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GLOBAL HEAT HEALTH

# Examining relationships between extreme heat and migration/ displacement and human mobility in Zacapa, Guatemala

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1.Executive summary

This report summarizes our examination of the relationship between extreme heat and migration/displacement/human mobility, as outlined in the original proposal. We conducted a mixed quantitative and qualitative analysis of the sociodemographic, attitudinal conditions, labor practices, perceptions and impact of the phenomenon of "Extreme Heat" and "Climate Change" in two communities of the Department of Zacapa, Guatemala in the "Corredor Seco en Centroamérica (Dry Corridor of Central America)". On the qualitative front, we conducted semi-structured interviews in two communities: the city of Zacapa, the capital city of the Department, and the neighboring municipality of Estanzuela. The semi-structured interviews had the following sections:

a) introductory questions;

b) perceived socio-ecological risks;

c) perceptions and experiences of extreme heat;

d) perceptions of adaptation;

e) perceptions and needs of organizations and NGOs challenges faced in terms of access to resources and information;

f) perceptions of the organizational response to farmworkers during "heat waves";

g) perceptions of ways to improve organizational responses to future crises, and

h) demographics.

The population sample consists of 50 interviews, 25 conducted in the Departmental Headquarters of Zacapa and 25 in the Municipality of Estanzuela. In addition to qualitative data, we also conducted climatological analyses to determine how and if the prevalence of extreme heat days and temperatures of extreme days are increasing over time.

Results from this interdisciplinary, collaborative effort illuminate contextual insights into how people experience extreme heat across Zacapa. Our climatological analysis shows that, indeed, heat waves in Zacapa are intensifying. Our qualitative interview data shows that people are experiencing extreme heat, in addition to related changes in water scarcity, deforestation, and economic challenges. Results also indicate that extreme heat, when intersecting with economic challenges, can further increase the adverse impact of extreme heat across both locations. Relatedly, interviewees also shared that people largely migrate to the United States and other international locations because of economic stress. This was particularly prevalent in the rural municipality of Estanzuela. We also found that people were adapting to these changes by conducting reforestation activities, wearing long sleeved shirts and hats, using fans inside their homes, and occasionally, visiting cooler places during the hotter months. They largely used cell phones, social media (WhatsApp and Facebook), the internet, and radio to communicate and learn about extreme heat.

Interviewees' opinions of organizational response varied across the two sites and within sites. In the more rural site, Estanzuela, interviewees expressed deep frustration and felt that the local organizations largely neglected their needs. While some respondents in the capital city of Zacapa expressed similar negative sentiments, others were pleased by the municipality's response during heat waves.

Moving forward, interviewees recommended that organizations help community members with securing employment and thus decreasing how extreme heat and related changes impact their livelihoods. They also recommended that organizations communicate details about extreme heat through the radio and the internet. People also expressed that increasing the capacity of public health centers (i.e., "*centros de salud*") to support communities during heat waves would be critical. Finally, many interviewees worked in agriculture and forestry and recommended supporting those industries by conducting reforestation activities and providing seeds to local people as context-specific adaptation strategies.

Keywords: Extreme heat; Climate change; Guatemala; Zacapa, Adaptation; High Temperature Trends; Corredor Seco en Centroamérica.

#### 2. Purpose

This research presents statistical and graphic results of how extreme temperatures have changed over time the Department of Zacapa, Guatemala. It also presents data from and analyses of 50 qualitative interviews delineating how people experience and adapt to extreme heat, and recommendations for community-scale adaptation programs. Interviews were gathered from the communities of the capital of Zacapa (Zacapa) and in the municipality of Estanzuela. Results inform how organizations can improve adaptation programs and counteract the impacts of climate change in the Guatemalan Dry Corridor.

## 3.0 Literature Review: An Interdisciplinary Approach to Studying Extreme Heat

Research shows that communities experience extreme heat and other climate-related changes in distinct ways (Erwin et al., 2021; Kaijser & Kronsell, 2014). In particular, case study research from places like China and Peru shows how people experience interrelated social-ecological changes, including but not limited to diminishing glaciers, shifting seasons, decreased water supply, changes in human migration, increased deaths of animals and plants, new and different levels of pest infestations, land change, and increased heat (Burnham & Ma, 2016, 2018; Erwin, et al. 2021; Popovici, et al., 2021b). These changes, as well as the ways people adapt, take place at the individual, household, community, and national scale (Burnham & Ma, 2016, 2018; Erwin et al., 2021). Scholarship on the human and social dimensions of social-ecological change has also demonstrated how these changes impact people's livelihoods, especially small-holder farmers in the Global South (Erwin et al., 2021; Popovici, et al., 2021a, b).

In response to these types of changes, people use different processes of adaptation, defined as "a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity" (Smit & Wandel, 2006, p. 282). Case studies from across the globe have demonstrated that many people use these adaptation strategies to address climate change (Burnham & Ma, 2016, 2018; Erwin, et al. 2021; Popovici, et al., 2021b; Rao et al., 2019). Additional research shows how climate change, adaptation, social-ecological resilience and conflict intersect and complicate longstanding political conflicts in western Guatemala (Hellen et al., 2018). However, there is still little understanding of whether and how people use these strategies in the Corredor Seco of Guatemala.

Scholars have identified the following as common adaptation strategies that occur at the individual or household scale: environmental management, income diversification, labor migration, communal pooling, and mobility (Agrawal et al., 2008; Burnham & Ma, 2016). One particular area of inquiry for this project was to better understand how social-ecological changes shape labor migration. Particularly across Central America, people are migrating or being displaced, within country and transnationally, voluntarily or forcefully, due to interrelated, social-ecological changes like political violence, climate change, natural disasters, and economic hardship (Radel et al., 2010, 2018). While there is ample evidence that people are migrating, there is still little understanding of whether people migrate because of climate and other linked social-ecological changes or for other reasons, and how this mobility happens, either in Guatemala or beyond (Black et al., 2011).

We also aim to inform and support local and international institutions as they support communities in the face of climate and other social-ecological changes. Research consistently shows that access to institutions shapes whether and how people can adapt to climatic and other social-ecological changes (Agrawal et al., 2008; Erwin et al., 2022; Nightingale, 2017; Popovici, et al., 2021a). There is a critical need for local and international organizations to obtain and use context-specific data in the design and implementation of adaptation programs.

In addition, gathering context-specific information, scholars recommend that interdisciplinary, collaborative approaches are most effective for both understanding and addressing the complexity of climate change (Lemos & Morehouse, 2005; Maxwell et al., 2019). However, to date there is still a lack of access to data that combines social and biophysical sciences to better understanding how people and natural systems are experiencing climate change. There is also little understanding of how extreme heat is impacting people in Guatemala. This research begins to fill these gaps. In the following pages we first present our interdisciplinary, collaborative research approach, including how we collected biophysical and social science data. We then present climatological data and semi-structured interview data on extreme heat in the Corredor Seco of Guatemala. We conclude our report by providing recommendations for scholars and practitioners who endeavor to work with communities to understand and address extreme heat in Guatemala and beyond.

#### 4.0 Research Design

Our mixed-methods approach is best suited to provide a baseline for understanding the ways people perceive and respond to extreme heat, how marginalized groups partake in common adaptation strategies, and the ways in which people use localized, indigenous knowledge to respond. Our approach also offers insights into how extreme heat impacts people living in different contexts, providing additional insights into the problem and ways to address it in diverse contexts. Finally, our approach generates insights into human adaptation strategies in the Corredor Seco of Guatemala to respond to extreme heat; identifies possible obstacles to adaptation people from marginalized groups may experience; and provides valuable knowledge that can bolster approaches to adaptation in Guatemala and beyond. Most notably, this analysis will identify mitigation and adaptation mechanisms to address extreme heat in Chiquimula, generating practical guidelines to be shared with local municipalities, non-government organizations (NGOs), the Red Cross, and other governmental and civil society entities. These guidelines can then be used to improve the well-being of people living in the context of extreme heat. Results will be disseminated back to community members through partner community organizations and in the form of peer-reviewed publications created by the team.

#### 4.1 Collaborative Interdisciplinary Research Design

In this research project, we used a collaborative, interdisciplinary approach to understand and document how people are experiencing and addressing extreme heat and other social-ecological changes in the Corredor Seco of Guatemala. Our research objectives were to document and analyze:

(1) How people perceive extreme heat in two communities in the Corredor Seco of Guatemala, in the Department of Zacapa, City of Zacapa, and in the municipality of Estanzuela;

(2) How people adapt and respond to extreme heat; and

(3) The ways that organizations respond to local needs and priorities.

# 4.1.1 Qualitative Data Collection and Analysis

To address these objectives, we conducted the following activities. First, we gathered semi-structured interviews from two different sites in Zacapa. The specific interview questions were updated after further collaboration, and generally cover: a) introductory questions; b) perceived socio-ecological risks; c) perceptions and experiences of extreme heat; d) perceptions of adaptation; e) perceptions and needs of organizations and NGOs challenges faced in terms of access to resources and information; f) perceptions of the organizational response to farmworkers during "heat waves"; g) perceptions of ways to improve organizational responses to future

crises, and h) demographics.



Figure 1: URL Researchers and Students preparing for data collection

To connect with interviewees, we used a combination of

purposive sampling and snowball sampling (Bailey, 2007). We reached data saturation, when interviews fail to add anything new to the analysis, at around 25 interviews in each site (N=50) (Bailey, 2007). All interviewees identified as Guatemalan, and most interviewees worked in agriculture. Specifically, people worked with melons, corn, peppers, tomatoes, and chilis. Relatedly, many people worked in horticulture and forestry, while 2 out of the 25 interviewees worked in carpentry or construction. Many interviewees also conducted seasonal work.

To analyze data, we conducted thematic and content analyses. The iterative analysis focused on unearthing perceptions, obstacles to adaptation, and localized strengths when responding to extreme heat. The research was led by health sciences researchers from Universidad Rafael Landívar -ULR- of Guatemala, in collaboration with researchers with expertise in environmental social sciences, geosciences, social determinants of health, and public health, emergency planning and international project design (The University of Texas Rio Grande Valley -UTRGV- School of Earth, Environmental and Marine Sciences and School of Social Work). We worked

together to create research instruments, collect primary qualitative data, secure access to secondary quantitative data, and conduct data analyses.

In August of 2022, professors from UTRGV held a 3-hour semi-structured interview training with students and faculty from URL. Following the training, in October of 2022, students and faculty from URL, from the Infirmary of the Zacapa Campus of URL, collected data. Interviewers partnered with community organizations to connect with participants to collect data. We abided by all ethical standards from URL's Institutional Review Board for Human Subjects Research (or equivalent), including an informed consent document which was elaborated and reviewed by both academic institutions (URL and UTRGV). We asked permission to audio record interviews and transcribe them in Spanish. We anticipated most interviews would be in Spanish, although some participants probably spoke indigenous languages as well, given the demographics of Guatemala. If a participant spoke a local dialect, we used an interpreter, but this was seldom needed. If a participant wanted to participate but did not want to be recorded, detailed notes were taken.

Given ongoing COVID risks, interviews were conducted mostly via telephone, and when in-person, outdoors. Recordings and notes were uploaded to a Google Drive archive with pertinent evidence to support the research,



Figure 2: URL Nursing Students Collecting Interview Data

including a) interview transcriptions; b) scanned documentation of the interviews conducted; c) audios from each interview; d) photos and publications on social media, and e) scanned documents of the informed consents signed by the participants. Ten (10) students were trained by UTRGV to be responsible for properly conducting the semi-structured interviews. Each student conducted 10 interviews, 5 from each site (Zacapa and Estanzuela), for a total of 50 interviews (25 in Zacapa and 25 in Estanzuela). URL field researchers and professors oversaw the collection of data interviews.

#### 4.1.2 Climatological Data Collection and Analysis

Heat waves are produced when the maximum temperature is above 38°C during three consecutive days, and the number of heat waves has been increasing in the Eastern and Northern regions of Guatemala during March, April, and May (Bardales et al., 2018). Moreover, models forecast a 50% decrease in the usual cumulative rain totals in the semiarid zone of the country or Corredor Seco (Bardales et al., 2018). These conditions continue today and are

impacting communities in the affected areas. Considering these important climatic factors and the availability of a weather station managed by INSIVUMEH (Instituto Nacional de Sismología, Vulcanologia, Meteorologia e Hidrología; National Institute of Seismology, Volcanology, Meteorology, and Hydrology) in Zacapa, two study sites, one urban and one rural, were selected in this department. We gathered historical and current data from Zacapa's weather station to document and analyze variabilities in temperature and precipitation for the longest possible time available.

#### 4.1.3 Research Site: Department of Zacapa, Guatemala

This research takes place within the Department of Zacapa, in the country of Guatemala (Figure 3). We chose Zacapa as our research site because it is an ideal place, both climatologically as well as socially, to investigate how to support vulnerable communities as they address climate change. Over the last decade, Zacapa, a department situated in the Región Valles de Oriente (Eastern Valley Region; INSIVUMEH, 2016), has experienced extreme heat events such as heat waves. Moreover, the department experiences prevalent moderate to high heat conditions for several months of the year in Zacapa. We also chose the site because weather stations managed by INSIVUMEH are located in the municipality of Estanzuela and the department of Zacapa, with 41 years of climatological data (Figure 4). Logistically, Universidad Rafael Landívar's (URL) Zacapa Campus is also located within a short distance of both locations, and faculty and staff have community partners in both sites. URL's existing geographical and social connections to the Department supported data collection and also provided the team with community partners who we plan to work with in the future to disseminate this study's results. Finally, this department presented two diverse sites, one more urban and one more rural, which allowed us to analyze climactic trends across two distinct geographical and social landscapes.

The municipality of *Estanzuela*, situated 195 meters above sea level, belongs to the department of Zacapa (Figure 2). Estanzuela is located at the departmental head, bordering to the north with the municipality of Río Hondo; southeast, south, and east with the municipality of Zacapa, and to the west with the municipalities of Teculután and Huité, all belonging to the department of Zacapa. In addition, it is located at a distance of 5 kilometers from the departmental capital of Zacapa, the investigation's other study site. According to the population projections of the National Institute of Statistics (INE; Instituto Nacional de Estadísticas), the population of Estanzuela for the year 2018 was 12,656 inhabitants, of which 51% were men and 49% women. Estanzuela is the seventh most populous municipality in the department of Zacapa, and its population represents 5.08% of the total for the department.

The city of *Zacapa* has a population of around 60,000 and is situated within the Cimarrón and Guaray mountains. It is supported by eight rivers –the main one being the Motagua River. Its economy is mainly supported by artisanal products, industry, and agriculture. In particular, cigars, cheeses, leather, sweets, bricks and clay tiles are produced in the Department head. It also has several important industries such as Licorera Zacapaneca, Embotelladora del Atlántico, Alimentos Congelados, Maderas Mayas, Maderas El Alto, and marble and hydrated lime processors. Corn, beans, watermelon, melon, tobacco, and vegetables as well as cattle and pigs support local agricultural livelihoods.



Figure 3: Location map of working meteorological stations of the Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH) as of 2015. Source: INSIVUMEH 2016.



Figure 4. Municipalities of Zacapa department. Picture source from Zacapa Department, Guatemala Genealogy (2022) https://www.familysearch.org/en/wiki/Zacapa\_Department,\_Guatemala\_Genealogy

# 4.1.4 Limitations

Although this is a pilot exploration, several limitations are worth noting. First, Guatemala does not publish the data from its climatological stations, especially from Estanzuela and the department head of Zacapa. For this reason, while we were able to gather climatological data from INSIVUMEH on the Department of Zacapa as whole, we were not able to gather data from each site separately. Future studies would be improved with access to sitespecific data.

Second, we endeavored to collect secondary data from the Guatemalan census and analyze that data using statistical methods. Indeed, we made numerous attempts at accessing data from Guatemala's Instituto Nacional de Estadística (National Institute of Statistics; INE). However, we were not able to access this data, and therefore, our capacity to understand and analyze human migration/mobility using quantitative methods was severely limited. We addressed this limitation by documenting and analyzing when interviewees identified migration as a significant social-ecological change. Future studies that quantitatively analyze census and survey data would improve our understanding of migration, and how it connects with social-ecological change and extreme heat in this region.

Finally, our sample was a convenience sample recruited by students on the ground and dealing with day to day, real-world challenges. We intended to use purposive sampling to specifically interview women, older individuals, and people with disabilities, but these could not be identified given the restricted data collection timeframe. Future studies with a more extended timeframe should attempt to identify and interview these important populations.

# 5.0 Findings: Extreme Heat in the Department of Zacapa

# 5.1 Extreme Heat and Change in the Department of Zacapa

Figure 5 shows the temperature trends for the department of Zacapa. The general trend is that temperature is increasing as a function of time. The detail of how this trend is changing is observed by comparing the slope of the three trend periods (1951-2020, 1971-2020, and 1991-2020). It is noticed that the most recent maximum temperature period trend has the steepest slope (1991-2020) and therefore the fastest variations of temperature over time. This confirms that the department of Zacapa has all the climatological factors for having serious heatwave impacts.



Figure 5: Annual maximum temperatures and trends for the Zacapa department. (Data source: Climate Change Knowledge Portal, 2022)

Figure 6 shows a different representation for the time series. These are called "heatplots" for the department of Zacapa. It shows the mean maximum temperature variations for two decades (1971-1980 and 2011-2020) which allows for a shorter time analysis. The solid blue line represents the "Current Climatological Trend (1991-2020)" of maximum temperatures. The dots represent the number of monthly temperature events above and below the "Current Climatological Trend (1991-2020)". It is clearly noticed that in the decade of 1971-1980, there were 12 events above 30 °C (Figure 6a) compared to 72 in the decade of 2011-2020 (Figure 6b). In addition, the heatplots for (2011-2020) are more numerous than 1971-1980, and also there are more occurrences of maximum temperatures above 30 °C all year around, making Zacapa highly vulnerable to the impact of heatwaves.



Figure 6: Heatplots for the Zacapa department, Guatemala (Data source: Climate Change Knowledge Portal, 2022)

Data and graphics generated from the Climate Change Knowledge Portal, 2022 provide with high degree of certainty that the department of Zacapa is highly exposed to maximum temperature events greater than 30 °C. These events are increasing each decade. In the 2011-2020 decade there were 72 events (Figure 6b), compared to 12 events in the 1971-1980 decade (Figure 6a).

#### 5.2 Experiences of and adaptation to extreme heat in Estanzuela

In this section, we document how residents of Estanzuela experience and adapt to extreme heat. While Estanzuela is urbanizing, it is the more rural of the two research sites. We first document how people experience both extreme heat and its impacts. Next, we document how people gain information about extreme heat. We then describe the section by documenting organizational responses to extreme heat, from the point of view of local residents, and then document respondents' recommendations for improving organizational response to extreme heat.

## 5.2.1 Social-ecological changes in Estanzuela

Interviewees in Estanzuela first informed us that they were experiencing numerous social-ecological changes. These changes were causing increased concern as the recognition of numerous factors was expanding. The reported that things had changed significantly across numerous domains, as one interviewee described: "*Everything in the community things are changing*." Others provided us with more specific details about the changes they were experiencing. For instance, many respondents reported that the economy was changing. In particular, they described how there was overall "*more poverty*." Similarly, interviewees told us that "*there were many challenges to caring for one's family while only earning a minimum amount,*" and that there were "*overall less jobs while the cost of everything was going up*."

They also expressed concerns about social-ecological changes, including diminishing trees. One interviewee told us: "there has been a lot of deforestation," and "there are much less trees because people are building more and more houses." Others expressed concern over climate change. One interviewee told us, "With climate change, there are many variations in the climate." Others expressed concern about land use and water availability. For instance, an interviewee told us that, "the lands where I work for such production are highly exploited." Another participant said that there were overall issues with water and sewer systems. An interviewee told us: "water is not always available." Specifically on the subject of water, one participant reported, "30 years ago we had more [water] and now I think it's running out." Another reported that "The harvest doesn't give us very much because of climate change," and "we are seeing much more drought, which is destroying our farms." Another person told us: "At the moment, as it has been raining, the water remains, but in other years the water has also run out." At the same time, interviewees told us that their communities had developed significantly over the last 30 years, with much more "paved roads and streetlights." Similarly, people echoed this by saying: "in the past, everything was dirt, now there's pavement, houses with 2 or 3 stories, and electricity and parks." People also expressed concern over hurricanes, with one interviewee telling us: "Hurricanes Eta and Iota caused a lot of loss in all of the crops, and the rivers, they went out of their way"

# 5.2.2 Perceptions and Impacts of Extreme Heat in Estanzuela

Results also demonstrated that interviewees were indeed experiencing increased instances of extreme heat (Table 1). They discussed experiencing increased heat and many more, hotter days. They also described the relationship between extreme heat and less water. Still, others discussed climate variability and climate change in general. Table 1 (below) summarizes some of these statements.

	Castellano/Español	English Translation
Perceptions of	"Que cada día el calor aumenta."	"Every day the heat intensifies."
Extreme Heat	"Que cada día empeora por el calentamiento global."	"Every day global warming gets worse."
	"Si, más calor."	"Yes, it is getting hotter."
	"Por tanta variacón de clima."	"The climate varies so much."
	"Hay menos agua y más calor."	"There's less water and more heat."

Table 1: Perceptions of extreme heat in Estanzuela

"Cambios del tiempo. No nos agradan los niveles altos	"There are weather changes. We do not like the
de calor."	extreme heat."
"A costado mucho por el calor que hay cada día."	"It costs a lot because it is hot every day."

Interviewees also described how extreme heat changed their day-to-day experiences and their livelihoods as a whole (see Table 2, below). First, interviewees described to us how extreme heat was impacting agricultural fields and the industry as a whole. Moreover, interviewees in Estanzuela told us how they saw extreme heat impacting their health and the health of their community as a whole.

Impacts of	Castellano/Español	English Translation
Extreme Heat		
Agriculture	"Se han secado por el calentamiento global."	"Things have dried up because of global
		warming."
	"Quema los cultivos."	"It burns our crops."
	"Que se secan por el calentamiento global."	"Things are drying out because of global
		warming."
	"En el tiempo de frio afecta la cosecha y el calor	"Cold weather affects the harvest, and the heat
	ayuda a crecer el melón, aquí en Estanzuela se da más	helps melons grow, here in Estanzuela melons
	el melón por el calor."	grow more because of the heat."
	"Ha estado afectando, secando las siembras."	"It has dried out our crops."
	"La falta de lluvia, y el exceso de sol que quema las	"The lack of rain and excessive sun is killing
	plantas."	our plants."
	"Si, y cada vez es más difícil cosechar."	"Every year it is more difficult to harvest."
Health	"Estamos acudiendo en los hospitales por el cambio de	"We are going to hospitals because of climate
	clima."	change"
	"Cuando está muy caliente el clima cambia a frio uno	"When the climate changes from very hot to
	sufre lo que es el problema respiratorio. "	cold, people suffer from respiratory problems."

Table 2: Community identified impacts of extreme heat in the domains of agriculture and health in Estanzuela

# 5.2.3 Adaptation to Extreme Heat and other Changes

Interviewees told us that they were adapting to extreme heat in numerous, diverse ways. In their households, numerous interviewees told us that they had increased their use of fans within their homes. Interviewees also told us that they would wear hats and long-sleeved shirts to protect their skin from the sun. Others also discussed planting trees to decrease heat. For example, one interviewee described this as, "*I'm also planting more trees*." When working in agriculture, they told us that they had to change their practices and sometimes apply more chemicals. One interviewee described this as: "*Over time, I've learned to add more chemicals to increase plant resistance*." Other interviewees informed us that they planted trees as a way to adapt to increasing temperatures. Others expressed that their capacity to adapt was strained by economic challenges. In particular, someone told us

that: "Yes, we all work with corn. However, lately, we can only depend on it as part of our income because buying fertilizer is very difficult and the extreme heat or the lack of water ruins our harvest."

# 5.2.4 Obtaining Information about extreme heat in Estanzuela

As part of this study, we also asked people to describe where and how they accessed information about extreme heat, especially weather changes. The most frequent answers were, "*information from the news and from searching on the internet*." Similarly, many people gained information from the TV and radio, and "*sometimes even the telephone*." People also told us that they gained information from word of mouth, "*by family and friends*." Two people also told us that they would look to authorities or the municipality to secure information. In particular, one interviewee told us that they would "*ask for information from someone with more understanding and training*," while another interviewee told us that they "got their information form the municipality."

#### 5.2.5 Improving organizational responses to extreme heat in Estanzuela

Another dimension to our study was to investigate peoples' perceptions of organizational responses to extreme heat. While a couple of interviewees gained information from the municipality and other experts, many people also told us that they "*did not participate in any organization*." Others told us that "*no organizations exist here. They don't come here.*" When there were local organizations, some expressed frustration with their local organizations, describing their opinion as follows: "*they don't say anything to us. They don't give us any information or any help.*" Finally, given that many people worked in agriculture, interviewees told us that they often gathered information and worked with the Ministerio de Agricultura, Ganadería, y Alimentación (Ministry of Agriculture, Livestock, and Feeding; MAGA) to access information about and make plans to address extreme heat.

We also asked interviewees to provide recommendations to organizations that endeavored to help their community in times of extreme heat. People in Estanzuela told us that they would like to work with organizations, if possible. First people recommended that organizations support community members by providing necessities that would "benefit everyone in the community." Related to economic challenges, they identified "providing employment opportunities" as a way that organizations could help people adapt to extreme heat. Others recommended that organizations deliver capacity building to the local health centers on how to address extreme-heat-related health issues. In particular, an interviewee told us: "it would be great if the community could have better medicines in the health centers."

Interviewees also gave us recommendations for addressing social-ecological changes and supporting farmers. For instance, some interviewees suggested that organizations "support farmers." In particular, they suggested that organizations, "help farmers by providing products that help with crop cultivation," and expressed a desire for an "emergence of organizations to support farmers." Others were particularly interested in reforestation as a way to address extreme heat. An interviewee told us: "It is important that we are able to reforest. Trees are vital for life." They also told us that they wished organizations could provide "up-to-date information" about climate change and extreme heat.

# 5.3 Experience and adaptation to extreme heat in the city of Zacapa

In this section, we document how residents of the city of Zacapa experience and adapt to extreme heat. Zacapa is the capital city of the Department of Zacapa and is overall more urban than Estanzuela. In what follows, we document how people experience both extreme heat and its impacts. We then document how people gain information about extreme heat and evaluate organizational response to extreme heat, from the point of view of local people. We conclude with peoples' recommendations for improving organizational responses to extreme heat.

# 5.3.1 Social-ecological changes in Zacapa

Interviewees in Zacapa identified numerous social-ecological changes occurring in their city. First, interviewees told us that, in general, there used to be more water wells, but now there are fewer. Others told us that before, their area was largely a jungle, but over time "*it has really dried out*." In addition, interviewees identified economic issues as being a primary concern. Others also discussed seeing increased emigration as a significant change in their community as one interviewee described: "*the population has grown a lot.*"

People also talked about how the climate was changing, as one interviewee described: "the climate isn't like it was before," with another interviewee telling us that "there have been drastic climate changes." Another prominent change in Zacapa was in regard to water. On the one hand, numerous interviewees told that they were concerned with "an extreme lack of water," water instability," "increasing droughts," and "a lot of erosion." On the other hand, people told us that they now had access to potable water, whereas in the past they did not.

These issues not only impacted people's health and sanitation but also their livelihoods, as they also told as that they often "*lacked adequate water to irrigate*" and "*had little water to give to livestock*." Others told us that "*the streams had dried up*." People were also concerned with the decrease in productive agricultural lands, with one person telling us, "*The land no longer produces without fertilizers*," and "*before we didn't irrigate in the winter* (i.e., the rainy season) *because we had enough water, now we irrigate all year*." Finally, interviewees, time and time again, referred to deforestation as a key concern. Some even identified increased occurrences of forest fires as a concern. One told us: "*if we don't take care of the forests, then we will have no forests. We have to take care of the environment.*" Even though they had concerns over deforestation, some also expressed hopelessness, with one interviewee telling us: "*there's no more open land to reforest.*"

# 5.3.2 Perceptions and Impacts of Extreme Heat in Estanzuela

Interviewees in Zacapa expressed that they were experiencing extreme heat (Table 3). In particular, they told us that they saw more hot days and that temperatures were increasing and getting stronger.

Perceptions of	Castellano/Español	English Translation
Extreme Heat		
	"Que cada día el calor aumenta."	"Every day the heat gets worse."
	"Si, hay más calor."	"Yes, it's hotter."

# Table 3: Perceptions of extreme heat in Estanzuela

"Sí, los calores son más fuertes."	"The heat is getting stronger."
"Hay plagas, calentamiento, sequías y poca lluvia."	"There are bugs, it's hotter, droughts
	and very little rain."
"La temperatura cada vez más alta."	"The temperature rises every day."

Interviewees in Zacapa also informed us that they had witnessed numerous impacts from the increasing heat (Table 4). Two themes emerged. In particular, interviewees told us that they saw agricultural impacts, changing the crops, soil, and trees. Others also told us that the heat impacted public health, with people experiencing hypertension. One person told us they knew someone who had died from the heat.

Table 4: Community identified impacts of extreme heat in the domains of agriculture and health in the capital city of Zacapa

Impacts of	Castellano/Español	English Translation
Extreme Heat		
Agriculture	"Afectar los cultivos."	"It affects our crops."
	"Sí, ahora las tierras no producen sin abono."	"The land no longer produces
		without fertilizers."
	"Afecta bastante a las fincas."	"It really impacts the farms."
	"Por el clima hay mucho calor y los suelos ya no producen."	"Because of the climate, it's a lot
		hotter and the soils no longer
		produce."
	"Si, mucha sequedad en el suelo."	"The soil is so dry."
	"Se secan las plantas y son muy común las plagas."	"The plants dry out and pests are
		more common."
	"El calor extremo, ya no hay árboles."	"The heat is extreme, and there are
		no more trees."
Health	"Muchas enfermedades."	"There are many illnesses."
	"Que afecta a la piel."	"It affects our skin."
	"Se enferman más porque cambia el clima."	"People get sick more because of
		climate change."
	"Que afecta a la piel y también a las personas que sufren de	"It impacts our skin, and people also
	presión alta (hipertensión)."	suffer from hypertension."
	"Presión arterial por mucho calor."	"People get hypertension because it
		is so hot."
	"Se han visto muertes por calor."	"I've seen people die from heat."

# 5.3.3 Adaptation to Extreme Heat and other Changes

We also asked interviewees how they were currently adapting to extreme heat and other social-ecological changes. We received diverse answers. First, interviewees realized that adaptation would become more necessary as time goes on. One interviewee explained this as: "*One adapts to what comes, there is no other option*." Others also discussed increasing their use of a fan in times of extreme heat, while others told us that they "*stored water in their* 

*houses to be prepared for future heatwaves,*" and they collected water during the rainy season to use during heatwaves, while others told us that had yet to adapt.

Others discussed ongoing, interconnected adaptation and mitigation strategies. In particular, numerous interviewees told us that protecting trees in Zacapa has already had a "collective impact" on the community. Another farmer told us that he had attended: "numerous meetings and trainings with agronomists," started "to buy fertilizers and make wells on his property," and "use organic waste as fertilizer." However, even with these efforts, many interviewees still felt that additional efforts should be made to adapt and mitigate.

People wanted to increase efforts to "*protect trees and forests*." In particular, interviewees who worked in forestry mentioned that they had started planting more seeds to decrease the impacts of deforestation and help with adaptation. Relatedly, they suggested that buying and planting live trees could help mitigate the impacts of extreme heat. Others also mentioned that they would like to care for some property and conduct reforestation activities, but they rented. One interview told us, "*I don't have my own land, so I don't plant seeds here*." Interviewees also told us that economic support, in particular "*economic stability*," could create conditions for future adaptation.

# 5.3.4 Obtaining Information about extreme heat in Zacapa

Interviewees informed us that they used many different modalities to access information. They told us that they watch the television, especially the news, to understand local as well as global changes. One person said that the local news warned them when "*there was going to be a lot of heat*." They also discussed using Facebook and WhatsApp as means to communicate with family and friends about issues. Interviewees also told us that they would "*just chat with neighbors*" and "*find out information at work*." One interviewee also mentioned that they obtained information from "*international associations, like the KFW, an organization that helps us a little*."

However, even though people used these modalities, one interviewee told us that "sometimes you don't have the economic resources to gain access to information, particularly if you don't have money to buy cell phone minutes or data." One interviewee also told us that they often consulted with experts, especially agronomists and engineers, to obtain information about extreme heat and adaptation.

#### 5.3.5 Improving organizational responses to extreme heat in Zacapa

We received mixed information regarding organizational support in Zacapa. For instance, some interviewees in Zacapa told us that they often received support from the municipality during heat waves, and that the support was "*very good*" and that they have a positive perception of the municipality because "*they help them a lot*." Interviewees in Zacapa also told us that they often worked with local cooperatives, the Ministry of Agriculture and Feeding (MAGA), the National Institute of Electrification, and an international organization called Plan International. However, other interviewees told us that "*nobody cares about us*," and another said, "*there has been absolutely no help*." One person expressed concern over corruption. He told us: "*corruption impacts everything*." Similarly, another person said that bad organization negatively impacted adaptation.

Moving forward, interviewees recommended that organizations help with economic stability, reforestation, and caring for plants in general. In Zacapa, interviewees also gave recommendations for decision-making. For

example, one interviewee told us that organizations should "*take into account peoples*' opinions when making decisions." Similarly, someone told us that they wanted organizations "*to strengthen their support and conduct a needs assessment*." Others said that "future research projects would be helpful," and "information on how to adapt would be great."

One particular recommendation was to work with communities to build greenhouses for reforestation purposes. Another was to give away seed donations for reforestation purposes. They also recommended money to pay laborers to increase the city's capacity to adapt to forest fires. Someone else told us "*Only owners protect forests*." Interviewees also made recommendations regarding how organizations communicated with communities. They recommended that organizations use the radio, internet, and television to improve environmental awareness and communicate heat risks. Another person expressed a desire for information to detect extreme changes in weather and climate. Another interviewee explained this desire as: "*Being able to detect the weather and to see if it will be a good harvest would be great because on that, there is a lot of waste of both time and economic resources [when there's a bad harvest].*" Still others expressed a desire for support from professionals, including veterinarians.

# 5.4 Human Migration in the Department of Zacapa

This section documents if and how people perceived migration to be a common social-ecological change in their community. We asked interviewees to identify their community's most pressing social-ecological changes over the past 30 years. In what follows, we present how people described migration and mobility, both immigration and emigration as a prominent change across both research sites.

# 5.4.1 Emigration from Estanzuela to other countries

First, across sites, multiple interviewees told us that "many people leave, and a big change in their community has been the "movement of people to find other jobs." They told us that people left their area "to look for employment opportunities," something that was motivated by the need to have more "economic stability for their families." This finding was especially prominent in the rural area of Estanzuela. One interviewee in Estanzuela told us that "yes, a lot of people have left to go to other countries, especially the United States." When we asked one interviewee about why they moved abroad, someone told us: "most of us almost do because there is little work, and you have to go out seek life one and thus the family and one does not suffer."

# 5.4.2 Emigration and immigration to the Capital City of Zacapa

In the capital city of Zacapa, we have conflicting migration results. In particular, interviewees told us that many people have left. However, numerous interviewees also told us that "*many people have moved there, and "our population has increased.*" Interviewees expressed concern over the increasing population in Zacapa because "*when the population increases, there we have less resources.*"

## 5.4.3 Mobility and climate change in the Department of Zacapa

While few interviewees, across sites, connected instances of extreme heat with mobility or migration, results did provide some insight. In particular, one interviewee told us that "when it gets really hot, they often look for or visit cooler places." Another interviewee discussed their resistance to move and a preference to stay on their farm. This interviewee told us: "at the same time, this is **my farm**. I have not moved. I have stayed here on my farm."

# 6.0 Discussion and Analysis

Our research also provides details into how people in the two sites perceive and adapt to social-ecological change. Findings indicate that people across both sites expressed concerns about diminishing water supplies, climate change, deforestation, and economic challenges. At the same time, they discussed how their communities were also developing, which most interviewees expressed in a positive manner. These data align with other studies across numerous sites, that show that social-ecological changes and issues like land change, extreme heat, migration, climate change, public health, and water scarcity are interconnected (Erwin, et al., 2021). Together, our results, along with other studies, indicate that addressing social-ecological requires interdisciplinary, context-specific approaches that work alongside strategies designed and implemented from larger scales (Agrawal, 2008; Burnham and Ma, 2016; Lemos & Morehouse, 2005; Popovici, et al., 2021b).

In addition to illuminating broad social-ecological changes, our climatological data also show that instances of extreme heat and heatwaves are indeed becoming more prominent over time. In particular, our social science data shows that people are experiencing these impacts in numerous ways, especially in the dimensions of agriculture, health, and human mobility. This data expands numerous scholarly studies that show how climate change impacts communities around the world (Burnham & Ma, 2016, 2018; Erwin et al., 2021; Rao et al., 2019) by detailing how people in the Corredor Seco of Central America experience and address extreme heat.

Our results show that people adapt to these changes at the household and community levels, and thus, provide valuable knowledge that can bolster approaches to adaptation in Guatemala and beyond. Burnham and Ma (2016) and Agrawal et al. (2008) have shown adaptation occurs at autonomous and planned scales. Their description of autonomous adaptation includes the following actions taken at the household and individual scale: environmental management, communal pooling of resources, income diversification, labor migration, market exchange, and storage. Our results show that residents of these two sites are practicing environmental management, income diversification, and labor migration as their primary means to adapting to social-ecological changes. In particular, interviewees were already practicing adaptation and mitigation strategies through pursuing reforestation, income diversification, and labor migration to address ongoing changes in their communities.

Findings also expand Burnham and Ma (2016) and Agrawal et al. (2008) typology in two ways. First, results show the importance of radio, social-media, and television when supporting households and individuals as they adapt to social ecological change, extreme heat, specifically. Second, results also reveal adaptation strategies that protect individuals and households from extreme heat. In particular, people used fans, wore sunscreen, and were using actions to protect their health

Burnham and Ma (2016) and Agrawal et al. (2008) also describe planned adaptations as adaptations taken beyond the household or individual scale. These strategies often encompass policies and planning strategies that support individuals, households, and communities as they adapt. Our results also indicate that individuals and households also looked beyond their household to entities like the municipality, international nongovernmental organizations, and businesses support their capacity to adapt to extreme heat and other changes they were experiencing. Our results, differ from other studies (Erwin, 2021; Popovici, 2021ab), did not illuminate how people across both sites worked with community-scale natural resource organizations, like water commission or irrigation councils, to address concerns. Given that many interviewees worked agriculture, future studies in the Corredor Seco of Guatemala could expand our findings by investigating the role community-scale natural resource organizations play when supporting adaptation to extreme heat.

Results also show how economic factors shape adaptive capacity, the capacity of one to adapt to climatic or other social-ecological changes (Smit & Wandel, 2006). According to the National Institute of Statistics of Guatemala (2016), the "poverty rate and proportion" in the department of Zacapa deepened to almost 50% of the population. These indicators denote that living conditions in this region of the country could create enormous challenges to addressing climate change, especially as it increases the prevalence and intensity of extreme heat. Our data confirms this concern and builds on evidence from other locations, showing how different factors, including but not limited to economic resources, limit peoples' adaptation (Erwin et al., 2021).

Finally, as indicated in our limitations section, were not able to acquire data from the National Institute of Statistics. However, our qualitative findings do align with existing theoretical and empirical studies about the relationship between migration and social-ecological change. In particular, scholars argue show that migration is both a social-ecological change and a migration strategy (Erwin et al., 2021; Black, 2011). We also found that people discussed how migration was both a change and an adaptation strategy that they would like to pursue. These results indicate a need for understanding why certain people are able to migrate int eh first place while others stay behind in the context of social-ecological changes, like extreme heat. Moreover, extensive scholarship has also shown that migration is rarely solely induced by climate but instead a result of how numerous factors, including climate change and economic security, intersect and motivate, at times force, people to migrate to new places (see Black et al., 2011).

Our preliminary results highlight how migration across the two sites is connected to economic challenges. These results indicate a need for two additional areas of study. First, future studies that connect migration to economic challenges and extreme heat in the Corredor Seco could illuminate how these combined factors impact people's capacity to adapt in situ. Second, interviewees indicated that they often used mobility, a strategy described in Burnham and Ma (2016) and Agrawal's (2008) typology, to escape the heat in the summer. Future studies that build on our qualitative analyses through surveys or quantitative analyses of secondary data could also improve the capacity of scholars and policymakers to understand migration and mobility's connection to extreme heat and other connected social-ecological changes.

# 7.0 Conclusions

Overall, our interdisciplinary, collaborative research approach provided numerous insights into how socialecological changes, especially extreme heat, impact people in the Corredor Seco (Dry Corredor) of Guatemala. Although small and based on a pilot study, these results contribute to a growing body of research studies that use collaborative, interdisciplinary approaches to document climate change (Lemos & Morehouse, 2005; Popovici, et al., 2021b). Results generate insights into human adaptation strategies in the Corredor Seco to respond to extreme heat and identify possible obstacles to adaptation people from marginalized groups may experience. These results are based on a small pilot with a convenience sample, and they should be replicated with larger samples. This approach will offer insights into how extreme heat impacts people living in different contexts, providing additional insight into the problem and ways to address it in diverse contexts.

# 7.0 Practical application for humanitarian work and recommendations

Our partnership and analyses also illuminated numerous ways in which organizations and governments can support people of the Corredor Seco of Guatemala during heatwaves. Most notably, this analysis identifies adaptation mechanisms to address extreme heat in Zacapa, generating practical guidelines to be shared with local municipalities, NGOs, the Red Cross, and other governmental entities so they could be used to improve the wellbeing of people living in the context of extreme heat.

For instance, results, especially from Zacapa, indicate that partnering with local municipalities, especially as interviewees regarded them positively, could be an effective mode of transmitting information and support to local communities. Interviewees in Estanzuela provided less details about municipal support during heatwaves. In addition to partnering with municipalities, respondents called for partnering with health centers and working with agriculture and combating deforestation through reforestation efforts.

Heatplots and trend tendency analyses for the Zacapa department indicate the need for government agencies, NGOs, private industry, universities, and the scientific community to help create mitigation and adaptation programs that effectively will protect the most vulnerable populations in Zacapa: children, the elderly, and rural communities. Since the Zacapa department is located in the Corredor Seco of Guatemala, the findings listed above may apply to the other departments within the Corredor Seco. It is recommended to expand the study of the impact and perception of heatwaves to other departments in Guatemala.

# 8.0 Next Steps for UTRGV / URL Team

We plan to disseminate results in numerous ways. First, faculty from UTRGV and URL plan to present our results to our community partners. Then, with the support of our community partners, we plan to deliver the results to residents and authorities in the city of Zacapa and Estanzuela. We plan to work with community partners to present our results to the two communities. Second, we plan to work together to publish two peer-reviewed articles resulting from the collection and analysis of social and biophysical data.

By the end, we will present a series of recommendations, driven by local and indigenous practices, to inform the ways that municipalities, the Red Cross, and other NGOs can work independently and together to address extreme heat. In each Zacapa community, URL researchers and students will partner with local community organizations to connect with community members, pursue our research goals, and disseminate results back to the communities. 9.0 References

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