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The Relationship Between Anthropogenic Climate Change, Poverty, and Health Equity: A Systematic Review

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ABSTRACT

Anthropogenic climate change can be defined as a shift in the Earth's long-term weather patterns attributed to human activities that increase the amount of carbon dioxide and other greenhouse gases in the atmosphere, particularly the unrestricted burning of fossil fuels (United Nations 1992:7). Even though this definition may seem simple, climate change is a complex issue with various underlying and interconnected factors. To come up with solutions and coping strategies regarding climate change, there will need to be a change in human behavior and our decision process concerning the use of fossil fuels. The question we have to ask is: What are the effects of climate change on health and poverty and how does that impact our ability to adapt to climate change? This systematic literature review meticulously analyzes 23 studies that examine climate change and its effects on human health and poverty. This review of the literature has helped illustrate the circular relationship between climate change, poverty, and health. Disadvantaged individuals already have a low adaptive capacity which is further exacerbated by low socioeconomic status, in addition to other individual and community level characteristics. When these factors are combined with the increasing threat of climate change, it can have a negative and disproportionate impact on their health and well-being. This cycle will continue unless action is taken to assist individuals and communities in improving their adaptive capacity in conjunction with helping to alleviate the impact of climate change. Additionally, individuals with multiple intersecting disadvantaged characteristics consequently have higher vulnerability and lower adaptive capacity, which is a dangerous combination. These findings highlight the fact that climate change will not impact everyone equally due to differing adaptive capacities and specific individual-level and community-level characteristics. It is essential to consider the

specific context of the location and the people who reside there when determining the best course of action to mitigate the impact of climate change. This research is important because as the climate continues to change and extreme weather events become commonplace, the health and well-being of the human population may be at stake unless we are properly prepared to adapt and manage these changes collectively.

BACKGROUND

Throughout history the earth has experienced a changing climate. The climate of our modern era started around 11,700 years ago when the last ice age ended and human civilization began (Black 2013). With human civilization came the use of fossil fuels. The use of these fossil fuels by humans and industry resulted in the harmful emissions of carbon dioxide into the atmosphere. Over the years, these emissions have created a change in our natural climate. In 1896, Swedish chemist Svante Arrhenius concluded that these harmful emissions of carbon dioxide into the atmosphere would trap the warmth of the sun, known as the greenhouse effect, and therefore change our climate (Black 2013). Over the years, the name for this change in climate has varied widely.

Before 1975 climate change was referred to as inadvertent climate modification (Conway 2008). Geochemist Wallace Broecker of Columbia University first used the term global warming in 1975 in an article titled, *Climatic Change: Are We on the Brink of a Pronounced Global Warming?* Later in 1979, The National Academy of Science published a decisive report on carbon dioxide and its impact on the climate. Their conclusion included the term climate change instead of inadvertent climate modification because they found that if carbon dioxide continued

to increase, then climate change would result (Conway 2008). As of 1992, the United Nations defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (United Nations 1992:7). Although this definition of climate change may seem simple, climate change is a complex issue with various underlying and interconnected factors.

Over time, we have seen carbon dioxide levels rise from 323 parts per million (ppm) in the late 1960's to 369 ppm by the year 2000 (Wiles 2018). Current carbon dioxide levels currently sit at 385 ppm. This increase has created a half degree temperature increase from averages during the pre-industrial period. Later studies have shown that carbon dioxide increases above the 450-600 ppm level would be irreversible until 1,000 years after the emissions stopped (Solomon et al. 2009). In order for the emissions to stop, we would have to stop use of fossil fuels. The United Nations Climate Report of 2018 says there is little chance of staying in a temperature rise of 1.5 degrees by the 2040's that is deemed safe by scientists (Wiles 2018).

The Intergovernmental Panel on Climate Change (IPCC) in 2007 released a report with unquestionable evidence of global warming because of greenhouse gases and that more warming could be expected in the coming decades (Luber and Prudent 2009). Currently, natural systems show the effects of global warming. Oceans are warming and rising due to the melting of glaciers and ice-caps around the world, and weather patterns are becoming more extreme. The IPPC sees the converse effect being a 90 percent chance that heat waves will be more intense and occur more often, rainfall will be heavier and more frequent, cyclones will be stronger, drought will be more widespread, and sea levels will rise. Ultimately there will be an effect on the human

population as a result of the changing climate. This change in the regularity and severity of weather events can produce a ripple effect throughout both natural and human systems (IPCC 2014; NASA 2019). These extreme weather events can have a negative impact on the well-being of both humans and the natural environment (NASA 2019). As the population of the world increases, the effects of climate change also increases. With the increase in population, there will be an increase in carbon dioxide emissions resulting in a greater variation in climate change. The result is greater harm to our planet and, in turn, more problems in our ability to cope with the effects of climate change (Scovronick et al. 2017). It is important that we look at what impacts climate change will have on society so we are better able to deal with them. In addition, we need to look at what behavior changes can be made from the standpoint of society so we can mitigate some of the effects that might come from climate change.

Anthony Leiserowitz argues that climate change should be looked at from a social and behavioral perspective since climate change is the result of human activity (Maibach, Roser-Renouf, and Leiserowitz 2008). To come up with solutions and coping strategies regarding climate change, there will need to be a change in human behavior and our decision process concerning the use of fossil fuels. A study by NASA, Mitigation and Adaptation/Solutions - Climate Change: Vital Signs of the Planet, documents solutions needed to deal with climate change (NASA 2018). We have to adjust our use of natural resources and daily living. Beyond that, we as a society and as individuals need to cope with the effects of climate change by looking at the impact climate change will have on our daily lives.

Two of the most important areas affecting daily living would be human health and economic capabilities. The consequences that can result because of global warming can have

such an impact on human health and poverty that further studies are warranted. The question we have to ask is: What are the effects of climate change on health and poverty and how does that impact our ability to adapt to climate change?

There is a general consensus that the most disadvantaged individuals, particularly those with low-income, will experience the brunt of the impact of climate change even though they are least responsible for this catastrophe (Mertz et al. 2009; Levy and Patz 2015). Although, the mechanism responsible for the relationship between climate change, poverty, and health is poorly understood. This systematic literature review looks at studies that examine climate change and its effects on human health and poverty. This research is important because as the climate continues to change and extreme weather events become commonplace, the health and well-being of the human population may be at stake.

METHODS

Database Search and Inclusion Criteria

Prisma Reviews are "systematic reviews of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research and to collect and analyze data from the studies that are included in the review" (Moher et al. 2009:264). Each systematic review addresses a clearly formulated question; for example: *the relationship between anthropogenic climate change, poverty, and health equity*. The existing research on this topic that meets certain criteria is searched for and collated, and then assessed using stringent guidelines, to establish whether or not there is conclusive evidence about this question. The aims of this systematic review include: clarifying the relative strengths and

weaknesses of the literature on the question, summarizing a large amount of literature, and improving the general understanding of the relationship between climate change, poverty, and health equity.

The inquiry began on October 11, 2019, with a basic search of four databases including: PubMed, EBSCO, Web of Science, and Sage, using the syntax: (climate change OR global warming OR anthropogenic climate change OR environmental change) AND (poverty OR low income OR socioeconomic status OR SES OR vulnerable OR impoverish* OR disadvantag* OR social determinants of health) AND (health equity OR health inequalit* OR health inequity OR social justice OR human rights OR systematic disparit* OR systematic disadvantage* OR social inequalities in health OR social disadvantage OR health disparit*). These four databases were then utilized to extract data with the intention of synthesizing the evidence on the relationship between climate change, poverty, and health equity.

Completed on December 2nd, 2019, the final exhaustive search process was based on the eligibility criteria that was established before beginning the process of identifying, locating, and retrieving the research needed to address the relationship between climate change, poverty, and health equity. This criteria specified which studies were included and excluded from the analysis. The language that was employed to extract information from the databases was English. The set time frame or publication date range for this inquiry was set from 2014 through 2019. This protocol can be used to replicate the search and should result in a collection of 1,128 articles or 1,030 articles after deleting duplicates in any preferred citation management software such as Zotero, Mendeley or Endnote. For this project specifically, Zotero was used to extract and manage the articles that were found.

After conducting the initial search, the studies were considered relevant if they included elements of climate change, poverty, and health equity. In the first round of exclusion, the title of the article was examined to determine if it was relevant to the topic. Based on this criteria, 396 studies advanced to the second round of exclusion. The second round of exclusion involved carefully reading the abstracts of the articles and manually deleting articles that were not original research or were unable to be accessed. After reading the abstracts of the 396 original articles, 160 articles advanced to the third round of exclusion. The third round of exclusion entailed scanning the articles in order to determine if the elements of climate change, poverty, and health equity were sufficiently present and relevant to the topic at hand. Out of the 160 articles in the third round of exclusion, 79 articles advanced to the final round based on the previously mentioned criteria. The final round of exclusion involved analyzing the full article in order to determine whether or not it adds to the discourse surrounding the relationship between climate change, poverty, and health equity. Out of the 79 articles in the final round of exclusion, only 18 articles were selected to be evaluated for this systematic review. In order to fill the gaps that may have been missed in the search syntax, the references from the most recent articles were analyzed to find relevant articles that contributed to the discourse of this topic. Upon further investigation of the references from the articles published in 2019, there were 5 articles found to be relevant that were incorporated into this analysis. This resulted in a total of 23 articles to be evaluated in this systematic review of the literature. Figure 1 presents a flowchart that outlines the electronic search and hand selection process of literature for this paper.

The articles were coded based on author, institution, title, journal name, journal type, year, location, climate change issue, health issue, sample characteristics, research methodology,

findings, and funding source. For a more detailed list of coding criteria, please see figure 2 in the appendix which presents the coding template that was used to code articles for this systematic review. The articles came from many different journals which included the disciplines of healthcare, public health, medicine, urban studies, social science, sociology, ecology, environmental science, and more. There was a variety of multidisciplinary, interdisciplinary, and transdisciplinary journals that appeared in the literature. For clarification, multidisciplinary journals contain articles from multiple disciplines but there is little to no interaction between the different disciplines (Caldwell 2015). On the other hand, interdisciplinary journals combine perspectives from two or more disciplines while transdisciplinary journals provide a more holistic view of a topic using an integrated approach from multiple different disciplines (Caldwell 2015).

This paper aims to systematically review the relationship between anthropogenic climate change, poverty, and health equity.

Literature Analysis

In total, there were 23 articles that met the search criteria that were chosen to be meticulously analyzed for this systematic review. Each article was assigned a reference number that will be used to cite the article throughout this paper. The reference number for each article can be found in Table 1 which is located in the appendix. The following themes will be investigated in this paper:

Study Setting and Participants

1. Location

2. Sample Characteristics

Study Design

1. Climate Change Issue

2. Health Issue

3. Research Methodology

Study Outcomes

1. Findings

Journal Characteristics

Author Affiliation

Funding

RESULTS

Study Setting and Participants

Location

A bulk of the studies, 26% (n=6), were published in the year 2016 (1234, 1239, 1240, 1248, 1251, 1252). Also, 22% (n=5) of the studies were published in both 2018 (1235, 1237, 1244, 1246, 1247) and 2019 (1241, 1245, 1249, 1250, 1253). However, 17% (n=4) of the studies were published in the year 2015 (1233, 1238, 1242, 1243). Lastly, 9% (n=2) and 4% (n=1) of the studies were published in the year 2014 (1232 & 1236) and the year 2017 (1254), respectively.

Almost half, 48% (n=11), of the studies were conducted in the United States. California was the most popular location with three studies that occurred solely in California. Out of the studies that were located in California, one was a state-wide study (1235), one was conducted in San Diego county (1237), and the last one took place in the San Francisco Bay Area (1240).

There were also two multi-state studies that included the city of Los Angeles (1239 & 1246). Aside from California, there were three other single-state studies that transpired in the United States, which consisted of the states Louisiana (1236), New York (1244), and Michigan (1249). The cities in which these studies took place included New Orleans (1236), New York City (1244) and Detroit (1249), respectively. There were five multi-state studies that occurred in the United States (1239, 1243, 1246, 1251, 1253). Article 1239 included the states of California, Georgia, Michigan, Ohio, Pennsylvania, and Texas. Article 1243 comprised the states of Connecticut, New Jersey, and New York. Another study covered the states of Arizona, California, Colorado, Connecticut, Florida, Georgia, Illinois, Massachusetts, Michigan, Minnesota, Missouri, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Tennessee, Texas, Washington State, and the territory of Washington D.C. (1246). Lastly, there was a study that included the states of Arizona and New Mexico (1251). In addition to these studies, there was a nationwide study that transpired in the United States (1253).

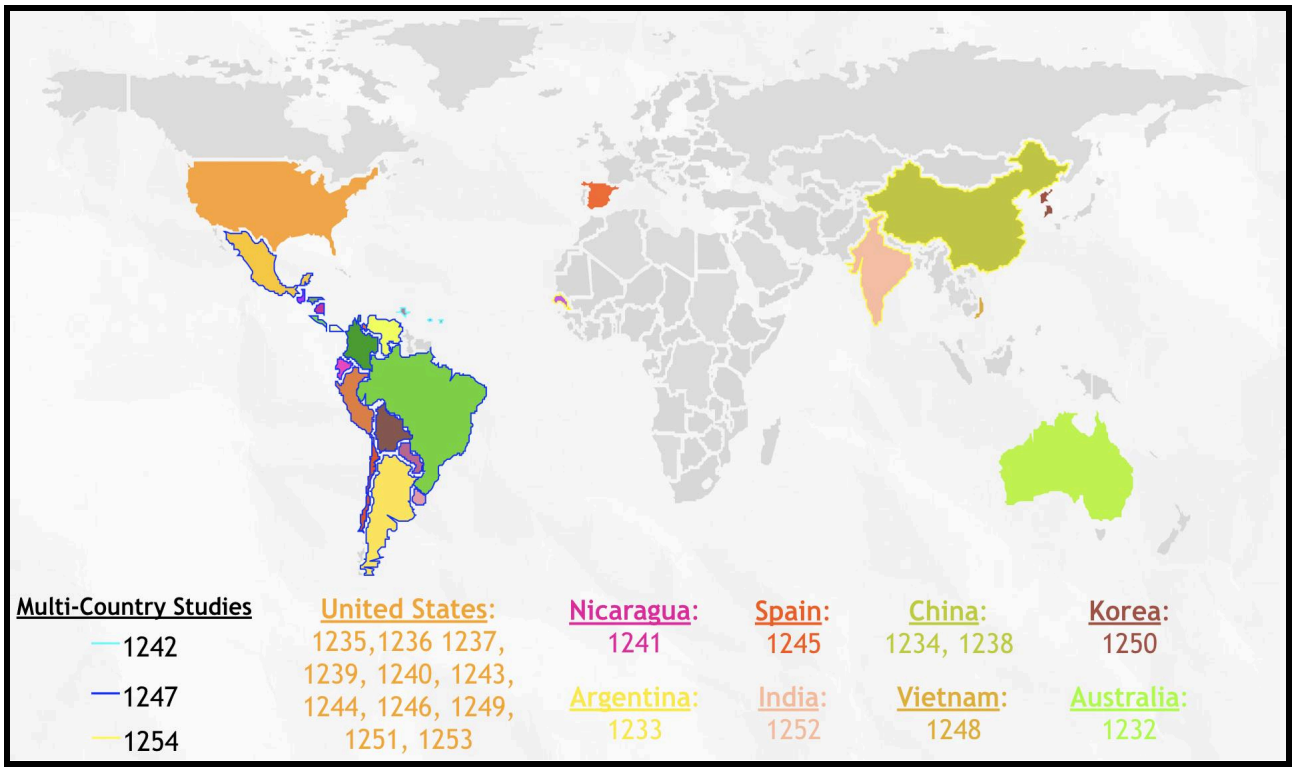
There were five studies (22%) conducted in Asia that encompassed the countries of India (1252), Korea (1250), Vietnam (1248), and China (1234 & 1238). Article 1250 occurred in the city of Seoul. Article 1248 took place in the Mekong Delta Region. And one of the studies that was conducted in China took place in the Jiangsu Province (1234) while the other was a nationwide study (1238).

There was one study (4%) conducted in the European country of Spain, which took place in Barcelona (1245). There was one study (4%) that occurred in the large Australian region of Greater Western Sydney (1232). In South America, there was one study (4%) that took place in

Córdoba, Argentina (1233). Furthermore, there was one study (4%) that occurred in Central America in the country of Nicaragua (1241).

There were three studies (13%) that comprised multiple countries. One of the studies took place in South America, Central America, and North America and involved the countries of Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela (1247). Another study took place in the Caribbean region and encompassed the countries of Trinidad and Tobago, and Grenada (1242). Lastly, there was a study that was conducted in Asia and Africa that included the countries of China, India, and Senegal (1254). Figure 3 shows a world map that specifies the location of each study.

Figure 3: Map of Article Site Locations



Sample Characteristics

The studies were similar in that they each contained a component of poverty or low socioeconomic status, but the specific target population of the studies varied. There were three studies (13%) that utilized data on the general population of a specific area and then investigated how factors related to socioeconomic status influenced the results of the study (1232, 1240, 1244). One study was conducted in Australia in the Greater Western Sydney region that involved determining how different socioeconomic status and household income levels modified the affordability and accessibility of healthy and sustainable foods (1232). Another study analyzed how an increase in the severity and frequency of flooding may disrupt transportation networks in the San Francisco Bay Area in California which may then, in turn, impact the accessibility of healthcare facilities for low income individuals (1240). Lastly, there was a study that occurred in New York City that explored how socioeconomic disparities contribute to heat-related susceptibility (1244).

A theme that emerged in the literature was the use of data from healthcare facilities or healthcare professionals (1233, 1237, 1238, 1242, 1245, 1247, 1248). There were three articles (13%) that utilized hospital admission data for their research (1233, 1237, 1248). One of the studies used data on patients diagnosed with either upper or lower respiratory infections (1233). Upper respiratory infections were classified as a diagnosis of otitis, pharyngitis, sinusitis, and laryngitis while lower respiratory infections were classified as bronchitis and pneumonia (1233). A separate study used hospital admissions data on all cardiovascular diseases, all respiratory diseases, mental health, heat illness, dehydration, and acute renal failure (1237). Additionally,

there was a study that compared hospitalization data on admission for all-causes, respiratory diseases, cardiovascular diseases, and infectious diseases (1248). Moreover, there were two studies (9%) that examined mortality registry data (1238 & 1245). On the other hand, two studies (9%) used qualitative information from health-care providers, one in the small island developing states of the Caribbean (1242) and one in Latin America (1247).

Another theme that was prominent in the literature was the comparison of urban and non-urban areas (1234 & 1243), or studies that individually examined urban areas (1246, 1249, 1252, 1253) or rural areas (1254). There were two studies (9%) that focused on the comparison of urban and non-urban areas (1234 & 1243). On the other hand, there were four studies (17%) that explicitly addressed urban communities (1246, 1249, 1252, 1253). Article 1249 took place in Detroit, Michigan while articles 1246 and 1253 looked at urban communities across the United States. Article 1252 examined urban communities in India. Lastly, there was one study (4%) that concentrated on rural poor areas in China, India, and Senegal (1254).

A few articles placed emphasis on individuals who may be more susceptible to the impact of climate change due to multiple intersecting factors (1235, 1236, 1239, 1250, 1251). Articles 1236 and 1241 both encompassed individuals burdened by natural disasters, but article 1236 addressed low-income African American single mothers who experienced Hurricane Katrina. In addition, there was one article (4%) that focused particularly on pregnant women and the consequences of extreme heat (1250). Alternatively, there was one study (4%) that used qualitative information from individuals with chronic health conditions and low socioeconomic status (1239). Lastly, there was one article (4%) that involved racial or ethnic minority individuals with low socioeconomic status (1251). In addition to these studies, there was one

study (4%) that took place in California that combined census data and the CalEnviroScreen program to identify disadvantaged communities, which are defined as the communities that scored the worst on population vulnerability and environmental quality measures (1235).

Study Design

Climate Change Issue

There was a wide variety of climate change issues covered in these articles. A large majority of the articles, 48% (n=11), dealt with temperature and encompassed topics such as extreme heat (1234, 1237, 1243, 1244, 1248, 1250), daily temperature range (1233), the urban heat island effect (1246), and both extreme heat and cold (1238, 1245, 1253).

Another dominant theme that appeared in the literature was natural disasters (1236, 1240, 1241, 1249). Two articles (9%) addressed displacement associated with the aftermath of hurricanes, specifically Hurricane Katrina (1236) and Hurricane Mitch (1241). Two articles (9%) focused on flooding and covered topics such as recurrent urban household flooding (1249) and how future flooding may impact transportation networks (1240). There were three other articles (13%) that addressed extreme weather events and environmental conditions more broadly (1239, 1247, 1254).

The rest of the articles, 22% (n=5), utilized a more general approach to investigating climate change (1232, 1235, 1242, 1251, 1252). Article 1235 concentrated on greenhouse gas emissions under California's cap-and-trade program. Additionally, there were four other articles that evaluated climate change on a broad scale and encompassed multiple components (1232, 1242, 1251, 1252).

Health Issue

A fairly large portion of the literature, 22% (n=5), focused on mortality associated with the changing climate (1234, 1238, 1243, 1245, 1253). Two articles addressed mortality in general (1243 & 1245), while the others evaluated specific types of mortality such as heat-related mortality (1234), cardiorespiratory mortality (1253), and both cardiovascular and respiratory mortality (1238). On the other hand, there was one article (4%) that examined adverse birth outcomes such as preterm birth and term low birth weight (1250).

Another topic that came up in the literature was access to healthcare. One article (4%) concentrated on inequality related to spatial access to healthcare facilities (1240). Three other articles (13%) focused on the topic of hospitalization. One article included hospitalizations from cardiovascular diseases, respiratory diseases, and infectious/parasitic diseases (1248) and another involved hospitalizations from heat illness, dehydration, acute renal failure, and respiratory diseases (1237). Lastly, article 1233 analyzed health data from 95 health care centers pertaining to admissions from upper and lower respiratory infections.

There was one article (4%) that examined communicable diseases such as diarrheal disease and respiratory disease (1241) while another considered chronic health issues such as asthma, allergies, heat-related health outcomes, obesity, heart disease, and diabetes (1239). Article 1237 briefly mentions mental health, but only one article (4%) explicitly addressed mental health, specifically general psychological distress, post-traumatic stress, and perceived stress (1236).

There were two articles (9%) that examined access to basic civic amenities like safe drinking water and sanitation (1252 & 1254). In addition to access to safe drinking water and sanitation, article 1254 contained components of malnutrition and infant mortality. There was one article (4%) that focused on urban food security in particular, with regards to a healthy and sustainable diet (1232). Plus, one article (4%) explored the burden of air pollutants on health (1235).

Another issue that appeared in the literature was heat-related health outcomes. One article analyzed sensitivity to heat-related health outcomes (1244) while a separate study investigated heat-related illness and heat exposure (1246). The rest of the articles, 17% (n=4), dealt with a combination of multiple health issues and outcomes (1242, 1247, 1249, 1251).

Research Methodology

A bulk of the articles, 61% (n=14), utilized secondary analysis as a research method (1233, 1234, 1235, 1237, 1238, 1240, 1241, 1243, 1245, 1248, 1250, 1252, 1253, 1254). Furthermore, two articles (9%) conducted research using random digit-dial telephone surveys (1236 & 1244). The other methods used included semi-structured in-depth interviews (1249), a retrospective cross-sectional study design (1246), focus groups (1242), and a basket survey (1232). Three studies, 13% (n=3), used a combination of research methods. One of the studies entailed a combination of secondary analysis and an online survey via email (1247) while another one involved secondary analysis and in-depth interviews (1251). The last one employed an online quasi-experimental pre/post test survey and in-depth qualitative interviews (1239).

Study Outcomes

Findings

The results of the studies evaluated in this systematic review all encompassed components of climate change, poverty, and health equity, but the specific findings of each of these studies varied widely. The most prominent theme in the literature related to how demographic characteristics affect the relationship between climate change, poverty, and health equity. The main demographic factors that appeared in the literature were education (1233, 1234, 1235, 1238, 1245, 1246, 1248, 1250, 1253), age (1233, 1234, 1243, 1245, 1249, 1250, 1253), race (1246, 1251, 1253), and gender (1241 & 1245).

Education level was mentioned in 39% (n=9) of the studies as a factor that has the ability to either hinder or promote resilience against climate change (1233, 1234, 1235, 1238, 1245, 1246, 1248, 1250, 1253). Article 1234 found that those with high levels of education had a lower risk of heat-related mortality. The findings of article 1238 indicate that an individual's education level modified the relationship between mortality and extreme temperatures, both hot and cold. In other words, low education levels resulted in a higher risk of morality from extreme temperatures (1238). Article 1253 determined that low levels of education exacerbate an individual's risk of cardiorespiratory mortality due to heat-related and cold-related burden. However, the results of article 1245 showed an interesting relationship between gender and education. This study discovered that males with primary education or more had a higher risk of mortality attributed to extreme temperatures, both hot and cold, than males without studies (1245). On the other hand, heat-related mortality did not differ between educational levels of

females but when it came to cold-related mortality, females without studies had higher risk of mortality than those with studies (1245).

The outcome of article 1248 suggests that individuals with a low literacy rate had a higher risk of hospitalization accredited to extreme heat. Article 1233 found that individuals with low levels of education were at a higher risk for both upper and lower respiratory infections related to daily temperature range. When examining adverse birth outcomes, article 1250 determined that mothers with low levels of education had a higher risk of preterm birth due to extreme heat.

Another study discovered that a large fraction of the greenhouse gas emitting facilities under California's cap-and-trade program are disproportionately located in neighborhoods with higher proportions of individuals with low educational levels (1235). In addition, article 1246 ascertained that low levels of education were associated with a greater exposure to urban heat.

When it comes to age, 30% (n=7) of the studies mentioned the influence of age on vulnerability towards climate change (1233, 1234, 1243, 1245, 1249, 1250, 1253). Out of these seven articles, six of them (86%) explicitly state that elderly individuals are a population that is extremely sensitive to the impacts of climate change (1233, 1234, 1243, 1245, 1249, 1253). Article 1234 determined that areas with a higher percentage of elderly population have an increased risk of heat-related mortality. Furthermore, the results of article 1253 indicate that areas with a higher percentage of elderly individuals had an elevated risk of cardiorespiratory mortality affiliated with both high and low temperatures. Article 1243 suggested that areas with a high percentage of elderly residents are associated with an inflated risk of mortality attributed to ozone concentration. One study identified age inequalities that exist within the relationship

between temperature and mortality (1245). This study discovered that, for men, cold-related mortality was highest among those aged 65 and older (1245). On the other hand, cold-related mortality for women was highest among individuals in the age group of 75-84 (1245). When it comes to heat-related mortality, men aged 75 and older displayed a significant risk of mortality while women of all age groups showed an amplified risk of heat-related mortality (1245). The age groups that exhibited the highest risk of heat-related mortality among women were ages 25 to 64 and those 85 and older (1245).

Article 1249 recognized elderly individuals as a group that is extremely susceptible to the health-related consequences of recurrent household flooding. Additionally, the findings of article 1233 revealed that older individuals had a higher risk for both upper and lower respiratory infections linked to daily temperature range. Lastly, article 1250 determined that pregnant women on either side of the age spectrum, both young and old, had an increased risk of preterm birth due to extreme heat.

The influence of racial and ethnic identity on the relationship between climate change, poverty, and health equity was a theme that appeared in 13% (n=3) of the studies (1246, 1251, 1253). One study investigated the relationship between racial segregation and exposure to urban heat (1246). This study discovered an inconsistent relationship between racial minority status and exposure to urban heat due to different social geographies (1246). However, this study did find that socioeconomic status was consistently and significantly associated with a disproportionate exposure to urban heat (1246). Article 1253 found that areas with a higher proportion of people of color had an inflated risk of cardiorespiratory mortality attributed to both high and low temperatures. Article 1251 focused on the states of Arizona and New Mexico,

which have a high population of racial minorities, and discovered that these areas are disproportionately burdened by heat-related illnesses due to rising temperatures.

Gender arose as an additional characteristic that altered the relationship between climate change, poverty, and health equity in 9% (n=2) of the studies (1241 & 1245). As previously mentioned, article 1245 determined that women had a higher risk of heat-related mortality compared to men. Although, the risk of cold-related mortality was similar among both men and women (1245). Article 1241 found a higher risk of displacement to a shelter after Hurricane Mitch for households headed by women.

The health-related impacts of disaster displacement were featured in 9% (n=2) of the studies (1236 & 1241). Article 1236 discovered that displacement due to natural disasters and extreme weather events has a negative impact on individuals mental health. Furthermore, article 1241 determined that being displaced to a shelter increases an individual's chance of contracting respiratory disease. These studies highlight the importance of reducing post-disaster housing instability.

In addition, 4% (n=1) of the studies evaluated communication materials regarding climate change (1239) and 26% (n=6) of the studies mentioned public alert systems for extreme weather events (1237, 1244, 1245, 1247, 1249, 1251). Article 1239 determined that framing climate change in a way that is relevant to vulnerable individuals immediate concerns not only increases their knowledge of the health effects of climate change but also their belief that climate change is occurring. When it comes to public alert systems, article 1237 determined that effective heat warnings that are tailored to specific groups and locations are needed to reduce the adverse consequences of extreme heat. Additionally, article 1244 suggests that low-income individuals

are less likely to be aware of heat warnings which highlights the need for improved and tailored public alert systems. On the other hand, the outcome of article 1245 illustrates the need for early warning systems for extreme cold weather that are similar to existing warnings for heat. One article calls attention to the need for improved flood warning systems to help individuals prepare for an upcoming flood event (1249). An additional article found that lack of public awareness increases the harmful climate-related consequences on human health and well-being (1247). Lastly, article 1251 highlights the importance of tailored public alert systems that are both culturally appropriate and available in multiple languages.

The analysis of the impact of climate change on urban and rural areas was a subject that was present in 30% (n=7) of the studies (1234, 1240, 1243, 1246, 1248, 1252, 1253). Article 1234 discovered a higher risk of heat-related mortality in rural areas compared to urban areas. On the other hand, article 1243 discovered a similar impact of heat-related mortality on both urban and rural areas. However, this study also found that rural areas had an increased risk of heat-related mortality linked to an increase in ozone concentration (1243). Article 1253 determined that highly urbanized areas had a greater burden of cardiorespiratory mortality attributed to both high and low temperatures. Article 1246 examined urban heat exposure and found that individuals with low income and low levels of education were more likely to be exposed to urban heat. Article 1240 ascertained that spatial disparities in accessibility to healthcare facilities are more prevalent for rural residents compared to urban residents. This study determined that excessive flooding will disrupt transportation networks which will exacerbate rural residents' lack of access to healthcare facilities (1240). The results of article

1252 illustrate that urban areas' resilience to climate change differs depending on specific geographic and socioeconomic characteristics.

Furthermore, article 1248 found that amplified population density resulted in a higher risk of hospitalization due to extreme heat. Article 1243 discovered that high population density was associated with elevated risk of mortality due to high temperatures.

The topic of health services and the accessibility of healthcare facilities appeared in 9% (n=2) of the studies (1234 & 1240). Article 1234 ascertained that insufficient hospital infrastructure was associated with a higher risk of heat-related mortality in rural areas. In addition, article 1240 showed that climate change will aggravate low income individuals' lack of access to healthcare facilities due to the disruption of transportation networks.

The prevalence of air conditioning was discussed in 13% (n=3) of the studies (1234, 1237, 1244). Article 1234 discovered that the prevalence of air conditioning resulted in a lower risk of heat-related mortality. Similarly, the findings of article 1237 revealed that lack of air conditioning amplified the risk of heat-related morbidity and that the ownership of air conditioning varied by income, homeownership, and race. Lastly, article 1244 determined that access to air conditioning partially explained disparities in health outcomes affiliated with heat. More importantly, this study also found that air conditioning ownership was associated with race and income (1244).

The overarching theme of these articles is that certain areas and certain groups have unique vulnerabilities to climate change that require specific tailored solutions. There is no one-size fits all solution for climate change and the solution depends on the interaction of specific vulnerabilities.

The concept of multi-layered vulnerabilities was explicitly present in 65% (n=15) of the articles (1233, 1235, 1236, 1237, 1238, 1239, 1240, 1241, 1244, 1245, 1249, 1250, 1251, 1252, 1253). The conclusions of articles 1241 and 1250 highlight how individual-level factors and community-level factors interact and influence susceptibility to the adverse impacts of climate change. Article 1233 discovered that the interaction of low socioeconomic status, low education, old age, poor living conditions, and lack of sanitary services exacerbate climate change vulnerability. Article 1252 ascertained that individuals who have low income and live in low lying areas with weak housing conditions and poor sanitation are at a higher risk of experiencing the harmful consequences of climate change. Articles 1244 and 1251 highlight the interaction of race and socioeconomic status on susceptibility to climate change. The results of article 1235 show that people of color who have low socioeconomic status, low educational levels, and are linguistically isolated are more subject to the adverse consequences of climate change. Article 1236 found that African American single mothers with low income were negatively impacted by Hurricane Katrina. Article 1237 discovered that the interaction of location, race, and socioeconomic status affect an individual's sensitivity to climate change. As previously mentioned, the findings of article 1245 show that gender, education, and age contribute to the relationship between mortality and climate change, specifically extreme temperatures. Article 1238 determined that age, sex, place of death, cause of death, and education level modify an individuals susceptibility to the harmful consequences of climate change. The outcome of article 1253 shows that the interaction of poverty, unemployment, low education, and highly urbanized areas result in higher susceptibility to climate change. Article 1240 ascertained that individuals who have low income, are uninsured, and live in rural areas have a higher chance of being

unable to access healthcare facilities due to the disruption of transportation networks by climate change. The conclusion of article 1239 illustrates that individuals with a chronic health condition and low socioeconomic status are more likely to be negatively impacted by climate change. Article 1249 indicates that increased social stressors and environmental exposures in addition to lack of social support decrease an individual's adaptive capacity and increase their vulnerability.

Furthermore, there were a few other overarching themes that emerged in the literature. First, the concept that disadvantaged individuals have a harder time adjusting and adapting to climate change appeared in 30% (n=7) of the studies (1232, 1244, 1247, 1249, 1251, 1252, 1254). Second, the claim that lack of sanitary services increases risk of poor health outcomes linked to climate change was present in 17% (n=4) of the literature (1233, 1241, 1249, 1252). Lastly, recognition of the fact that actions to mitigate climate change do not impact everyone equally arose in 13% (n=3) of the studies (1235, 1252, 1254).

Journal Characteristics

The studies came from a variety of journals. There were 20 different journals that appeared in this systematic review of the literature. A theme that became apparent in the journal characteristics was health. There were three articles (13%) from the International Journal of Environmental Research and Public Health (1244, 1247, 1249) which is a journal in the healthcare discipline. There were three articles (13%) that are considered in the domain of public health from the journals BMC (BioMed Central) Public Health (1239), the Australian and New Zealand Journal of Public Health (1232), and the International Journal of Public Health (1245).

Lastly, there were two articles (9%) in the discipline of medicine from the journals PLoS Medicine (1235) and BMJ (British Medical Journal) Open (1238).

There were four journals present in this literature review that primarily focused on sociological characteristics. There were two articles (9%) from the Local Environment: The International Journal of Justice and Sustainability (1246 & 1251) which is a journal in the urban studies domain. There were two articles (9%) in the social science domain, one from the journal entitled Cities: The International Journal of Urban Policy and Planning (1240) and the other from the Social Science and Medicine journal (1236). There was one article (4%) in the sociology domain from the journal Habitat International (1252).

In addition, there were three journals that encompassed either environmental science, social science, or a combination of both. There was one article (4%) from a journal called Environmental Pollution (1233) which is presumed to be in the domain of environmental science. Also, there was one article (4%) in the domain of environmental and social science from the journal titled Population and Environment (1241). Lastly, there was one article (4%) from the domain of ecology from Environmental Science and Pollution Research (1253).

The rest of the journals were deemed to be multidisciplinary (22%, n=5), transdisciplinary (4%, n=1), and interdisciplinary (4%, n=1). The multidisciplinary journals included Environmental Health Perspectives (1234), Public Health Ethics (1242), Environmental Health (1243), Environmental International (1248), and Environmental Research (1250). The journal of Environmental Health Perspectives contains topics such as experimental toxicology, epidemiology, exposure science, and risk assessment. The journal of Public Health Ethics covers topics relating to public health and bioethics. Environmental Health involves topics such as

environmental health and occupational medicine. The journals called Environmental International and Environmental Research cover topics such as environmental science and environmental health. There was one journal (4%) that is presumed to be transdisciplinary, which was the journal of GeoHealth (1237). The journal of GeoHealth integrates perspectives from health sciences and environmental sciences in relation to the Earth as a whole. Plus, there was one journal (4%) that is regarded as interdisciplinary called Physics and Chemistry of the Earth (1254) which covers topics such as geodesy, hydrology, oceanography, atmospheric science, solar-terrestrial science, and planetary science.

Author Affiliation

When considering the authors who published these studies, there was a wide variation in the schools, departments, and organizations in which these authors were affiliated with. Out of the 120 different authors who worked on these articles, there were five universities that appeared in at least two or more articles. Furthermore, there were only three repeated authors, Patrick L. Kinney (1234 & 1243), Jaime Madrigano (1243 & 1244), and Michelle L. Bell (1243 & 1250), who are each featured on two different articles.

Columbia University was the most prominent university and appeared in 17% (n=4) of the studies (1234, 1236, 1243, 1244). Articles 1234, 1236, and 1243 had authors that came from the Mailman School of Public Health at Columbia University in New York. Although most of these authors differed by department. Two authors from article 1234, Kai Chen and Patrick L. Kinney, are from the Department of Environmental Health Sciences, specifically the program in climate and health. Additionally, two authors from article 1243 are also from the Department of

Environmental Health Sciences at Columbia University, one of them being Patrick L. Kinney again and the other being Darby Jack. There was one author from the Epidemiology Department at Columbia University in article 1236 named Sarah R. Lowe. Lastly, article 1244 had one author from the Earth Institute at Columbia University named Nada Petrovic.

The remaining four universities were featured in two different articles each. The University of California, Berkeley (9%, n=2) had four authors from article 1235 and two authors from article 1240. The authors from article 1235 are from the Department of Environmental Science, Policy and Management, the School of Public Health, the Goldman School of Public Policy, and the Department of Electrical Engineering and Computer Sciences. Laura Cushing, the main author of article 1235, is from the Department of Environmental Science, Policy, and Management. Plus, Rachel Morello-Frosch is from both the School of Public Health and the Department of Environmental Science, Policy, and Management (1235). In addition, Dan Blaustein-Rejto is from the Goldman School of Public Policy and Allen Zhu is from the Department of Electrical Engineering and Computer Sciences (1235). However, the two authors from article 1240, Wei Lang and John D. Radke, are from the Department of City and Regional Planning in the College of Environmental Design.

The University of Utah (9%, n=2) had one author from article 1241 and one author from article 1252. The author from article 1241, Kim Korinek, is from the Department of Sociology while the author from article 1252, Dennis Yehua Wei, is from the Department of Geography.

Yale University (9%, n=2) had one author from article 1243 and two authors from article 1250. The author from article 1243, Michelle L. Bell, is from the School of Forestry and

Environmental Studies. Michelle L. Bell is also an author on article 1250. The other author from article 1250, Ji-Young Son, is also from the School of Forestry and Environmental Studies.

Lastly, the University of Chinese Academy of Sciences and the Chinese Academy of Sciences (CAS) appeared in two articles (9%) (1252 & 1254). These institutions are related, but separate entities. The Chinese Academy of Sciences is a research institution while the University of Chinese Academy of Sciences is a public university that is under direct leadership of the CAS. There were three authors from article 1252 who are from the Chinese Academy of Sciences. Two of these authors, Komali Yenneti and Gaurav Joshi, are from the Nanjing Institute of Geography and Limnology while the last author, Wen Chen, is from the Key Laboratory of Watershed Geographic Sciences within the Nanjing Institute of Geography and Limnology. Lastly, Gaurav Joshi is also from the University of Chinese Academy of Sciences. Furthermore, article 1254 had one author, Zhihui Lu, who is from the Center for Chinese Agricultural Policy and the Institute of Geographic Sciences and Natural Resources within the Chinese Academy of Sciences. In addition, Zhihui Lu is from the University of Chinese Academy of Sciences as well.

Funding

The funding for these research projects came from a wide variety of sources, although there were a few sources that financed multiple projects. The United States Environmental Protection Agency (EPA) supplied financial support for three studies (13%) through grants, including article 1233, 1243, and 1250. However, the funding for article 1250 was actually provided to Yale University from the United States EPA. The National Oceanic and Atmospheric Association (NOAA) supplied finances for three studies (13%) (1237, 1243, 1251). Article 1237

was supplied funding through the Coastal and Ocean Climate Applications (COCA) program and also through the Regional Integrated Sciences and Assessments (RISA) program via the California and Nevada Applications program grant. In addition, article 1251 was provided financial support through a grant given to the Climate Assessment for the Southwest program at the University of Arizona by the NOAA Climate Program Office. The Climate Assessment for the Southwest program is a part of the United States Global Change Research Program's National Climate Assessment.

The National Institutes of Health (NIH) supplied funding for three research projects (13%) (1234, 1236, 1250). However, the funding for article 1250 came from the National Institute on Minority Health and Health Disparities, which is a part of the NIH. Lastly, there were two studies (9%) that received financial support from the United States National Institute of Environmental Health Sciences (NIEHS) (1234 & 1243).

The National Science Foundation (NSF) contributed funding for two studies (9%) (1236 & 1237), although article 1237 was provided financial support through the Climate Education Partners which receives funds from the NSF. Additionally, there were two studies (9%) that were funded by the National Natural Science Foundation of China (1234 & 1252).

Lastly, there were two studies (9%) that received financial support from Columbia University (1243 & 1244). Article 1243 was supplied funding through the Earth Institute Postdoctoral Fellows program at Columbia University and article 1244 obtained financial support from the Cross-Cutting Initiative at the Earth Institute of Columbia University. Moreover, there were four studies (17%) that did not mention their source of funding (1241, 1246, 1247, 1253).

DISCUSSION

This systematic review of the current academic literature on climate change, poverty, and health equity sheds light on many interesting themes and connections between these topics. As the impact of climate change continues to escalate, this information is pertinent to increasing individuals adaptive capacity and creating resilient communities, especially for those most vulnerable.

Study Setting and Participants

Location

The studies included in this systematic review were fairly evenly distributed across the timeframe of this analysis. Most of the studies were published in the year 2016, with the years 2018 and 2019 following closely behind. A possible explanation for the bulk of the studies being published in 2016 and beyond, minus the year 2017, is that in 2015 the Paris Climate Agreement was in its beginning stages (United Nations Framework Convention on Climate Change (UNFCCC) 2020). The Paris Climate Agreement is a global treaty created to combat the adverse impacts of climate change and its primary goal is to prevent the global temperature from rising two degrees celsius above the recorded temperature of pre-industrial times (UNFCCC 2020). Considering that 2016, 2018, and 2019 were the years with the most studies published it is inconsistent that only one study was published in the year 2017. However, this could be explained by the lag that occurs between conducting research and publication of that research. The Paris Climate Agreement was officially enacted on November 4th, 2016 (UNFCCC 2020),

which may help explain why there was only one study published in 2017. The Paris Climate Agreement may have sparked a pressing need for more research regarding the adverse ramifications of climate change and it is possible that a large portion of the research was actually conducted in 2017 but published in 2018 and 2019.

The location in which these studies occurred differed significantly, as did the socioeconomic composition of these locations. A large portion of the studies took place in the United States with California being the most numerous location. China was another leading location, although it did not have as large of a presence as the United States. Consistent with current research, a majority of the locations in this systematic review of the literature were developing nations. This is expected because developing nations will face the brunt of the impact of climate change due to their low adaptive capacity, even though they are least responsible for the carbon dioxide emissions that caused this catastrophe (Mertz et al. 2009). Therefore, we would expect to see a large number of research studies conducted in developing nations. Out of the 27 countries that were covered in the research, there were only three developed nations (Australia, Spain, and the United States) and twenty-four developing nations (Argentina, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Ecuador, El Salvador, Grenada, Guatemala, Honduras, India, Korea, Mexico, Nicaragua, Panama, Paraguay, Peru, Senegal, Trinidad & Tobago, Uruguay, Venezuela, and Vietnam). The classifications for these countries is based on the 2019 World Economic Situation and Prospects from the United Nations (2019). It is important to note that the studies were relatively evenly dispersed between developed and developing nations, even though there were more developing countries within those studies. For

instance, there were thirteen studies conducted in developed countries, a majority of them within the United States, and ten studies conducted in developing countries.

In regards to climate change, it is important to study a variety of locations because each location is unique in their susceptibility and sensitivity to the changing climate. For instance, some locations may experience more rainfall while others may experience extreme heat and some may experience both, which is why it is important to consider the context of that location and the people who reside there when determining the best course of action to mitigate the impact of climate change.

Sample Characteristics

The studies were similar in that they each encompassed a component of poverty or low socioeconomic status, but the specific population of the studies varied. A theme that emerged in the literature was the use of hospital data to create samples. There were seven studies that used hospital or medical data to conduct their research. Multiple studies used hospital patients to compose their sample while a few studies utilized mortality registries to gather data for a sample. Plus, there were a few studies that involved qualitative data from health-care providers. This large number of studies that used hospital or medical data to create samples was expected due to the health equity component of this literature review. For example, the search syntax included words such as health equity, health inequality, health inequity, systematic disparity, health disparities, and social inequalities in health.

Another topic that was distinguishable in the literature was the study of urban and rural areas. There were seven studies that included a discussion of urban and rural areas relative to the

impact of climate change on health. It is important to examine the differential impact that climate change has on urban and rural areas in order to create tailored preventative and response actions. Urban and rural areas experience dissimilar repercussions of climate change because of differences in temperature, population density, evaporation rate, and rainwater surface runoff (Zeleňáková et al. 2015). Urban areas generally have a higher population density, less evaporation, increased temperature, and more rainwater surface runoff (Zeleňáková et al. 2015). The latter of the three (less evaporation, increased temperature, and more rainwater surface runoff) can be attributed to the structural characteristics of urban areas such as abundant concrete sidewalks and parking lots (Zeleňáková et al. 2015). Furthermore, a phenomenon known as the urban heat island effect is a result of the structural characteristics and human activities of urban communities (Yang et al. 2015). The urban heat island (UHI) effect is characterized by an accumulation of heat in urban areas attributed to less vegetation coverage, increased conductive surface areas (such as concrete, asphalt, etc.), lower prevalence of bodies of water, population density, and human activities (Yang et al. 2015). However, this systematic review of the literature revealed some interesting findings pertaining to rural areas. Article 1234 discovered a higher risk of heat-related mortality in rural areas compared to urban areas. On the other hand, article 1243 discovered a similar impact of heat-related mortality on both urban and rural areas. However, article 1243 also found that rural areas had an increased risk of heat-related mortality linked to an increase in ozone concentration. In addition, article 1240 ascertained that spatial disparities in accessibility to healthcare facilities are more prevalent for rural residents compared to urban residents. This study determined that excessive flooding will disrupt transportation networks which will exacerbate rural residents' lack of access to healthcare facilities (1240). Therefore, it

is impossible to determine whether rural or urban areas will be more adversely impacted by climate change because the repercussions of climate change depend on the specific context of the location and the individuals within that area.

Lastly, disadvantaged individuals composed multiple study samples including individuals with chronic health conditions, pregnant women, single mothers, and people of color. There were four studies that explicitly included individuals with disadvantaged characteristics in addition to low socioeconomic status. The appearance of disadvantaged individuals in the literature can be attributed to the inclusion of certain words in the search syntax such as vulnerable, disadvantaged, social justice, human rights, systematic disparities, systematic disadvantage, social disadvantage, and social inequalities in health.

Disadvantaged individuals already have a low adaptive capacity which is further exacerbated by low socioeconomic status. When these factors are combined with the increasing threat of climate change, it can have a negative and disproportionate impact on their health and well-being. Previous research has shown that an individual's susceptibility to the impacts of climate change stems from a combination of vulnerability and adaptive capacity (Smit and Wandel 2006). Individuals with multiple intersecting disadvantaged characteristics consequently have higher vulnerability and lower adaptive capacity, which is a dangerous combination. In addition to individual adaptive capacity and vulnerability, there is also the larger-scale community level vulnerability and adaptive capacity (Smit and Wandel 2006). A community's adaptive capacity and vulnerability can be influenced by external forces such as economic, political, and social forces within the community and beyond (Smit and Wandel 2006). In order to combat the repercussions of climate change, local initiatives should be enacted to enhance

both the community's adaptive capacity as well as the adaptive capacity of the individuals within that community simultaneously.

Study Design

Climate Change Issue

The most common climate change issue analyzed in these studies was extreme temperatures. There were eleven studies that explored the impact of extreme temperatures on health. A majority of the studies concentrated on extreme heat rather than extreme cold, but a few studies examined the burden of both. It is vital that more studies be conducted on the impact of extreme cold. There were no studies that explicitly focused on extreme cold, alternatively, there were three studies that examined both extreme heat and extreme cold. As previously mentioned, climate change is context dependent and some areas may experience extreme cold rather than extreme heat, potentially even both, which highlights the importance of understanding the health impacts of both extreme cold and extreme heat equally.

Another topic that came up in numerous studies was natural disasters and environmental conditions, such as hurricanes, flooding, air pollution, and more. There were four articles that specifically mentioned natural disasters in the literature, two of them involved flooding while the other two discussed Hurricane Katrina and Hurricane Mitch, respectively. In addition there were three articles that analyzed extreme weather events and environmental conditions more broadly. Furthermore, there were five studies that looked at climate change on a broader scale that contained multiple components such as social vulnerability and greenhouse gas emissions.

As previously mentioned, disadvantaged individuals, such as individuals with low socioeconomic status, have a lower adaptive capacity and potentially higher vulnerability to the adverse impacts of climate change (Smit and Wandel 2006). Low income individuals have a higher vulnerability to extreme temperatures and natural disasters due to poor housing conditions, lack of proper protective clothing, minimal resources, and lack of amenities such as air conditioning. For instance, there were three studies (1234, 1237, 1244) that examined the prevalence of air conditioning and determined that lack of air conditioning can exacerbate heat-related mortality and morbidity. Furthermore, these studies found that ownership of air conditioning varied by income and race, specifically that low income individuals and racial minorities had a lower prevalence of air conditioning ownership. These findings illustrate that climate change will not impact everyone equally due to differing adaptive capacities and specific individual and community characteristics.

Health Issue

The health issue that appeared most frequently in the literature was mortality. There were five articles that specifically discussed mortality related to climate change. Some articles addressed mortality in general while others focused on specific types of mortality such as heat-related mortality, cardiovascular mortality, respiratory mortality, and cardiorespiratory mortality. It is vital to investigate mortality attributed to climate change, but it is just as important to study morbidity from climate change as well. There were ten studies that stressed the negative impact that climate change can have on the prevalence of morbidity. For instance, a concept that was prevalent in the literature was the analysis of hospitalization data. There were three studies

that examined hospitalizations and these studies included data on hospitalizations from cardiovascular diseases, respiratory diseases, infectious/parasitic diseases, heat illness, dehydration, and acute renal failure. A few other health issues mentioned in the literature included adverse birth outcomes, communicable diseases, and chronic health issues.

Additionally, the literature contained research on the subjects of food security, accessibility of healthcare facilities, safe drinking water, and sanitation services. There were four articles that addressed multiple health outcomes within one study. There was only one article that concentrated solely on mental health and one article that briefly mentioned anxiety and depression. Climate change has the ability to impact mental health both directly and indirectly (Berry, Bowen, and Kjellstrom 2010). Climate change can influence mental health directly through natural disasters and other traumatic events (Berry et al. 2010). Furthermore, climate change can impact an individual's mental health indirectly through physical health and community well-being (Berry et al. 2010). In addition, climate change has the ability to negatively impact food, air, and water which are essential components of human health and well-being (WHO 2008). Therefore, it is essential to study the ramifications that climate change can have on both physical health and mental health.

Research Methodology

A large portion of the research involved secondary analysis of publicly available data from sources such as the National Center for Health Statistics, National Statistics Office, National Center for Disease Control and Prevention, the census, hospital records, mortality records, meteorological stations, and more. Secondary analysis is an appealing research method

due to its low cost and small time commitment compared to other research methods (Cheng & Phillips 2014). Nevertheless, secondary analysis has its drawbacks. These disadvantages include the fact that the data was originally collected for a different purpose and may be missing important variables or populations of interest (Cheng & Phillips 2014). In addition, certain information in publicly available data may be deleted to protect the confidentiality of the sample which further exacerbates the problem of missing variables and limits the researchers interpretation of the data (Cheng & Phillips 2014). Lastly, the researchers who analyze secondary data may not be aware of specific nuances of the study which further complicates the researchers interpretation of the data (Cheng & Phillips 2014).

The different research methods that came up in the literature besides secondary analysis included focus groups, phone surveys, and basket surveys. Furthermore, three articles used a combination of research methods such as secondary analysis, online surveys, and in-depth interviews. In order to improve our understanding of how context influences the interaction between climate change, poverty, and health, future research should focus on utilizing qualitative research methods such as in-depth interviews and focus groups. Qualitative research methods provide a better understanding of the context dependent nature of the relationship between climate change, poverty, and health because it allows researchers to investigate the interaction of multiple community-level and individual-level characteristics.

Study Outcomes

Findings

The specific findings of these studies varied widely, but the overarching theme of these articles is that certain areas and certain groups have unique vulnerabilities to climate change that require specific tailored solutions. There is no one-size fits all solution for climate change and the solution depends on the interaction of specific vulnerabilities.

Some individuals have multi-layered vulnerabilities that influence their susceptibility and adaptive capacity towards climate change. In addition, individual-level characteristics and community-level characteristics can interact and influence vulnerability and adaptive capacity. Some characteristics mentioned in the literature included socioeconomic status (unemployment, insurance status), education (literacy rate), age, race, gender, living conditions, sanitary services, geography (low lying areas, urban, rural), urbanization, and chronic health conditions. The interaction of multiple characteristics may lead to increased social stress and environmental exposures, which increases vulnerability and decreases adaptive capacity.

As previously mentioned, low socioeconomic status results in low adaptive capacity due to lack of resources, poor living conditions, and lack of sanitary services. Additionally, individuals who live in low lying areas or have weak housing structure may be more vulnerable to climate change. Individuals with more education seem to have a greater adaptive capacity towards climate change. However, article 1245 found that men with primary education or more had a higher vulnerability to extreme cold temperatures than men without studies. Although, this study was conducted in Spain and the authors attributed this finding to the fact that men with higher socioeconomic status had a higher prevalence of smoking in the earliest stages of the tobacco epidemic, which may have resulted in an increased vulnerability to cold for men with higher education (Marí-Dell'Olmo et al. 2019). In agreement with previous research, multiple

studies in the literature cited elderly individuals as a population that is extremely susceptible to the adverse impacts of climate change. In addition, people of color or individuals with chronic health conditions may be more vulnerable to climate change due to their already disadvantaged position which is further exacerbated by low income and as a result lowers their adaptive capacity towards climate change and other stressors.

Another theme that was clear in the literature was the interaction of gender, age, and education. These core demographic characteristics, along with race, interact and influence adaptive capacity and vulnerability to climate change. Furthermore, there were a few other overarching themes that emerged in the literature. First, the concept that disadvantaged individuals have a harder time adjusting and adapting to climate change. Second, lack of sanitary services increases risk of poor health outcomes linked to climate change. Lastly, it is important to recognize that actions to mitigate climate change do not impact everyone equally. These studies demonstrate that health and socioeconomic status have the ability to influence an individual's adaptive capacity and vulnerability towards climate change.

Journal Characteristics

The journal disciplines that appeared in the literature included public health, healthcare, medicine, social science, urban studies, sociology, ecology, and environmental science. The disciplines of public health and healthcare produced the most publications among the articles incorporated in this systematic review of the literature. This was expected as the search syntax included words such as social determinants of health, health equity, health inequality, health inequity, health disparities, and social inequalities in health. There were three journals from the

discipline of public health which included BMC Public Health, the Australian and New Zealand Journal of Public Health, and the International Journal of Public Health. While the journal with the greatest number of publications was the International Journal of Environmental Research and Public Health from the healthcare discipline. There were also various multidisciplinary, transdisciplinary, and interdisciplinary journals as well. This array of disciplines attest to the multifaceted and complex nature of the relationship between climate change, poverty, and health equity.

Author Affiliation

There was a significant degree of variation among the authors that appeared in this systematic review of the literature. There were 120 different authors that contributed to these articles and there were five universities or institutions that were featured in at least two different articles. Additionally, there were only three repeated authors, including Patrick L. Kinney, Jaime Madrigano, and Michelle L. Bell, who appeared in two different articles each. The variability of authors who contributed to the literature highlights the multidisciplinary nature of this work.

Funding

The funding for these research projects came from a vast assortment of institutions and organizations. There were only seven institutions or organizations that funded more than one study. The United States Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Association (NOAA), and the National Institutes of Health (NIH) each funded three research projects. Additionally, the United States National Institute of Environmental

Health Sciences (NIEHS), the National Science Foundation (NSF), the National Natural Science Foundation of China, and Columbia University each supplied financial support for two studies. However, there were four studies that did not mention their source of funding. The remainder of the funding sources were from an extensive array of institutions and organizations.

Recommendations for Future Research

It is evident from this systematic review of the literature that more research is required to fully understand the relationship between climate change, poverty, and health equity. This paper provides a foundation on which to begin to understand the interaction of climate change, poverty, and health but more research is needed to define this relationship and determine a course of action to alleviate disparities based on the specific context of the situation.

Future research should consider using qualitative research methods such as in-depth interviews and focus groups in order to better understand how context influences the relationship between climate change, poverty, and health equity. Another topic that warrants further investigation is the impact of extreme cold on health, especially individuals with low income. There was abundant research on the health-related consequences of extreme heat but few studies discussed the health-related impact of extreme cold. Furthermore, there is a need for more research on the mental health impacts of climate change, especially disaster displacement and extreme weather events. Also, there have been ample studies on the consequences of climate change for elderly individuals yet none of the literature in this systematic review focused on children or adolescents. Children may be a harder population to study due to the Institutional Review Board (IRB) additional protections and specifications for research involving children

(HHS 2020). Regardless of the laborious nature of studying children and adolescents, this is an important population to study due to their extended exposure to the adverse impact of climate change.

In addition, there have been multiple studies that explore the process of measuring a community's adaptive capacity and vulnerability. However, more studies need to put that research into action and determine how to improve adaptive capacity and reduce vulnerability on both the individual and the community level.

Limitations

There are limitations to this systematic review of the literature that must be acknowledged. First, the process of selection, exclusion, coding, and writing were all conducted by one individual, the author, which leaves the data to be interpreted under the author's subjective opinion and eliminates the opportunity for data to be collectively evaluated by multiple viewpoints. Additionally, the coding process is extensive and time consuming, especially for one person with limited time. The organization and cleanliness of the coding process could have been improved by including multiple coders to help with the workload. Second, the classification of journal disciplines is solely based on the author's subjective point of view. Therefore, there is the possibility of misclassification based on the author's limited knowledge of academic journal disciplines. Third, the search syntax could have been improved by including input from a more experienced researcher. This was the first time the author had written a search syntax which may have resulted in a subpar search syntax that omitted important keywords and as a result, valuable research articles could have been excluded. Lastly, this

systematic review could have been improved by including a citation network analysis but time limitations prevented this analysis from being conducted.

CONCLUSION

Disadvantaged individuals already have a low adaptive capacity which is further exacerbated by low socioeconomic status in addition to other individual and community level characteristics. When these factors are combined with the increasing threat of climate change, it can have a negative and disproportionate impact on their health and well-being. This systematic review of the literature has helped illustrate the circular relationship between climate change, poverty, and health. For instance, an individual with low socioeconomic status may have difficulties maintaining health due to lack of resources, or vice versa, and climate change has the ability to exacerbate both financial resources and health issues. In addition, the prevalence of health issues or lack of financial resources further limits an individual's adaptive capacity towards climate change. This cycle will continue unless action is taken to assist individuals and communities in improving their adaptive capacity in conjunction with helping to alleviate the impact of climate change.

Climate change has the ability to negatively impact food, air, and water which are essential components of human health and well-being (WHO 2008). In addition, climate change has the ability to impact mental health both directly and indirectly (Berry, Bowen, and Kjellstrom 2010). Climate change can influence mental health directly through natural disasters and other traumatic events (Berry et al. 2010). Furthermore, climate change can impact an individual's mental health indirectly through physical health and community well-being (Berry et al. 2010).

Therefore, it is essential to study the ramifications that climate change can have on both physical health and mental health.

Previous research has shown that an individual's susceptibility to the impacts of climate change stems from a combination of vulnerability and adaptive capacity (Smit and Wandel 2006). In addition to individual adaptive capacity and vulnerability, there is also the larger scale community-level vulnerability and adaptive capacity (Smit and Wandel 2006). A community's adaptive capacity and vulnerability can be influenced by external forces such as economic, political, and social forces within the community and beyond (Smit and Wandel 2006). In order to combat the repercussions of climate change, local initiatives should be enacted to enhance both the community's adaptive capacity as well as the adaptive capacity of the individuals within that community simultaneously.

Disadvantaged individuals, such as individuals with low socioeconomic status, have a lower adaptive capacity and higher vulnerability to the adverse impacts of climate change (Smit and Wandel 2006). Low income individuals have a higher vulnerability to extreme temperatures and natural disasters due to poor housing conditions, lack of proper protective clothing, minimal resources, and lack of amenities such as air conditioning. In addition, individuals with multiple intersecting disadvantaged characteristics consequently have higher vulnerability and lower adaptive capacity, which is a dangerous combination. These findings illustrate that climate change will not impact everyone equally due to differing adaptive capacities and specific individual-level and community-level characteristics. It is essential to consider the specific context of that location and the people who reside there when determining the best course of action to mitigate the impact of climate change.

In order to improve our understanding of how context influences the interaction between climate change, poverty, and health, future research should focus on utilizing qualitative research methods such as in-depth interviews and focus groups. Qualitative research methods provide a better understanding of the context dependent nature of the relationship between climate change, poverty, and health because it allows researchers to investigate the interaction of multiple community-level and individual-level characteristics. Additionally, this systematic review of the literature revealed that there is no uniform measurement of poverty. In the future, researchers should attempt to agree on a uniform measurement of poverty in order to simplify the comparison of different studies. Furthermore, future studies should investigate ways to improve adaptive capacity. There has been plenty of research on how to measure adaptive capacity, yet few studies have actually looked into actions that can improve the adaptive capacity of both individuals and communities.

This systematic review of the academic literature on anthropogenic climate change, poverty, and health equity illustrates the complex and multifaceted nature of this issue. The overarching theme of these articles is that certain areas and certain groups have unique vulnerabilities to climate change that require specific tailored solutions. There is no one-size fits all solution for climate change and the solution depends on the interaction of specific vulnerabilities. Therefore, more research is needed to explore the interaction of multiple characteristics in order to determine the best course of action to mitigate climate change based on specific geographical, community, and individual-level factors. The impact of climate change is highly dependent on context, therefore, it is critical to study a wide variety of locations in order

to better understand the distinctive impact that climate change has on certain combinations of location and population characteristics.

APPENDIX

Tables and Figures

Figure 1: Systematic Review Process Flow Diagram

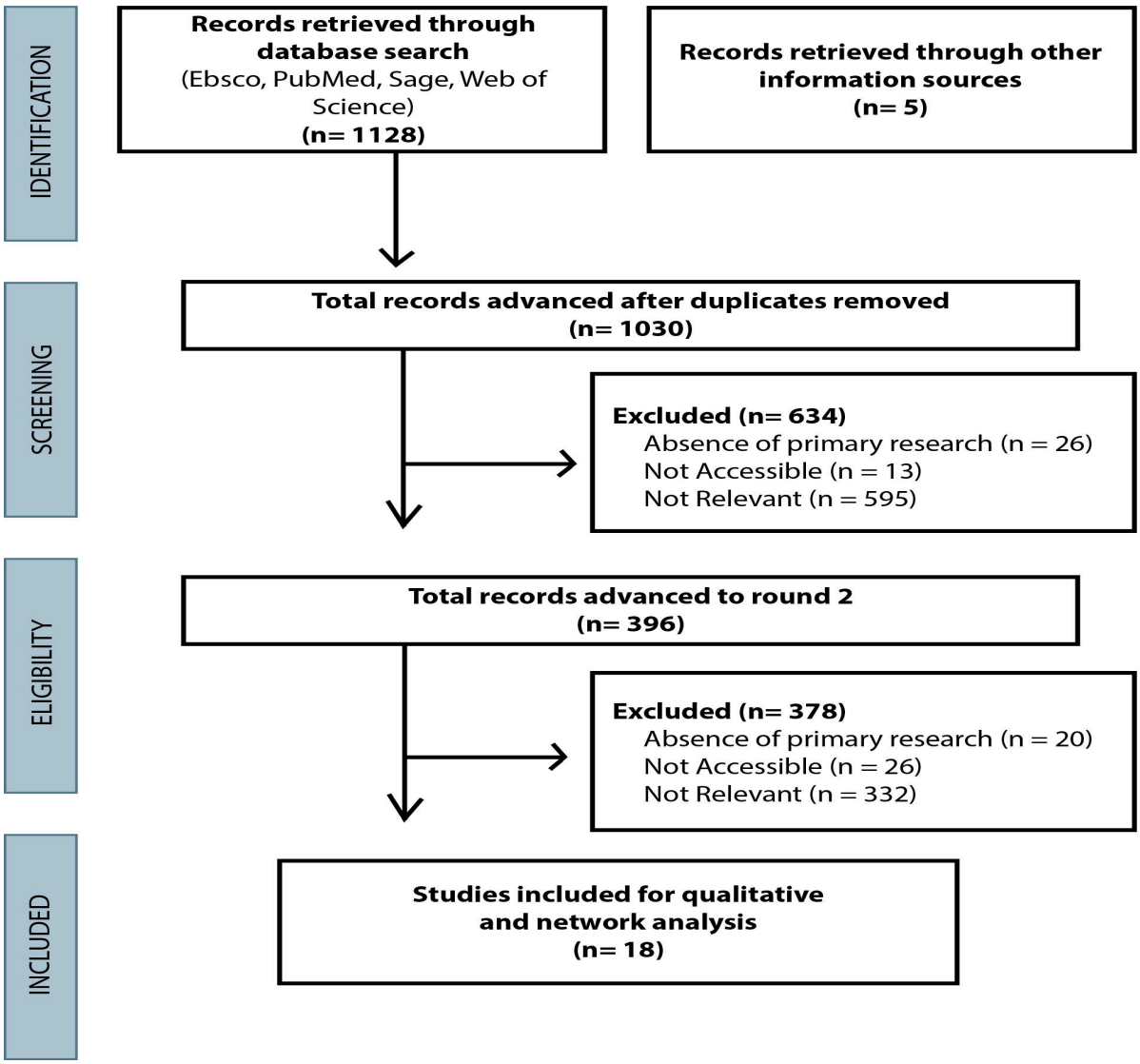


Figure 2: Coding Template

Publication Details		
Authors		
Author1	AU1:	
Institution1	IN1:	
Author2	AU2:	
Institution2	IN2:	
AuthorLast	AUL:	
InstitutionLast	INL:	
Article		
Title	TT:	
Keyword	KW1:	
Keyword	KW2:	
Keyword	KW3:	
Keyword	KW4:	
Keyword	KW5:	
Keyword	KW6:	
Keyword	KW7:	
Journal		
Journal Name	JN:	
Journal Type	JT:	
Volume Number	VN:	
Issue	IS:	
Pages	PP:	

Year	YR:	
Study Design		
Location	LC:	
Climate Change Issue	CI:	
Health Issue	HI:	
Sample Size	SP:	
Sample Characteristics	SC:	
Target Population	TP:	
Research Methodology	RM:	
Findings	FN:	
Funding Source	FS:	

Table 1: Twenty-Three articles and their corresponding reference numbers

Article	Reference number
Barosh, Laurel, Sharon Friel, Katrin Engelhardt, and Lilian Chan. 2014. "The Cost of a Healthy and Sustainable Diet - Who Can Afford It?" *Australian and New Zealand Journal of Public Health* 38(1):7–12.	[1232]
Carreras, Hebe, Antonella Zanobetti, and Petros Koutrakis. 2015. "Effect of Daily Temperature Range on Respiratory Health in Argentina and Its Modification by Impaired Socio-Economic Conditions and PM10 Exposures." *Environmental Pollution* 206:175–82.	[1233]
Chen, Kai et al. 2016. "Urbanization Level and Vulnerability to Heat-Related Mortality in Jiangsu Province, China." *Environmental Health Perspectives* 124(12):1863–69.	[1234]

Cushing, Lara et al. 2018. “Carbon Trading, Co-Pollutants, and Environmental Equity: Evidence from California’s Cap-and-Trade Program (2011–2015).” *PLOS Medicine* 15(7).	[1235]
Fussell, Elizabeth and Sarah R. Lowe. 2014. “The Impact of Housing Displacement on the Mental Health of Low-Income Parents after Hurricane Katrina.” *Social Science & Medicine* 113:137–44.	[1236]
Guirguis, Kristen et al. 2018. “Heat, Disparities, and Health Outcomes in San Diego County's Diverse Climate Zones.” *GeoHealth* 2(7):212–23.	[1237]
Huang, Zhengjing et al. 2015. “Individual-Level and Community-Level Effect Modifiers of the Temperature–Mortality Relationship in 66 Chinese Communities.” *BMJ Open* 5(9).	[1238]
Kreslake, Jennifer M., Katherine M. Price, and Mona Sarfaty. 2016. “Developing Effective Communication Materials on the Health Effects of Climate Change for Vulnerable Groups: a Mixed Methods Study.” *BMC Public Health* 16(1).	[1239]
Lang, Wei, John D. Radke, Tingting Chen, and Edwin H.W. Chan. 2016. “Will Affordability Policy Transcend Climate Change? A New Lens to Re-Examine Equitable Access to Healthcare in the San Francisco Bay Area.” *Cities: The International Journal of Urban Policy and Planning* 58:124–36.	[1240]
Loebach, Peter and Kim Korinek. 2019. “Disaster Vulnerability, Displacement, and Infectious Disease: Nicaragua and Hurricane Mitch.” *Population and Environment* 40(4):434–55.	[1241]
Macpherson, Cheryl C. and Muge Akpinar-Elci. 2015. “Caribbean Heat Threatens Health, Well-Being and the Future of Humanity: Table 1.” *Public Health Ethics* 8(2):196–208.	[1242]

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Marí-Dell’Olmo, Marc et al. 2019. “Social Inequalities in the Association between Temperature and Mortality in a South European Context.” *International Journal of Public Health* 64(1):27–37.	[1245]
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Nagy, Gustavo J. et al. 2018. “An Assessment of the Relationships between Extreme Weather Events, Vulnerability, and the Impacts on Human Wellbeing in Latin America.” *International Journal of Environmental Research and Public Health* 15(9).	[1247]
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Wilder, Margaret, Diana Liverman, Laurel Bellante, and Tracey Osborne. 2016. "Southwest Climate Gap: Poverty and Environmental Justice in the US Southwest." *Local Environment* 21(11):1332–53.	[1251]
Yenneti, Komali, Sabyasachi Tripathi, Yehua Dennis Wei, Wen Chen, and Gaurav Joshi. 2016. "The Truly Disadvantaged? Assessing Social Vulnerability to Climate Change in Urban India." *Habitat International* 56:124–35.	[1252]
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