nephrotoxic agrochemicals in the etiology of CKDu and the extent of their contribution to the CKDu epidemic, if any, cannot be adequately evaluated based on currently available data. Given the diversity of pesticide use, such research is difficult and costly, but necessary to elucidate the role, if any, of agrochemicals in this epidemic. We recommend that any	Literature review

			future pesticide research should be conducted with the best possible assessment of lifetime exposures to relevant specific pesticides and enough power to look at interactions with other risk factors, in particular heat stress."	
Weather Shocks and Health at Birth in Colombia	2016	Colombia	Exposure to moderate heat during the third trimester of pregnancy declines birthweight. In addition, they find a positive and significant association "between normal Apgar scores and the most extreme definition of high-temperature shocks" --------------- General result: temperature shocks have adversely affected health outcomes at birth. 1. Main finding: "birthweight declines with exposure to moderate heat waves (high-temperature shocks) during the third trimester of pregnancy." 2. Apgar scores: "positive and statistically significant association between normal Apgar scores and the most extreme definition of high-temperature shocks (events 2.0 or more SDs above the historical mean). We hypothesize that this may be explained by selective mortality, by the potential implementation of coping strategies among households to protect pregnant women from the effects of extreme weather events, or by both. However, we cannot measure the degree of these effects because we do not observe these phenomena in our data."	Econometrics. Fixed effects model.
Geographic, Demographic, and Temporal Variations in the Association between Heat Exposure and Hospitalization in Brazil: A	2019	Brazil	An increase in 5°C in daily temperature in Brazil led during 2000-2015 to an increase in the risk of hospitalizations, in large part because of heat exposure, and with elderly and children being the most vulnerable. Although there were no differences according	Statistical analysis.

Nationwide Study between 2000 and 2015			to the sex, older women were most vulnerable to heat exposure as well as boys and middle-age men. -------- 1. General result: “adverse effects of heat on a range of health outcomes in the Brazilian population that were greatest in children and the elderly. residents) could be attributable to heat exposure during every hot season, with the attributable ASR greatest for infectious and parasitic admissions.” 2. Demographic implications: “the entire Brazilian population, the youth and the elderly ≥80 years old had higher heat susceptibility than adults below age 80 did, possibly due to immature or impaired physiological systems against heat exposure (Committee on Sports Medicine Fitness 2000; Landrigan and Garg 2005). Our analyses indicated that the heat–hospitalization association and the associated attributable fraction were lowest for individuals at or around retirement age (50–79 y). This finding matches some mental–behavioral changes in this population that may benefit their health, such as less occupational stress and more time for healthier lifestyles (e.g., balanced diet) (Laranjeira et al. 2010; Monteiro et al. 2007).” 3. Gender approach: “no substantial sex difference was found in the heat effect and the attributable fraction of hospitalization. However, a marked sex–age difference was observed. (...) older women in Brazil were more vulnerable to heat exposure than were men, possibly due to the effects of menopause on their thermoregulatory capacity. In comparison, the higher estimated risk in adolescent boys and middle-age men	

			than in women may be explained by the males' higher levels of outdoor activities. The exception was among women of reproductive age, for whom, although they had low estimated risk of heat-related hospitalization, the attributable rate of hospitalization was still high due to the vast number of hospitalizations in this population subgroup."	
Resilient soybean and maize production under a varying climate in the semi-arid and sub-humid Chaco	2022	South America	In South America soybean is more tolerant to heat stress than maize.	1. Crop modelling: CERES-Maize and CROPGRO-Soybean. DSSAT v4.5. 2. Linear mixed models.
Impact of warmer constant and fluctuating temperatures in the male Jamaican field cricket, Gryllus assimilis (Fabricius, 1775) (Orthoptera: Gryllidae)	2022	Jamaica	Increasing appearance of heatwaves represent a risk in mortality of crickets and even extinction, especially in South America -------- 1. Main heat result: "deficits in heat loss or water conservation may be leading to the higher mortality observed in FT. The first analysis employed to explore this possibility was to quantify the water content in crickets subjected to our experimental temperature treatments. No significant differences were found in water content among treatments, thus suggesting no difference in water loss; therefore, it did not explain the differences in mortality. However, a slight difference in heat loss indicated that FT crickets lost heat slower than CT34 crickets. This is an interesting finding because the same amount of water is retained in the animals among treatments, and water has a high specific heat. Therefore, a less efficient mechanism of heat loss (e.g., evaporative cooling) found in FT crickets could result in adverse conditions for survival because of higher heat retention."	Different methodologies were used to understand mortality, locomotor activity, metabolic rate, among others. For heat 176me, ANOVAs were used.

			2. An increasing frequency of heatwaves and larger fluctuation in temperatures represent "a risk of higher mortality of G. assimilis males in the future, especially in South America where the risk of extinction for species is approximately 23% (Urban, 2015), and G. assimilis is widely distributed (Lieberman, 1961)." FT: Fluctuating 177merica177ura	
The Impact of climate change on economic output across industries in Chile	2022	Chile	High temperatures in Chile have negative impacts on the economic sector related to agriculture-silviculture and fishing. In addition, high temperatures may deteriorate other sectors such as Construction, as well as the one related with electricity, gas, and water. These results are concentrated during the summer (January-March), particularly in January. -------------- 1. From the literature review: Chile has received little impact from climate change in terms of labour hours lost to high temperatures [21] 2. Main result- Heat: "We find that high temperatures in the summer season (January to March) had a negative impact on the Agriculture-Silviculture and Fishing sectors. Furthermore, by separating the weather at a monthly level, we find that it is high temperature in January in particular, which causes the strongest negative impact. Higher temperatures in January may also cause some deterioration of activity for the Construction and EGA (Electricity, Gas, and Water) sectors. However, since Agriculture-Silviculture and Fishing represent just 4% of	Econometric model & regression 177merica177.

			GDP and summing the sectors of Construction (6.8% of GDP) and Electricity, Gas, and Water (4.0% of GDP), the analysis shows that 85% of the economic activity in Chile was not affected by climate change and that such effect was limited to either the summer season (January to March) or even just a single month (January)."	
Hotspots of extreme heat under global warming	2020	Global	1. Summer maximum temperature: "variability increases relative to pre-industrial levels up to 50% under 2 ◦C of global warming, mostly in Central South America and North America, Central Europe and India." 2. Tropical night conditions: "At 4 ◦C of global warming, extreme tropical night conditions are projected to occur almost everywhere in the world during more than a quarter of the summer months; while being sustained for the entirety of every summer month in tropical night hotspots over South East Asia, the Maritime Continent, Central Africa, and Central North and South America."	1. Transient climate MPI-GE simulations under historical forcing and three RCP scenarios. 2. Computation of monthly wet-bulb temperature estimates. 3. Representative samples of different climate conditions.
Disentangling snakebite dynamics in Colombia: How does rainfall and temperature drive snakebite temporal patterns?	2022	Colombia	Envenoming seasonality from snakebites is not explained by increasing heat. 1. Main result: "envenoming seasonality is significantly explained by rainfall-driven seasonality at the national level, but not by temperature. However, the association between incidence and rainfall is only present in certain regions with marked seasonal rainfall patterns"	Compartmental models.
Increasing trends in regional heatwaves	2020	Global	1. Main result for us: "According to Berkeley Earth, heatwave frequency demonstrates the most widespread and significant increase of the characteristics analyzed (Fig. 1b). Heatwave duration (Fig. 1d), although increasing, has significant trends restricted to South America, Africa, the Middle East, and	Data analysis

			Southwest Asia. Significant heatwave intensity trends (Fig. 1f) are non-existent for most of the globe, the exception being southern Australia and small areas of Africa and South America. On the other hand, significant cumulative heat trends (Fig. 1h) are comparable in space to heatwave frequency (Fig. 1b), with mainly positive magnitudes. The largest trends are seen over the Middle East and parts of Africa and South America, where the extra heat produced by heatwaves is increasing by 10 °C decade−1. For most other areas with significant trends, cumulative heat increases by 2−6 °C decade−1." 2. Regional trend: "temperature changes over this region24,25. While regional trends in heatwave frequency, maximum duration, and cumulative heat are mostly significantly increasing (exception is CNA, see above), trends in average intensity are only significant for regions Amazon (AMZ), Mediterranean (MED), North East Brazil (NEB), Southeast South America (SSA) and West Asia (WAS)."	
Responses to Temperature Shocks: Labor Markets and Migration Decisions in El Salvador	2022	El Salvador	1. Main result: "a sharp gain in temperature reduces agricultural productivity and total production. Farmers adjust by cutting demand for hired workers. Labor markets transmit the negative impact of weather shocks to agricultural workers, who react by migrating or moving to the nonagricultural sector."	Empirical econometric model that explotes temporal and geographical variations, between 2009 and 2018.
Extreme heat and migration	2017	Global		
Magnitude and frequency of heat and cold waves in recent decades: the case of South America	2016	South America	Heat waves result: "There is evidence that an increase of heat wave intensity is ongoing. Specifically, from 1995 onwards it is possible to observe heat waves spread across South America, with the maximum presence during	1. Computation of HWNI and CWMI. 2. Heat and cold waves computation. 3. Finding the trend of mean of temperatura range.

			2010–2014. Between 1980 and 1984 there have been heat waves with magnitude equal to 16 across the central part of the continent, mainly corresponding to Peru, whereas other regions do not show such great heat waves (for further details see the Supplement). In particular, in the austral summer of 1982–1983, during one of the strongest El Niño events (Cane, 1983) of the 20th century, the highest HWMI values in Peru were comparable with the HWMI peak of the 2003 European heat wave that killed more than 70 000 people (Robine et al., 2008; Russo et al., 2014). The central part of the continent also displays severe heat waves during 1995–1999 in correspondence with the 1997–98 El Niño event (McPhaden, 1999), whereas the rest of the region does not present patterns related to El Niño. Generally, HWMI's frequency is low until 1994 and then increases rapidly." Generally speaking, heat waves have increased their intensity and frequency in the last 10 years. NOTE: They make a case study about Bogotá. General trends in heat waves: "There is evidence of an ongoing increase in intensity and frequency of heat wave events. Specifically, from 1995 on-wards it is possible to observe heat wave spread with the maximum presence during 2010–2014. In the last 10 years (i.e. 2005–2014), the number of GSOD stations that experienced heat waves is greater than in the previous 25-year period (i.e. 1980–2004). Interestingly, the spatial patterns of heat waves across Peru display a correspondence with El Niño events	

			(Carmona-Moreno et al., 2005), whereas the rest of the continent does not show such great similarities.”	
A Heat Vulnerability Index: Spatial Patterns of Exposure, Sensitivity and Adaptive Capacity for Santiago de Chile	2016	Chile	1. Heat exposure patterns: LST values are higher where the vegetation cover is lower, while the lowest values could be attributable to higher building densities. In addition, large open spaces have a “strong cooling effect.” 2. Adaptive capacity: “The higher correlation (r-values) were found between HVI and no water supply (0.44) and materials (0.46), respectively, both variables for adaptive capacity. The sensibility analysis shows that important improvements in terms of adaptive capacity and heat vulnerability can be done by improving the water supply and material conditions of the census trats located in the heat clusters.” LST: Land Surface Temperature.	Heat vulnerability index (HVI) developed through GIS analysis.
Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua	2017	Nicaragua	Analyze heat stress, dehydration and kidney disfunction on different sectors, and find that sugarcane cutters present these conditions on sugarcane cutters, and in a less degree on construction workers and small-scale farmers. This because sugarcane cutters have less exposure to shade, among others. -------------- 1. General result: “This study found evidence for more frequent heat stress, dehydration and kidney dysfunction among sugarcane cutters, as expected, and to a lesser degree also reduced kidney function among construction workers but not among small-scale farmers.” 2. Heat stress result: “There was evidence for	Cross-sectional study that considered 194 man between 17-39 years old, working in different sectors: 86 were sugarcane cutters, 56 construction workers and 52 small-scale farmers. Differences between occupations were assessed with ANOVA and Kruskal-Wallis tests, among others.

			a greater risk of heat stress among sugarcane cutters. Sugarcane cutters labored at a faster pace, had less exposure to shade, reported more weight loss during the ongoing harvest and had more fainting episodes. While sugarcane cutters had greater heat stress exposure, they also drank more fluids during the course of the day, amounting to an average of 6.2 L per day (although this varied considerably, with approximately 20% drinking <2.5 L/day and 40% >7 L/day). However, the type of exertion and sweating that occurs with cane harvesting11–13 could still result in a dramatic loss of fluids such that dehydration can occur despite high fluid consumption. Cade et al28 found that college football players could lose as much as 8 quarts (about 7.6 L) of water in a 2-hour period, associated with loss of salt, decrease in blood glucose and a fall in blood pressure."	
Increase of core temperature affected the progression of kidney injury by repeated heat stress exposure	2019	Central America		
An Assessment of the Relationships between Extreme Weather Events, Vulnerability, and the Impacts on Human Wellbeing in Latin America	2018	Latin America	1. Literature: "from 2000 to 2015 the disasters in South America have increased significantly affecting almost 74 million people [21]. The most common disasters have been floods (50%), followed by storms (9%), landslides (8%), and extreme temperatures (8%) [22]."	
Regional disparities in the exposure to heat-related mortality risk under 1.5 °C and 2 °C global warming	2022	Global	NOTE: There is no specific analysis for central or South America. 1. They have great maps about EMR and EHF, which show that the countries surrounding the Amazon are particularly vulnerable (pag. 6).	Indices computation

			2. Central and south America appear as a region of high risk of the product derived from socio-economic pathways and multiple heat-related mortality indices during a climate change scenario (pag. 11) EHF: Excess heat factor EMR: Excessive mortality risk FUT 1.5: Temperature becomes 1.5°c warmer.	
Thermal stress and financial distress: Extreme temperatures and firms' loan defaults in Mexico	2022	Mexico		
The perils of climate change: In utero exposure to temperature variability and birth outcomes in the Andean region	2017	Andean region (Bolivia, Colombia, Peru)	A temperature increase of one SD, in relation with the longterm local mean temperature, "reduces birth weight by 20 g. and increases the probability a baby is born with low birth weight by a 0.7 percentage point, which represents a 10% reduction from the baseline prevalence of 7%." This results are mainly driven by an increase in temperature during the first trimester of pregnancy	Econometrics
Impact assessment of climate change on buildings in Paraguay—Overheating risk under different future climate scenarios	2019	Paraguay	In Paraguay, climate change projections are expected to increase overheating rates on buildings due to higher temperatures, for which regulations are necessary to improve thermal performance of buildings.	Data Modelling

Appendix 5. List of Key Informants

Key Informant	Geographic scope of work	Information contibuted for			
		Objective 2	Objective 3	Objective 6	Objective 7
Representative from the Inter-American Institute for Global Change Research	Americas			X	X
Representative from the Chilean Society of Planetary Health	Chile		X	X	X
Representative from La Isla Network and from The Costa Rica Institute of Technology	Central America and Costa Rica	X		X	X
Representative team from National Unit for Disaster Risk Management - Colombia	Colombia	X		X	
Representative from The International Federation of Medical Students Associations - Honduras	Honduras	X		X	
Representative from World Vision - Honduras	Honduras		X		X
Representative from the Ministry of Health of Argentina	Argentina	X	X	X	X
Representative from the Ministry of Environment and Sustainable Development of Paraguay	Paraguay	X		X	
Representative from Health Emergencies WHO/PAHO	Americas and Paraguay	X		X	X
Climate Change and Health expert	Americas		X	X	
Representative from The National Coordination for Disaster Reduction from Guatemala	Guatemala	X			X

Appendix 6. Coding Agenda

Category	Variable (sub-category)	Definition / description of variable	Examples from the interviews	Coding rule
KNOWN IMPACTS OF EXTREME HEAT				
Impacts	Health	Describes health impacts related to extreme heat	*"In a study for Buenos Aires ... we quantify excess mortality as 1,877 deaths, out of these only 12 were coded as a consequence of excess heat. … The elderly is the most affected group, as well as people with chronic diseases. A challenge we face in Argentina is the demographic and epidemiological transition, where the population is expected to live longer and the amount of vulnerable population will increase…"*	Must include any health impact from extreme or mention vulnerable populations
	Labor	Describe loses in any economic sector and labor productivity after extreme heat	*"Some firms modify working conditions, especially when workers perform duties outside… during hotter months and weeks, they adjust working hours or take breaks more frequently. In Mexico, for example, starting hours are modified and shifts stop at midday when temperatures are highest. They resume work after 3:00 or 4:00 p.m. when it's cooler… Costa Rica is the only country in Central America that has regulations for work and exposure to extreme heat, However, there is no enforcement mechanism."*	Must include impacts on labor market outcomes, such as productivity, income, hours worked, informal sectors, in any economic sector. Include adaptation strategies from firms.

	Agriculture	Describe loses of extreme heat and potential consequences on the agricultural sector	*"...the agricultural sector experienced significant losses triggered by these fires, especially in el Chaco, Paraguay. This is a livestock region, many animals perished and pastures were lost. This has important economic effects."*	Must include impacts on the agricultural sector and potential consequnces of heat on other hazards that affects this sector.
EARLY WARNING SYSTEMS				
Competent entities		Describes how the warning system works, who are the competent entities that act in the event of an extreme heat event.	*" In Argentina, we have separate competencies in terms of heat hour actions, the issuance of alerts is generated by the National Meteorological Service, and then there are two other actors, the National System of Integral Risk Management and Prevention, which depends on the Ministry of Security and there is a whole space of articulation with the rest of the ministries and particularly with regard to Health. Health issues recommendations for health care because the alerts generated by the Meteorological Service are designed and built on the basis of health data. So, although it can be applied to other sectors such as energy, animal health, and others, the system has a strong health component and has been built in that sense."*	Includes the competent entity. In case there is no EWS, indicate which would be the entity that would have to take charge.
Alert level		At what level is the alert given in the country	"*Brazil alerts, but it is that at the city level and there it depends, each city has or not, but it is not an integrated system. So this is one of the challenges. Sometimes there are*	It must include the level at which the alert is given, such as city, region, or country.

			capacities at the local level. But there is no program thought at the national level and by local or provincial meteorological information, the state can be done and put together this type of initiative, but identified as national systems, no."	
RESEARCH AND KNOWLEDGE GAPS				
Knowledge and scientific production	Definition of heat waves and event characterization	Refers to existing definitions of what a heat wave event is, its characteristics/or the existing challenges around the concept	*"But this is one of the problems of the definition, of the definitions that there are about hot days or heat stress or heat waves... ...I don't know if that will be possible, to make a single definition for all countries."*	Must include a definition of heat wave, the scope of the definition or refer to the gaps around the definition
	Correlation studies	Describes the current knowledge or the need of knowledge on correlation studies linking exposure to extremes of heat and impacts on health	*"I think it's more about being able to better characterize these types of events, correlate them with the impacts and generate a type of database and from there begin to design certain actions to begin to reduce those impacts."*	Must include references to the need of linking exposures with morbidity and mortality to stablish correlations
	Impacts	Mentions specific examples of studies that are needed in terms of impacts	*"Another super important issue and, I couldn't tell you how much research there is, but I suspect there's a lack of it, is the impact of heat on children and their whole development... ...How does that affect their ability to learn? Their mental health? Children are very vulnerable to the impacts of climate change, climate extremes, and a lot of times there's a lack of research on the impact on children."*	Must provide specific topics of impacts that up to date, are scarcely studied or have not yet been tackled in CSA or globally
	Vulnerability studies	Describes the importance or need of addressing social	*"Speaking specifically of the issue of vulnerabilities… …knowing better the*	Must include an aspect of vulnerability related to

		factors, dynamics and susceptibilities towards extremes of heat or heat waves in research	*social and development dynamics of the population I think could be very helpful… to know how to act and what needs can be covered before such an event"*	extremes of heat and the relevance in studying it
	Adaptation and early warning systems	Refers to evaluations, assessments or reviews needed in terms of measures, actions, interventions that need to be in place in order to be prepared and have resilience	*"...we are working on the issue of resilient service, but we could also make a line of whether the service is prepared to have heat waves, with oral rehydration serums, recovery beds, oxygen therapy."*	Must include references to research gaps on coping and adaptive capacities from a policy, government or society perspective
	Chronic Kidney Disease of unknown etiology	Refers to the state of the art in the knowledge of CKDu, the extend of that knowledge and the research needs around the topic	*..." when we interviewed Nephrologists in Ecuador, the answers were varied, but we did see – and this was not published, but they did tell us – that in rural and agricultural areas they described a pathology, a clinical presentation very similar to what we had heard in Central America".*	Must include examples of the knowledge on the link between temperature and CKDu, gaps in detection, prevention and diagnosis and opportunities for research
	Implementation science	Describes gaps that have to do with evidence of best practices and feasibility studies for the implementation of interventions or measures for public health solutions	*"There is a big gap, a gap between, let's say, the development of the models, to actually implementing an early warning system and all the factors that can facilitate or impede the fact that a government actually adopts, implements and sustains an early warning system. When we did for the IPCC an analysis of early warning systems for health in Central and South America, as part of their analysis, we did a feasibility assessment, but we didn't find any*	Must include examples of barriers and enablers of implementation, the role of research in implementation of solutions, specify topics for feasibility assessments

			studies directly talking about feasibility".	
Data generation and management	Health statistics	Describes the existing challenges to access reliable health data and statistics, particularly around CDKu	*"We have knowledge of many cases, let's say that companies come across cases of people who are suffering from dehydration or heat stroke, but these cases do not reach the health systems because they have care systems within these companies, they have nurses or doctors or small clinics where they give primary care to these people and they are not reported either, neither as incidents nor as illnesses. So, it escapes into the health statistics of the country".*	Must include examples on the barriers to access reliable health data and if possible, specify which health data is needed
	Data management	Describes the barriers and challenges that countries and governments face when it comes to understanding, analyzing and interpreting data and how this in turn contributes with research and knowledge gaps	*"...research is required, for example, to build models. I believe that this is also a very specific role of the technical part of building the statistical model... but in some countries it goes beyond the capabilities of the technical staff, to build a statistical model...".*	Must include examples on the barriers that are faced by the countries in terms on technical capacities, human resources and expertise, including barriers to articulate the data and knowledge between entities
Knowledge transfer and co-creation		Identifies gaps between spaces of dialogue and co-creation between scientists and policy-makers along with barriers on communicating science and the need of science diplomacy	*"In Latin America I think the big problem is that scientists are on one side, politicians are on the other side, there are no instances of communication or participation and that obviously affects everything that is the transfer a posteriori and understanding at different levels."*	Must include examples of barriers and bottlenecks in the knowledge transfer from evidence to action and if possible, identify examples on how to overcome the challenges particularly from the academic side
HEAT RISK KNOWLEDGE				

Urgency	Government	Describes the lack of urgency of some governments to take action and the reasons for this inaction.	*"As long as the Ministry of Public Health does not see it as a priority, the project will not move forward. And that's also why it's so important to have evidence."*	Must include whether or not there is a level of urgency. It can be analyzed through data such as: presents protocols or action plans.
	Population	It refers to the actions that must be taken in the population so that they see this issue as something important.	*"Reaching the population effectively through face-to-face work with the people, I think it is important. It is a very big problem that there are no government actors in this area. So, humanitarian organizations could make a contribution with more on-the-ground, more operational work."*	Must include topics on how to improve the work with the population to understand the urgency of heat waves.
Articulation of entities		Describe whether there is coordination between governmental entities in events of this magnitude.	*"Unfortunately, there is no articulation between institutions, since both COPECO and the Secretary of Environment should work together on this issue, but there is no joint work on this issue."*	Must include the level of articulation between the different governmental entities or the lack of such articulation.
Operational action		Describes what actions are taken in case of heat wave events and the lack of action	*"I do not believe that change will come from the central level, but rather from the work done at the municipal level"*	Must include actions that are currently being taken or actions that should be taken to improve.
Distribution of alerts and action		Describes in which areas the most significant effort is being made to alert the population or generate actions.	*"Because we think that one of the most vulnerable groups are the elderly and if our communication strategy is the social networks, maybe we are not using the best communication strategy. So we would have to think of other strategies to reach those populations that may not have a good command of the Internet, of the networks. So we should think about that, about how the different audiences are informed in order to*	It can include actions from how the population is alerted, to where early warnings are made.

		improve the timely arrival of the recommendations."	

Appendix 7. Protocol for semi-structured interview

Interview duration: 45-60 minutes.
Protocol translated from Spanish

Good morning [NAME].

Thank you very much for your time and willingness to speak with us.

We are doing a consultancy for the Global Disaster Preparedness Center seeking to understand how heat waves are impacting or could affect different sectors and geographical areas of Central and South America, limitations in knowledge and actions, with particular emphasis on Honduras, Guatemala and Colombia.

Considering your experience in [Mention the experience of the person to be interviewed], we think it is important to talk with you about this to continue to better understand the subject.

So far, do you have any questions?

Before we start, we would like to request for your verbal consent to participate in the process and to know if we can record this conversation. The recording would be solely for the purpose of transcribing it later and achieving a better analysis of everything that we are going to talk about today. *Wait for the person's response*. **´Ask you if the informant authorizes us to indicate the name of the organization they represent in the final report that might be public**

Let us begin. The first thing we would like to know is what is the experience you have had around heat waves?

GUIDANCE QUESTIONS

Objetive 2

- What is the experience you have around heat waves?

- What effects have you identified of heat waves on [Mention topic of respondent's main domain]?
- According to your experience and knowledge, do you know of any effects of heat waves on other sectors or productive activities?
- Do you recall any particular episode of heat waves in any Latin American country in the last ten years? What impact did it have?
- Is there any place, or places, in your country or in the region that is particularly vulnerable to heat waves?

Objetive 3

- Do you know of any local or national government in Latin America that has an early warning system for heat waves? How does it work?
- How is the population alerted? Using an application, news, communications in social media, etc.?
- Is there articulation between meteorological centers and ministries?

Objetive 6

- How would you describe the state of knowledge (general population, decision-makers, and academia) about heat vulnerability in Central and South America? What are the gaps in research?
- How would you describe the state of knowledge about heat exposure in Central and South America? What are the gaps at the research level?
- How would you describe the state of knowledge in Central and South America about heat adaptation capacity? What are the gaps at the research level?
- How would you describe the state of knowledge about heat risk in Latin America? What are the gaps at the research level?
- What other regional organizations are working on the impacts of heat waves, and what kind of work are they doing (research, advocacy, capacity building, etc.)
- What are the research strengths of Central and South America in addressing heat risk?
- What are the opportunities Central and South America has for heat risk research?
- What are Central and South America's weaknesses in heat risk research?
- What are the gaps in the production of knowledge regarding heat risk? What factors/conditions explain the existence of these gaps?

- What are the challenges for transferring and integrating heat risk knowledge in governments and entities that have competence in the subject? What factors/conditions explain the existence of these gaps?
- What weaknesses, difficulties, and obstacles face or affect the development of initiatives/experiences of knowledge co-production and knowledge transfer?
- What good practices or lessons learned can be identified that tend to address or resolve some of these difficulties/obstacles?
- What difficulties/barriers to heat risk awareness do decision-makers (especially from the State) face?

Objective 7

- How would you describe your country's response to an extreme temperature event? Is there an explicit mandate to manage, prepare for and respond to heat events? Who is/are the competent entity/entities?
- Is there articulation between governmental institutions to work in this type of case?
- Does the competent disaster risk management body have a protocol to follow when there is an event of this magnitude? What interventions are made by the ministries of health, environment, etc.?
- How does your country respond to this type of emergency?
- What capacities do you have to respond to a heat risk emergency?
- What capacities and resources do you lack to deal with this type of emergency?
- What role could humanitarian organizations play in this type of emergency?
- Are you aware of any organized communities adapting and responding to heat events?
- Do your local and national policies address heat risk warning and response systems effectively?

Appendix 8. Assessment of EWS in National Adaptation Plans

Country	EWS information in adaptation plans	Document name
Argentina	• The country currently has one EWS in operation. • Has an EWS for heat waves or extreme temperatures. • In the creation of the EWS, the participation of the health sector is contemplated.	Plan Nacional de Adaptación y Mitigación al Cambio Climático-Versión 1 (2019)
Chile	• The country currently has one EWS in operation. • Has an EWS for heat waves or extreme temperatures. • In the creation of the EWS, the participation of the health sector is contemplated.	Plan Nacional De Adaptación Al Cambio Climático
Uruguay	• The country currently has one EWS in operation. • Has a EWS for heat waves or extreme temperatures. • In the creation of the EWS, the participation of the health sector is contemplated.	Plan Nacional de Adaptación a la Variabilidad y el Cambio Climático en ciudades e infraestructuras
Brazil	• The country currently has one EWS in operation. • Has an EWS for heat waves or extreme temperatures. • In the creation of the EWS, it does not include the participation of the health sector.	National Adaptation Plan to Climate Change
Peru	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS will provide for extreme heat. • The document does not specify whether the EWS will include the participation of the health sector in the creation of the EWS.	Plan Nacional de Adaptación al Cambio Climático del Perú

Paraguay	• 1 The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS will provide for extreme heat. • The document does not specify whether the EWS will include the participation of the health sector in the creation of the EWS.	Plan Nacional De Adaptación Al Cambio Climático
Guatemala	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS will provide for extreme heat. • The document does not specify whether the EWS will include the participation of the health sector in the creation of the EWS.	Plan de acción nacional de cambio climático
Colombia	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS contemplates extreme heat. • The document does not specify the participation of the health sector in the creation of the EWS.	Plan Nacional de Adaptación al Cambio Climático
Suriname	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS contemplates extreme heat. • The document does not specify the participation of the health sector in the creation of the EWS.	Suriname National Adaptation Plan (NAP)
Belize	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS contemplates extreme heat. • The document does not specify the participation of the health sector in the creation of the EWS.	A National Adaptation Strategy to Address Climate Change in the Agriculture Sector in Belize

Nicaragua	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS contemplates extreme heat. • The document does not specify the participation of the health sector in the creation of the EWS.	Plan de Adaptación a la variabilidad y el Cambio Climático en el Sector Agropecuario, Forestal y Pesca en Nicaragua
Costa Rica	• The EWS is not yet implemented, but the document does contemplate the creation of one. • The document does not specify whether the EWS contemplates extreme heat. • The document does not specify the participation of the health sector in the creation of the EWS.	Plan Nacional de Adaptación al Cambio Climático 2022-2026
Honduras	• Early warning systems are not planned in the EWS	Plan Nacional de Adaptación al Cambio Climático – Honduras
El Salvador	• Early warning systems are not planned in the EWS	Plan Nacional de Adaptación al Cambio Climático – El Salvador
Ecuador	• NAP in the process of finalization	Website under construction
Guyana	• NAP in the process of finalization	Inception Report of National Adaptation Plan - Guyana
Panama	• NAP in the process of finalization	Website under construction
Bolivia	• NAP not found	
Venezuela	• NAP not found	

Appendix 9. Heat wave definitions by country

Country	Definition	Link
Argentina	An extreme temperature event is a period in which temperature values are expected to be recorded that may endanger people's health.	https://www.smn.gob.ar/sistema_temp_extremas_calor
Brazil	Period of uncomfortable and excessively hot weather. It can last several days or several weeks. The Weather Channel uses the following criteria to define a heat wave: the temperature must be above 90 F (32 degrees C) in at least 10 states and at least five degrees above normal in parts of that area for at least two days, or more.	https://portal.inmet.gov.br/glossario/gloss%C3%A1rio#O
Chile	A Heat Wave (diurnal) event is defined as a period of time in which daily maximum temperatures exceed a daily threshold considered extreme, for three consecutive days or more.	https://climatologia.meteochile.gob.cl/application/diario/mapaRecienteOlaDeCalor/
Colombia	Significant warming of the air, or invasion of very hot air, over a large area; it usually lasts from a few days to a few weeks.	http://www.ideam.gov.co/documents/11769/72085840/Anexo+10.+Glosario+meteorol%C3%B3gico.pdf/6a90e554-6607-43cf-8845-9eb34eb0af8e
El Salvador	The maximum temperature value exceeding 33 °C, for three consecutive days or more.	https://www.snet.gob.sv/UserFiles/meteorologia/finaliza_ola_calor.pdf
Paraguay	A heat wave refers to an unusually hot period, which has a strong impact on socioeconomic aspects of our country. The WMO (World Meteorological Organization) generally defines a heat wave as: "a significant warming of the air, or invasion of very hot air over a large area; it usually lasts a few days to a few weeks", however, in order to identify these special characteristics of the air in a region, some considerations must be taken into account. A Heat Wave event is considered to be a period of at least three consecutive days or more, in which the daily maximum and minimum temperatures are above an established threshold in a locality. The thresholds are determined using the 90th and 95th percentiles(*), the former for a typical Heat Wave event and the latter for an extreme Heat Wave event.	https://www.meteorologia.gov.py/wp-content/uploads/2020/11/Placa_Olas%20de%20calor%20-%20umbrales.pdf
Peru	An episode of at least three consecutive days in which at least 10% of the stations considered record maximum temperatures above the 95th percentile of their daily maximum temperature series for the months of July and August (HN summer) of the period 1971-2000. These temperatures increase significantly, generating discomfort in the	https://repositorio.senamhi.gob.pe/bitstream/handle/20.500.12542/358/Identificaci%C3%B3n-eventos-Olas-Calor-

	population, dehydration and sunstroke, mainly in children and the elderly; likewise, crop fields can also be affected by thermal stress. These particular events are called "heat wave".	Amazon%C3%ADa%20Peruana_2015.pdf?sequence=1&isAllowed=y
Uruguay	A heat wave is considered a heat wave when high temperatures are recorded for at least three days with minimum temperatures above 20° and maximum temperatures between 34° and 38°.	https://www.gub.uy/sistema-nacional-emergencias/politicas-gestion/ola-calor
	Sustained events of extremely high or extremely low temperature are referred to as a wave. The duration depends on the climate of the place. In Uruguay we speak of a wave when extreme temperatures persist for more than three consecutive days. Temperature thresholds are determined based on the season of the year and these have to be exceeded above or below. They respond to what we call blocking systems: many days with a certain atmospheric configuration. This is why they have a high predictability.	https://www.inumet.gub.uy/sala-de-prensa/videos/que-es-una-ola-de-calor-y-una-ola-de-frio

Appendix 10. Mapping of actors

N°	Name of actor	Type of actor	Addresses topic	Geographic scope	Geographic coverage	Key focus areas	Source
1	AKSIK: Native voices from the frontlines of climate change	Academy	Indirect	Andes	Bolivia	Adaptation	Web
2	Argentine Ministry of Health	Government	Direct	Country	Argentina	Exposure risk	Web
3	BBC News	Enterprice sector	Direct	Global	Argentina	Mortality seven people (2013),	Web
4	BBC News	Enterprice sector	Direct	Global	Argentina, Uruguay, Paraguay, Brazil	Exposure risk	Web
5	Boston University School of Public Health	Academy	Direct	Global	Nicaragua, El salvador	CKDu, Occupational health	Web
6	Brooke	NGO	Indirect	Global	Guatemala, Nicaragua,	Animal welfare and Health	Web
7	CAF Development Bank of Latin America	Enterprice sector	Indirect	Latin America	Haiti, Guatemala, El salvador, Honduras, Dominican Republic, Nicaragua, Paraguay, Belize, Bolivia, Venezuela, Ecuador, Guyana, Colombia, Peru, Panama, Brazil, Suriname, Argentina, Costa Rica, Uruguay, Chile	Climate Change Vulnerability Index	Report
8	Caribbean Community Climate Change Centre	NGO	Direct	Caribbean countries	Belize	Heat stroke, dehydratation and exhaustion, tension and collapse of vital funtions	Web
9	Caribbean Institute for Metereology and Hidrology	Government	Direct	Caribbean countries	Guayana, Belize	Heat rash to heat cramps, heat exhaustion, heat stroke and death.	Web

10	Caribbean Public Health Agency CARPHA	IGO	Indirect	Caribbean countries		Morbidity, apathy, general weakness, dizziness, fainting, exhaustion, CKDu	Bulletin
11	Caribbean Regional Climate Center	Government	Indirect	Caribbean countries	Guyana	Provides an outlook (how wet, how dry, how hot etc.)	Bulletin
12	Christian AID	Religious organization	Indirect	Global	Brazil, Uruguay, Argentina , Paraguay	The cost of smoke-related health issues (Extreme events-fires)	Report
13	Climate Action Tracker	IGO	Indirect	Global	Argentina, Brazil, Chile, Colombia, Costa Rica Perú	CAT quantifies and evaluates climate change mitigation targets, policies and action	Web
14	Climate centre´s mission - Red Cross and Red Crescent Movement	NGO	Indirect	Global	Colombia	Mortality, morbility	Report
15	Climate Change Knowledge Portal for Development Practitioners and Policy Makers	Enterprice sector	Indirect	Global	Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Gautemala, Haití, Paraguay	Climate change Overview	Web
16	Climate Transparency	IGO	Direct	G20	Argentina	Death rate attributable to air pollution	Web
17	Climate Transparency	IGO	Direct	G20	Brazil	Death rate attributable to air pollution	Report
18	Corporación Autónoma Regional Para la Defensa de la Meseta de Bucaramanga	Government	Indirect	Country	Colombia	Biodiversity information	Web

19	Diálogo Chino	Independent Journalism plataform	Direct	Latin america	Amazon	Food an water security	Web
20	Economic Commission for Latin America and the Caribbean (ECLAC)	IGO	Direct	Latin america and Caribbean	Belize	Malaria and dengue vector, diseases of skin, eyes	Report
21	Economic Commission for Latin America and the Caribbean (ECLAC)	IGO	Direct	Latin america and Caribbean	Guatemala, Nicaragua, Panama, El Salvador	Dengue	Report
22	Economic Commission for Latin America and the Caribbean (ECLAC)	IGO	Direct	Latin america and Caribbean	Belize, Panama	Malaria	Report
23	Economic Commission for Latin America and the Caribbean (ECLAC)	IGO	Direct	Latin america and Caribbean	Guatemala, Belize	Chagas	Report
24	Economic Commission for Latin America and the Caribbean (ECLAC)	IGO	Direct	Latin america and Caribbean	Brazil, Gautemala, Honduras, Nicaragua	Vector diseases, Dengue	Report
25	Environment Policy Committee -OCDE	IGO	Indirect	Global	Uruguay	Infectious diseases	Report
26	EurekAlert -American Association for the Advancement of science AAAS	Academy	Indirect	Country	Brazil	Dehydratation and exhaustion, tension and collapse of vital funtions, mood and mental illness	Web
27	Euroclima	IGO	Direct	Latin america and Caribbean	Uruguay	Development of a National System for the registration and quantification of adverse impacts of climate change	Web
28	Futures Center	NGO	Direct	Global	Nicaragua	CKDu, Occupational health	Web

29	GFDRR (Global Facility for Disaster Reduction and Recovery)	NGO	Indirect	Global	Perú, Bolivia, Brazil, Chile, Bolivia, Colombia, Ecuator, Guyana, Paraguay, Surinamme, Uruguay, Venezuela, Belize, Guatemala, Honduras, Nicaragua, Costa Rica	Environmental monitoring (ambient temperature, hot spots)	Monitoring extreme heat
30	Global Americans /smart news and research	NGO	Indirect	Global	El salvador	Food security, migration	Web
31	Global Climate Climate and Health Alliance	NGO	Direct	Global	Argentina	Vector-borne disease	Web
32	Global Consortium on Climate and Health Education	Association of health professionals	Indirect	Global	Chile	Infection disease, Heat stroke, cardiovascular crisis	Web
33	Global Heat Health Information Network	CBO	Direct	Global	Global	E-Learning and courses, tools, key messages in Heat Heath	Web
34	Healio News /Climate Change and Heath Resource Center	Academy	Indirect	Global	Brazil	Diabetes	Web
35	Instituto de Evaluación de Tecnologías en Salud e investigación (IETSI), Essalud	Government	Direct	Country	Peru	Heat stroke in children and adults	Guide
36	Inter-American Development Bank	Enterprice sector	Indirect	Latin america and Caribbean	Brazil, Argentina, Uruguay, Belize, Nicaragua, Guatemala, Paraguay	Heat stroke, mortality, distributions of pathogens and diseses	Report

37	International Labour Organization	IGO	Direct	Global	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela	Heat stress, working hour lost	Report
38	International Organization for Migration (IOM) - Environmental Migration Portal	IGO	Direct	Global	Costa Rica	Heat-related impacts on workers' health	Web
39	La Isla Network	NGO	Direct	Central America	Nicaragua	CKDu, Occupational health	Web
40	Ministerio de Salud de Chile	Government	Direct	Country	Chile	Outbreak of Dengue	Presentación
41	Ministerio de Salud y Desarrollo Social de Argentina	Government	Direct	Country	Argentina	Mortality (1877 defunciones 2013-2014)	Presentación
42	Ministerio de Vivienda y Ordenamiento territorial, Ministerio Ambiente, Sistema Nacional de Respuesta al Cambio climático SNRCC-Uruguay	Government	Indirect	Country	Uruguay	Vector diseases and zoonoses	Report
43	Ministry of the environment of Peru	Government	Direct	Country	Peru	Starvation, Occupational health	Report

44	National Geographic	Enterprice sector	Direct	Global	Argentina, Uruguay, Brazil	Trigger respiratory problems, such as bronchitis and asthma, circulatory and cardiac problems, and cause blurred vision and dizziness	Web
45	Oficina de Cambio Climático del Ministerio de Medio Ambiente de Chile	Government	Direct	Country	Chile	Deshydratation, Heat stroke, Aggravated Cradiovascular Illnesess, Agravated respiratory illnesess	Presentación
46	Ojo al Clima (Semanario Universidad de la Universidad de Costa Rica)	Academy	Indirect	Country	Costa Rica	CKDu, Occupational health	Web
47	Organización Panamericana de la Salud	IGO	Direct	Americas	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Guatemala, Nicaragua, Panamá, Paraguay, Perú, República Dominicana, Venezuela, y Uruguay.	Heat stroke, Morbility and mortality during heat waves, infectious or chronic diseases (cardiopulmonary, renal , endocrine and psychiatric)	Web
48	OXFAM internetional	NGO	Indirect	Global	Bolivia	Respiratory illnessness	Report
49	PAHO	IGO	Direct	Global	Argentina, Brazil, Peru, Paraguay, Uruguay	Mortality, morbility, edema, syncope, cramping, heat exhaustion, heat stroke, dehydratation, contribute to the formation of clots, exacerbation of cardiopulmonary, renal and psiquiatric diseases	Web
50	PAHO	IGO	Direct	Global	Costa Rica, El Salvador, Guatemala, Nicaragua, Panamá	Epidemia CKDu, Occupational health	Report

51	PAHO/WHO Emergencies News	IGO	Direct	Global	Argentina, Bolivia, Brazil, Dominican Republic, Perú , Nicaragua	Death toll of 737 over 10 days (Bazil 2010), Died of 1877 people (Argentina 2013-2014), Heat exhaustion, heat stroke, Dry skin, loss of consciousness, cardiopulmonary, kidney , endocrine and psiquiatric diseases, swelling in the legs, rashes on the neck, cramps, headache, irritabilitym lethargy, and weakness	Web
52	PAHO-WHO	IGO	Direct	Global	Argentina	Mortality: 2013-2014 cerebrovascular diseases, ischemic heart disease, drowning in rivers and deaths from fires or suffocation	Report
53	PAHO-WHO	IGO	Direct	Global	Brazil	2001,2010 y 2014 An estimated excess death of 737 people	Report
54	PAHO-WHO	IGO	Direct	Global	Chile	2011 y 2017 Difficulty falling asleep	Report
55	PAHO-WHO	IGO	Direct	Global	Nicaragua	2017 four deaths, cardiovascular and respiratory conditions,	Report
56	PAHO-WHO	IGO	Direct	Global	Peru	Eight minors died, with heat shock (fever, dehydration, diarrhea and seizures)	Report

57	Postdam Institute for climate impact research	Academy	Direct	Global	Peru	Mental health, vector-borne diseases (dengue, malaria, leptospirosis, respiratory problems, reduced nutrition, stomach and skin diseses	Report
58	Red de Universitarios de América Latina y le Caribe para la Reducción de Riesgos y Emergencias y Desastres (REDULAC)	Academy	Indirect	Latin america and Caribbean	Colombia, Chile, Peru, Guatemala	Risk reduction and climate change	Web
59	SALTRA	Academy	Indirect	Central America	Costa Rica	CKDu, Occupational health	Web
60	SciDevNet	Enterprice sector	Direct	Global	Ecuador, Colombia	Mortality	Web
61	Secretaría Distrital de Ambiente de Bogotá-Colombia	Government	Indirect	Country	Colombia	Actions that mitigate heat islands	Web
62	Servicio Metereológico Nacional Argentina	Government	Direct	Country	Argentina	Morbility and mortality during heat waves	Early warning system
63	Servicio Nacional de Meteorologíae Hidrología del Perú	Government	Direct	Country	Peru	Monitoring of heat events and the discomfort generated in health for the Amazon	Presentación

64	Servicio Nacional de Meteorologíae Hidrología del Perú	Government	Direct	Country	Peru	Identifications of dangers and threats , among others, of heatwaves	Web
65	Sistema de Información Ambiental Territorial de la Amazonía Colombiana - SIAT-AC (Instituto Sinchi)	Government	Indirect	Country	Colombia	Environmental monitoring (ambient temperature, hot spots)	Monitoring extreme heat
66	Sistema Nacional de Alerta Temprana de desastres SNATD	Government	Direct	Country	Bolivia	Monitor threat level and see if they require intervention	Report
67	Sociedad Chilena de Salud Planetaria	Association of health professionals	Direct	Country	Chile	Recommendations temperatures and heat waves	Web
68	Sustainability Times - Green news on teach, business and the environment	Academy	Indirect	Global	Brazil	Kidney disease, Occupational health	Web
69	The Intergovernmental Panel on Climate Change (IPCC)	IGO	Indirect	Global	Venezuela, Costa Rica , Chile, Brazil, Colombia, Argentina and Honduras	Rate mortality in risk mortality Geographical distributions of vector-borne diseases (e.g.,malaria, dengue)	Report
70	The Lancet Countdown: Health and Climate Change	Academy	Direct	Global	Latin america	Climate change and human health	Web
71	The Washington Post	Enterprice sector	Direct	Global	Argentina	Mortality, people with preexisting health conditions	Web

72	The World Bank Group	Enterprice sector	Direct	Latin america	Brazil, Argentina	Infectious deseases (Cholera, malaria, dengue, Zika)	Report
73	The World Bank Group	Enterprice sector	Direct	Latin america	Colombia	Food and water sucurity, distribution of vector-borne diseases malaria, zika, chinkungunya water-borne illnesses (cholera and diarrheal disease)	Report
74	The World Bank Group	Enterprice sector	Direct	Latin america	Ecuador	Food and water sucurity, distribution of vector-borne diseases malaria, zika, chinkungunya water-borne illnesses (cholera and diarrheal disease)	Report
75	The World Bank Group	Enterprice sector	Direct	Latin america	Costa Rica	Vector-borne diseases including dengue, malaria, as well as air pollution and associated respiratory illnesses, and water-borne illnesses such as cholera and diarrheal disease	Report

76	Umea University	Academy	Direct	Global	Costa Rica	Headache, nausea, renal dysfunction	Web
77	UNICEF	IGO	Indirect	Global	Venezuela	Children´s climate risk index	Monitoring environment and climate change
78	United Nations Development Programme UNDP	IGO	Indirect	Global	Belize	Infectious diseases, and increased morbidity and mortality	Report
79	United Nations for Disaster Risk Reduction (UNDRR)	IGO	Indirect	Central and south america	Colombia, Venezuela, Bolivia, Peru, Guyana	80 – 100% of the population are projected to be exposed to extreme heat	Report
80	United Nations Framework Convention on Climate Change UNFCCC	IGO	Indirect	Global	Belize	Insect dispersal and migration	Report
81	United Nations Institute for training and research	IGO	Indirect	Global	Colombia	Cadiovascular diseases, vector-borne diseases,	Web
82	United Nations weather for disaster risk reduction	IGO	Indirect	Caribbean countries	Guyana, Suriname	Infectious disease burden, increasing heat stress, lack of access to health services	Web
83	United Nations, News ONU	IGO	Direct	Global	Argentina, Bolivia, Brasil, Canadá, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Guatemala, Nicaragua, Panamá, Paraguay, Perú, Venezuela, y Uruguay.	Mortality, heat stroke, Heat rash to heat cramps, heat exhaustion,	Report
84	United States Agency for International Development (USAID)	IGO	Indirect	Global	Paraguay	Increased disease spread	Fact Sheet

85	United States Agency for International Development (USAID)- Environment and global Cliamte Change	IGO	Direct	Global	Honnduras, Argentina, Peru, Bolivia, Brazil, Chile, Colombia, Ecuador,Guyana, Paraguay, Suriname,Uruguay, Venezuela, Belice,Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica,Panama	Climate risk index, Score (lower score indicates higher vulnerability to extreme weather events)	Web
86	Urban Health Network for Latin Anerica and the Caribbean- LAC-Urban Health	NGO	Direct	Latin america and Caribbean	Argentina, Brazil, Chile, Colombia, Guatemala, Peru	Mortality	Web
87	Wellcome	NGO	Direct	Global	Brazil	Mortality	Web
88	WHO	IGO	Direct	Global	Brazil	Mortality, Vector-borne diseases, Malaria, y dengue	Fact sheet
89	WHO	IGO	Direct	Global	Colombia	Mortality, morbility, mental health	Fact sheet
90	WHO	IGO	Direct	Global	Peru	Mortality, malaria and dengue fever	Fact sheet
91	World Bank	IGO	Indirect	Global	Colombia	Enhanced technologies and sector capacities	Report
92	World Bank	Enterprice sector	Indirect	Global	Guatemala	Tropical disease vector	Report

93	World Metereological Organization (WMO)	IGO	Direct	Global	Brazil, Argentina, Peru, Paraguay, Bolivia, chile	Morbility and mortality during heat waves, Heat stroke, Dehydratation, Sunburn, air pollution, Drowing	Web
94	World Metereological Organization (WMO)	IGO	Direct	Global	Suriname, Peru, Argentina, Bolivia, Brasil, Chile, Colombia, Ecuador, Guyana, Paraguay, Uruguay, Venezuela, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama	Environmental monitoring (ambient temperature, hot spots)	Monitoring extreme heat
95	World Wildlife Fund WWF-Guatemala	NGO	Indirect	Global	Guatemala, Honduras, belize	Heatstroke, exacerbation of chronic cardiovascular and respiratory conditions	Web

Appendix 11. Monthly heat wave events from 2017 to 2021

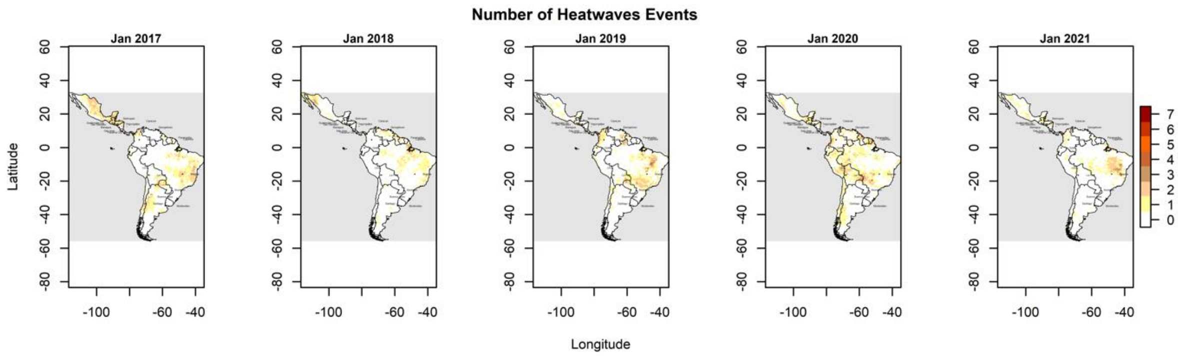

Figure 28. Number of heat waves events in CSA in January from 2017 to 2021. Data source: ERA5 – ECMWF

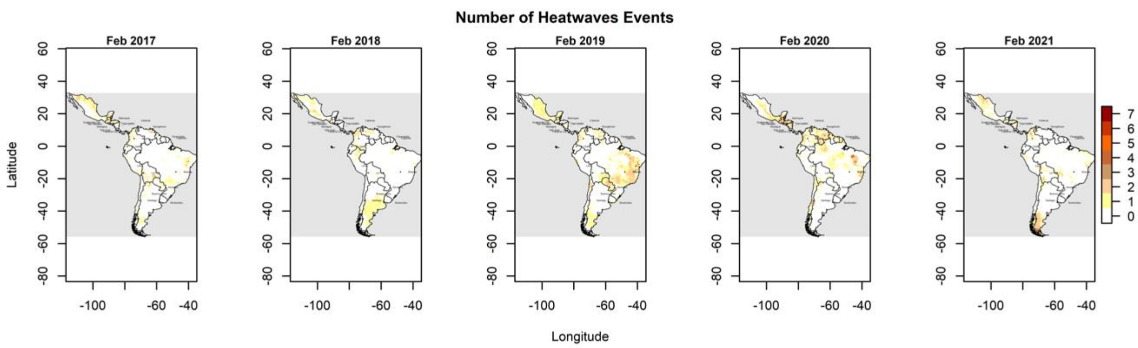

Figure 29. Number of heat waves events in CSA in February from 2017 to 2021. Data source: ERA5 – ECMWF

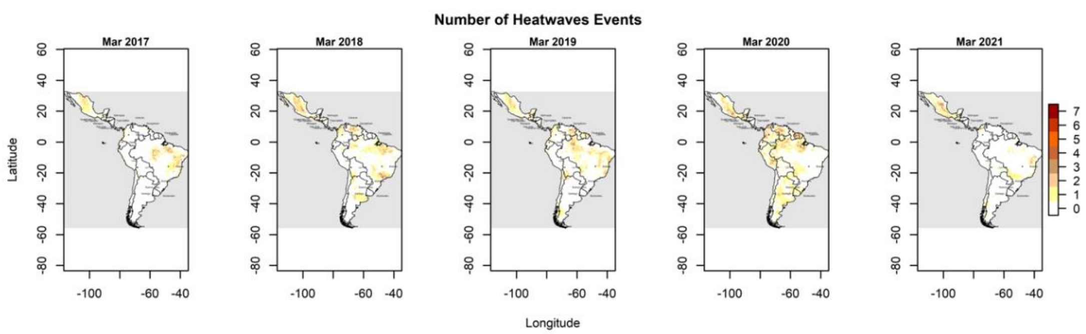

Figure 30. Number of heat waves events in CSA in March from 2017 to 2021. Data source: ERA5 – ECMWF

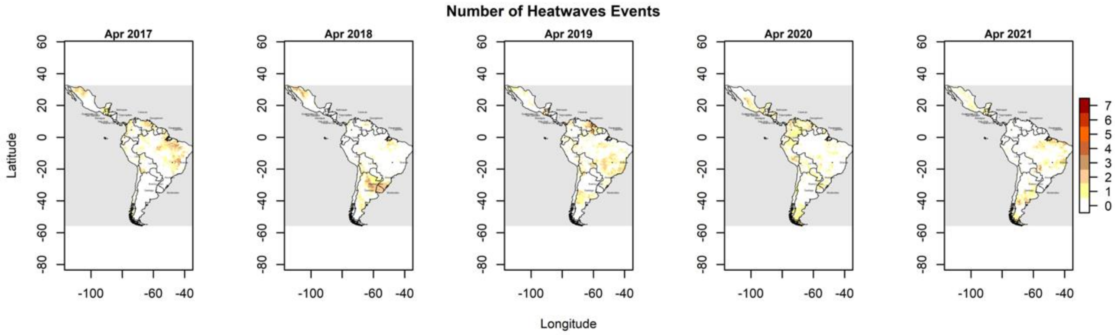

Figure 31. Number of heat waves events in CSA in April from 2017 to 2021. Data source: ERA5 – ECMWF

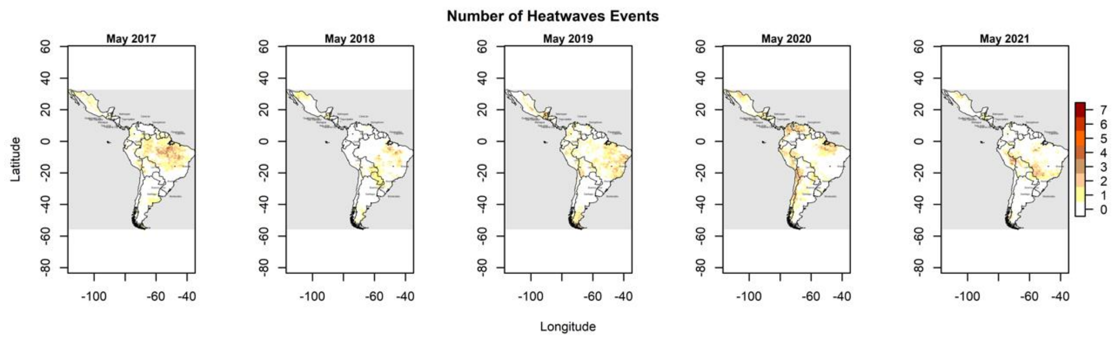

Figure 32. Number of heat waves events in CSA in May from 2017 to 2021. Data source: ERA5 – ECMWF

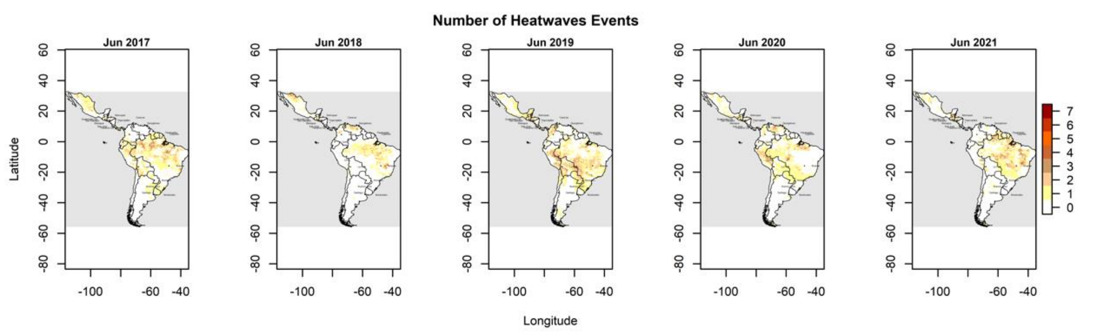

Figure 33. Number of heat waves events in CSA in June from 2017 to 2021. Data source: ERA5 – ECMWF

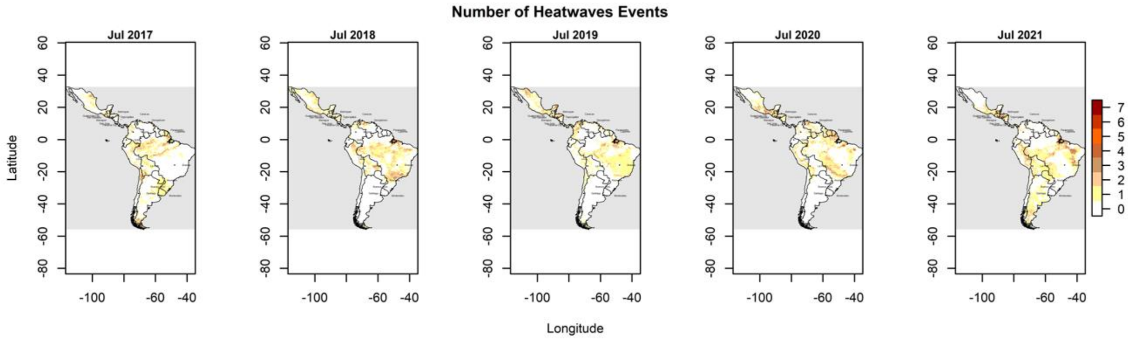

Figure 34. Number of heat waves events in CSA in July from 2017 to 2021. Data source: ERA5 – ECMWF

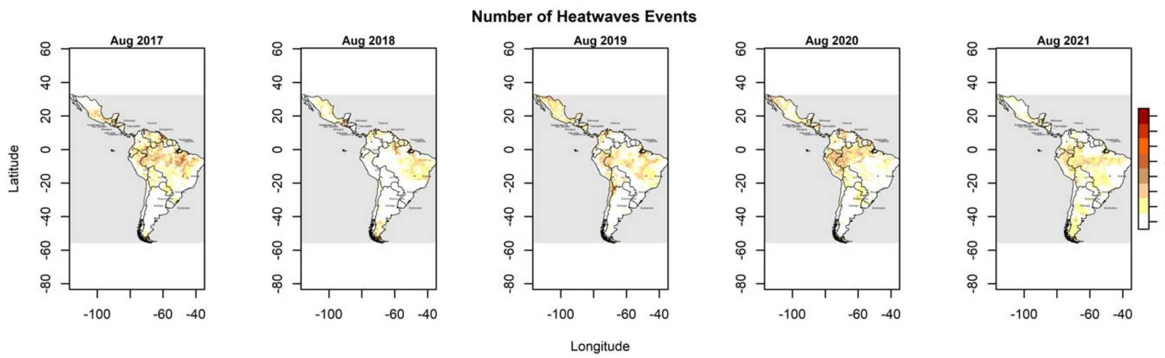

Figure 35. Number of heat waves events in CSA in August from 2017 to 2021. Data source: ERA5 – ECMWF

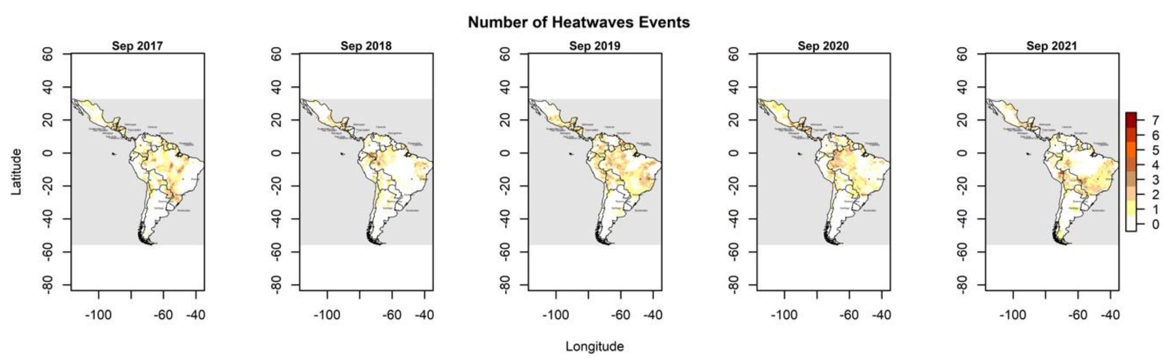

Figure 36. Number of heat waves events in CSA in September from 2017 to 2021. Data source: ERA5 – ECMWF

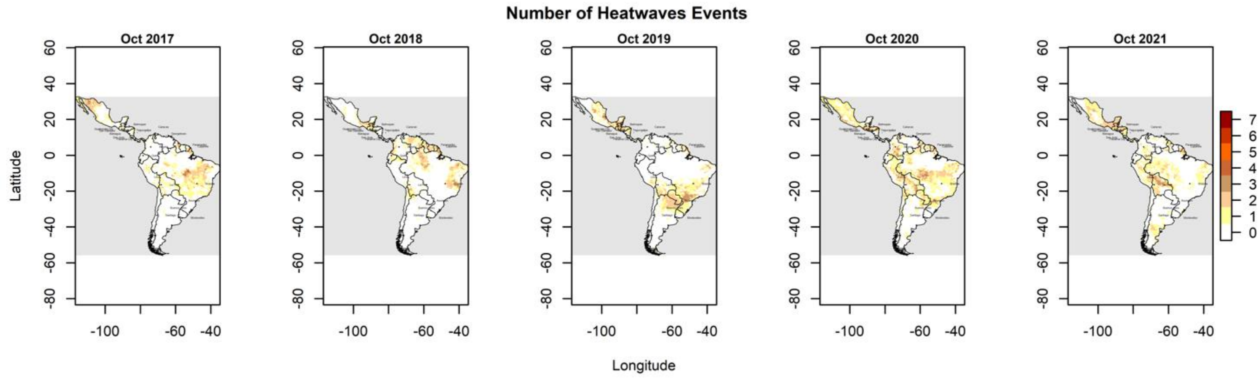

Figure 37. Number of heat waves events in CSA in October from 2017 to 2021. Data source: ERA5 – ECMWF

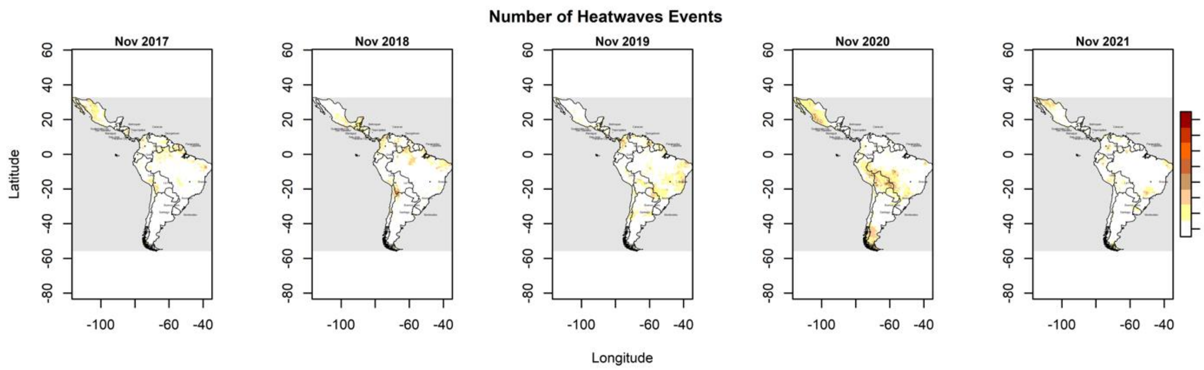

Figure 38. Number of heat waves events in CSA in November from 2017 to 2021. Data source: ERA5 – ECMWF

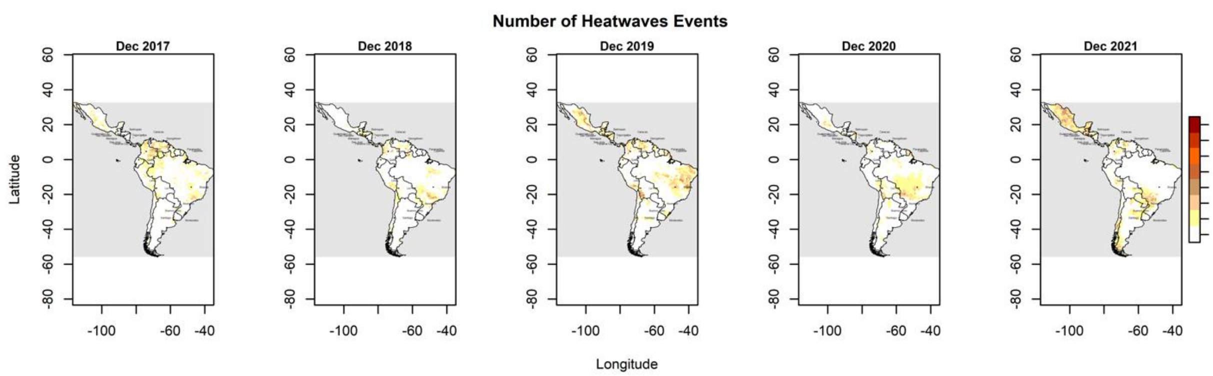

Figure 39. Number of heat waves events in CSA in December from 2017 to 2021. Data source: ERA5 – ECMWF