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Uneven resilience of urban and rural areas to heatwaves

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Abstract

Extreme heat represents one of the most challenging climate change impacts of the Anthropocene, exerting influence not only on the economy and built environment but also on daily human life, posing threats to health. Within the existing literature, heatwaves and extreme heat phenomena have predominantly been examined at the urban scale, emphasizing the vulnerabilities inherent in urban areas. Conversely, rural areas are often highlighted for their advantages related to the natural environment. However, a broader perspective reveals that rural areas have their unique vulnerabilities that warrant careful consideration. This paper seeks to comparatively assess the vulnerabilities of urban and rural areas. Through an extensive literature review, the paper explores the divergent resilience of urban and rural areas across economic, social, environmental, structural, and governmental factors. The study concludes that both rural and urban areas exhibit distinct advantages and disadvantages, influencing their levels of vulnerability and resilience. This research is instrumental in providing a comprehensive outlook on resilience studies related to extreme heat.

Keywords: extreme heat, urban areas, rural areas, vulnerability

1. Introduction

Climate change is one of the most challenging problems of the Anthropocene. The changing climate due to the effects of greenhouse gases accumulating in the atmosphere has irreversible impacts on both the built and natural environment. Melting of glaciers, change in precipitation regime, sea level rise, increase in average global temperatures bring problems such as more frequent and severe extreme weather events, droughts, floods, coastal floods, ecosystem degradation, decrease in biodiversity, and directly or indirectly affect areas such as energy, food, water, health, and economy (IPCC, 2018). In the United Nations Framework Convention on Climate Change (1992; 7), climate change is defined 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”. The inception of anthropogenic influences on the global climate can be traced back to the Industrial Revolution, which has shaped today’s human activities encompassing production-consumption dynamics, alterations in land use, dependence on fossil fuels, and the extensive practice of deforestation (IPCC 2014; 2023). Today, "anthropogenic climate change" triggered by human activities has caused global average temperatures to increase by 1.10C compared to the pre-industrialization period. This increase has led to the effects of climate change being observed with increasing severity and frequency all over the world. Projections show that if no action is taken, these temperatures could rise by up to 40C, with 1.50C being a critical threshold that should not be exceeded (IPCC 2018; 2023).

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One of the most critical human-induced impacts of climate change is the increase in heat waves and extreme heat stress. According to the latest assessment report published by the IPCC (2021), the duration, intensity and frequency of heat waves are "highly likely" to increase in the future. Prolonged exposure to heat waves is associated with health problems and fatalities (Kinney et al., 2008; Gasparrini et al., 2015). As a matter of fact, the measurement of the highest average temperatures in history in July 6th 2023 as 17.230C is an indication that the effects of climate change are already being observed today. In July 2023, 147 deaths were recorded in 5 states of the USA due to heat stress, while 60,000 people were recorded to have lost their lives in Europe due to increasing temperatures in the summer of 2022 (Niranjan, 2023; Rannard, 2023). Considering all these, it is clear that rising temperatures pose a deadly threat and this issue should be addressed as a priority.

Climate risk, which is referred to as "extreme/severe heat", "heat stress", "heat waves" in the literature, has negative consequences in many areas such as societies, health, economy and daily life. The decrease in outdoor thermal comfort due to increasing temperatures, even to the extent of threatening health, can directly affect people's daily lives by reducing the time spent outdoors and changing outdoor activities (Sharifi & Boland, 2017). Extreme heat should not only be evaluated in terms of its relationship with health, but should be considered from a broader perspective. Projections show that heat waves will have significant impacts on the built environment, natural environment and social life and economy (Zuo et al., 2015).

In the literature, numerous studies have concentrated on examining the impacts of heatwaves on urban areas. The emphasis on urban areas stems from their highly-dense populations and elevated temperatures compared to the surrounding natural areas (called as "urban heat island" effect). Consequently, it is widely acknowledged that urban areas exhibit heightened vulnerability to heatwaves. Nevertheless, resilience to extreme heat is not solely contingent upon exposure; it is concurrently influenced by social characteristics within society, including factors such as age, education, health condition, and social isolation (Li et al., 2017). Moreover, the living conditions, accessibility to services and mitigation tools and connection to the information services have important influence on the resilience of the communities (Lal et al., 2011). Cutter et al. (2012) identified the most vulnerable groups to climate change as the elderly, children, migrants and low-income households. It is known that heat waves affect the elderly, young children, individuals with social and physical limitations, low-income groups without access to cooling technologies such as air conditioners, immigrants, minorities, chronic patients more (Reid et al., 2009; Rebetez et al., 2009; Mueller et al., 2017; Bayar & Aygün Oğur, 2023; Kim et al., 2023). Therefore, the potential vulnerabilities linked to the characteristics of the settlements need to be identified.

Grounded in this perspective, the primary purpose of this study is to elucidate the distinct vulnerabilities associated with heatwaves in both urban and rural settings. Defining vulnerability as a component of resilience, the investigation undertakes a comparative analysis of rural and urban areas, evaluating them across a spectrum of factors to discern their respective strengths and weaknesses. Informed by a comprehensive literature review, the study scrutinizes these factors under five overarching categories: Economic, Social, Environmental, Structural Factors and Governance. The research aims to answer the following questions; "To what extend do urban and rural areas differ in vulnerability to heatwaves?" and "How economic, social, environmental, structural and governmental factors affect rural and urban area's vulnerability to heatwaves?"

2. Vulnerability as a Function of Resilience

Studies have shown that different geographies and social groups experience varying levels of impact from climate change (Javadinejad et al., 2019) which is strongly related to the vulnerability and resilience levels. Resilience is a widely employed term spanning various disciplines to characterize the capacity of a system to withstand shocks or stressors. Cambridge Dictionary defines resilience as "the quality of being able to return quickly to a previous good condition after problems" (Resilience, 2023). The concept was initially introduced in ecology by Holling (1973) to delineate the ecological system's capability to absorb disturbances and sustain its functionality. Subsequently, it permeated other disciplines, including psychology, economics, engineering, urban science, and climate change.

In a broader context, resilience is construed as the system's ability to confront change and perpetuate development. This system may encompass an economy, a city, a natural area, or an individual (Applegath, 2012). The definition encourages innovative thinking to overcome and renew following disruptive crises or shocks (Stockholm Resilience Centre, 2011). Climate change resilience specifically addresses a system's competence in absorbing climate variability (Trohanis et al., 2009). Resilience has become a ubiquitous concept in contemporary research, finding application in studies of political, physical, and natural systems.

Upon scrutinizing the definition of resilience, it becomes evident that the discourse revolves around the concept of an unpredictable shock or crisis. Presently, society grapples with pervasive uncertainty across various domains, encompassing the realms of the economic crisis, climate, and natural disasters. The repercussions of these uncertainties have the potential to yield profound and detrimental consequences for the global system. Specifically, these consequences may occur as economic downturns, environmental degradation, escalation of natural disasters that lead human suffering, mass migration, displacement, epidemics, etc. Indeed, the concept of resilience proffers a strategic framework that involves proactive preparedness to contend with and mitigate the impact of such uncertainties. Resilience is concerned not only with responding to the challenges encountered but also with shaping them (Davoudi, 2012).

Vulnerability constitutes a pivotal concept pertinent to the resilience exhibited by a system in the face of climate change. The association between vulnerability and resilience within the climate change context is typified by an inverse correlation. According to the Intergovernmental Panel on Climate Change (IPCC) in 2007, vulnerability is defined as the extent to which a system is susceptible to and incapable of managing adverse effects arising from climate change, encompassing both climate variability and extremes. Vulnerability is contingent upon the inherent characteristics, magnitude, and rate of exposure to climate change and variability, as well as the sensitivity and adaptive capacity inherent to the system. As articulated by this definition and the preceding discourse on resilience, an escalation in system’s vulnerability results in a decrease in resilience, and vice versa. Research indicates discernible variations in the exposure of diverse social groups across distinct geographical locations to disparate levels and types of climate variables. Furthermore, disparities exist in the vulnerabilities inherent to each region and social group. Therefore, each community, settlement or region will experience different level of severity in the impacts of climate change (Javadinejad et al., 2019).

The vulnerability definition provided by the IPCC (2007) encompasses three pivotal key terms essential for comprehending the assessment of vulnerability. These key terms—namely, exposure, sensitivity, and adaptive capacity—serve as foundational components in the evaluation of vulnerability. Exposure denotes the magnitude of climate variability within a given region. Sensitivity is elucidated as the extent to which a constructed, natural, or human system is directly or indirectly influenced by alterations in climate conditions, encompassing variables such as temperature and precipitation, or specific impacts resulting from climate change, such as sea level rise and elevated water temperature. Adaptive capacity is defined as the capability of constructed, natural, and human systems to accommodate alterations in climate, inclusive of both climate variability and extremes, with minimal potential damage or cost. In a general sense, systems exhibiting elevated adaptive capacity are more adept at managing the impacts of climate change (ICLEI, 2007).

This study investigates the vulnerability of both rural and urban areas within the aforementioned conceptual frameworks. The examination involves a comprehensive analysis and comparison of the exposure, vulnerability, and adaptive capacities specific to heatwaves in both rural and urban contexts. The study further conducts a comparative evaluation of the respective advantages and disadvantages inherent in each settlement type. Such an assessment provides valuable insights into the impediments and potential avenues for enhancing resilience in response to heatwaves.

3. Urban and Rural Vulnerability to Heatwaves

Given the distinct adaptive capacities, risk management experiences, and infrastructural disparities between rural and urban areas, a comprehensive understanding of their respective resilience assumes paramount significance. Variances in resilience levels across diverse living areas and lifestyles are anticipated, influenced by a multitude of factors. Identifying these discrepancies becomes imperative to formulate viable and effective strategies for augmenting resilience capacity. The meaningful pursuit of resilience initiatives for each settlement necessitates tailored, context-specific assessments, accounting for the unique attributes of the locality, community, and way of life. Identifying local resources and inherent resilience factors becomes pivotal for the formulation of pertinent strategies (Javadinejad et al., 2019).

Urbanization, as a human activity, not only contributes to climate change but also introduces substantial risks through the concentration of infrastructure, economic endeavors, populations, and construction within cities (Tuğaç, 2022). The combination of inadequate infrastructure, high-density settlements, and urban inequalities heightens the vulnerability of marginalized groups to the impacts of climate change (Yenneti et al., 2016). Existing literature consistently underscores the heightened severity of temperature-related effects within urban environments. Cities and urbanization occupy a central position in climate change studies, as urbanization is identified as a contributing factor to climate change, while simultaneously exacerbating climate risks due to the concentration of economic activities, sizable population cohorts, infrastructure investments, and socio-cultural activities within urban settings (Aygün Oğur & Baycan, 2022). Insufficient infrastructure, unregulated construction, and socio-spatial disparities in urban areas exacerbate their susceptibility to the impacts of climate change. The process of urbanization contributes to a reduction in ecosystem services, alterations in land use, the diminishment of natural areas, and an expansion of built-up spaces within urban and surrounding regions. Consequently, this amplifies the vulnerability of cities to climate-related risks and the escalating occurrence and intensity of heatwaves. In cities deemed vulnerable, both critical infrastructures and inhabitants confront substantial risks (Lapola et al., 2019). The transformation of land cover resulting from urbanization has further modified the microclimate of urban environments (Pappalardo et al., 2023).

Furthermore, an additional rationale for the emphasis on studying extreme heat within urban contexts is attributed to the phenomenon known as the "Urban Heat Island" (UHI) effect, a factor contributing to heightened heat stress. The UHI, characterized by elevated temperatures in urban areas compared to their surrounding natural and rural counterparts, is intricately linked to the structural attributes and settlement patterns of cities. Its manifestation is primarily associated with the widespread use of heat-absorbing materials such as asphalt and concrete, a scarcity of green spaces, and the prevalence of high-density construction (Venter et al., 2021; Xi et al., 2023). The urban canyon effect, engendered by densely constructed and tall buildings, particularly during summer periods, impedes natural air circulation. Additionally, the presence of spaces that absorb and retain heat throughout both day and night exacerbate the adverse effects of rising temperatures (Oke, 1973; Hatvani-Kovacs & Boland, 2015). The concept of urban heat encompasses the cumulative impact of the urban heat island and heatwaves (Wang et al., 2022).

Although the Urban Heat Island (UHI) effect takes significant attention in studies examining the temperature-related impacts of climate change within urban areas (Hatvani-Kovacs & Boland, 2015), it is essential to acknowledge that rural areas are equally susceptible to climate change. While discussions regarding the impact of temperature rise on urban areas commonly assert that urban locales are more vulnerable than their rural counterparts due to inherent structural characteristics (De Sherbinin et al., 2007; Mora et al., 2017), it is noteworthy that divergent perspectives exist within the literature. Fischer et al. (2012) posit that both rural and urban areas undergo a comparable escalation in heat stress under a scenario involving a doubling of CO_2 levels.

In addition to experiencing commensurate levels of stress, the vulnerabilities associated with the socio-economic and demographic structures of individuals residing in rural areas underscore the imperative for research attention equivalent to that given to urban areas. The population residing in rural settings exhibits cultural and economic dependencies on natural resources, coupled with a dearth of diverse services. In comparison to urban counterparts, the services available in rural areas, marked by limited quality and accessibility, constitute a factor amplifying vulnerability in these regions (Lal et al., 2011). Although the literature on this subject is limited, it does address the vulnerabilities inherent in rural areas. Notably, the prevalence of elderly individuals, who are more susceptible to heat stress in rural environments, forming the majority of the population, coupled with constrained access to health services and the concentration of lower socio-economic groups in these areas, are delineated as factors exacerbating vulnerability (Benmarhnia et al., 2015; Burkart et al.Cassi, 2014; CDKN, 2018). In this context, a critique has emerged within the literature, challenging studies concentrating on urban areas that remain confined to the health-rising temperatures-built environment nexus (Madrigano et al., 2015; Sarofim et al., 2016). It can be deduced from this analysis that a singular consideration of heat risk based solely on exposure offers a constrained viewpoint. When the distinctive vulnerabilities inherent in the social structure and service distribution are considered, urban and rural areas manifest divergent susceptibilities (Li et al., 2017). Building upon this insight, the present research diverges from a sole concentration on urban areas and extends its scope to encompass broader terrains, explicitly incorporating rural areas. Such an expansive approach is deemed essential to comprehensively scrutinize the ramifications of extreme heat in both urban and rural contexts, aiming to unveil the underlying factors contributing to these distinct impacts. Contrary to prevailing perceptions, elevated temperatures pose an equivalent, if not greater, risk to human health in rural areas compared to urban areas. The research landscape on heat vulnerability has predominantly centered on urban locales, with the urban heat island effect identified as a contributor to heat-related mortality in such settings (Li et al., 2017). This effect has fostered the presumption that urban residents face a higher vulnerability to heat compared to their rural counterparts. Nevertheless, a body of research contradicts this assumption.

Rural areas exhibit a vulnerability to climate change comparable to that of urban areas. The populations residing in these rural areas are characterized by a cultural and economic reliance on natural resources, coupled with a deficiency in various essential services (Krannich et al., 2014; Hemson et al., 2004). The anticipated consequences of climate change in these regions are poised to significantly impact the quality of life and health of the rural populations. Notably, when contrasted with urban counterparts, the provision of services in rural areas, marked by limited quality and accessibility, emerges as a factor amplifying the vulnerability of these regions. Additionally, demographic and economic conditions further compound the susceptibility of rural areas to climate change. Communities in rural settings, often endowed with fewer resources and alternatives, are predisposed to experiencing more pronounced impacts as a result of climate change (Lal et al., 2011; Altıntaş & Hovardaoğlu, 2022).

Building upon this review, the classification of categories for scrutinizing the disparities in vulnerability between rural and urban areas to heatwaves can be delineated into five primary domains, each with associated subcategories: Economic Factors; (Economic Activities), Social Factors; (Demographics and Socio-economic Factors, Community Dynamics), Environmental Factors; (Natural Environment, Air Quality), Structural Factors; (Building Design and Materials, Connectivity, Infrastructure and Technology, Health Care Access and Services), Governance; (Policy and Governance). This categorization provides a comprehensive framework for systematically examining the multifaceted dimensions of vulnerability in both rural and urban contexts, facilitating a nuanced understanding of the factors influencing susceptibility to heatwaves within these distinct settings.

3.1. Economic Factors

Economic activities in both rural and urban areas can contribute to increased vulnerability to heatwaves through various mechanisms. This factor presents how the economic activities in urban and rural areas have influence on exposure, sensitivity and adaptive capacity for heatwaves.

3.1.1. Economic Activities

Economic activities within urban areas are inherently linked to the Urban Heat Island (UHI) effect, a phenomenon driven by heat-generating processes as in industries or manufacturing (He et al., 2020; Li et al., 2020). The UHI effect manifests as elevated temperatures within urban regions relative to their surrounding rural counterparts (Phelan et al., 2015). This localized warming effect results in heightened exposure to heat for the inhabitants, exacerbating the thermal conditions within urban environments. On the other hand, rural landscapes undergo transformation pressures associated with economic development, notably exemplified by activities like deforestation. These alterations impose stress on the microclimate of rural areas over the medium to long term. The gradual loss of natural habitat heightens the susceptibility of rural regions to increased heat exposure (Wolff et al., 2018).

Another crucial aspect involves the economic activities upon which people in settlements depend. In rural areas, a predominant portion of the population engages in agricultural production. This circumstance not only exposes them to heightened temperatures during fieldwork (Frimpong et al., 2020), with limited recourse for mitigation, but also renders agricultural productivity in rural locales particularly susceptible to the impacts of extreme heat (El Khayat et al., 2022; De Lima et al., 2021). The adverse effects on agricultural output extend beyond the immediate challenges faced by laborers, holding broader economic implications that reverberate through the livelihoods of farmers and the overall economic stability of rural communities. Furthermore, the combination of extreme heat and insufficient precipitation triggering water scarcity affect both human consumption and agricultural irrigation (Taft, 2015). The restricted availability of clean water for human use not only poses health risks but also complicates the daily lives of rural communities. It poses health challenges for urban inhabitants as well (Rijsberman, 2006). The complex interdependence among agricultural production, local economies, and food security underscores the vulnerability of rural areas to the extreme heat. This vulnerability assumes heightened significance in regions where agriculture constitutes a primary source of sustenance and income. Heatwaves exert adverse effects on outdoor workers within urban locales, with the impacts being magnified by the Urban Heat Island (UHI) effect (Moda et a., 2019). Nevertheless, despite these challenges, urban areas benefit the advantage of diverse range of economic activities, in contrast to rural areas.

3.2. Social Factors

Today, over 50% of the global population resides in urban areas, and projections indicate that this proportion is anticipated to surpass 65% by the year 2050 (UN, 2018). Notably, cities, already hosting a substantial population, continue to experience growth, primarily fueled by rural-urban migration. The phenomenon of shrinking rural settlements poses a challenge for both rural and urban regions in the face of climate change. Moreover, the demographic structure, cultural norms, and social dynamics within rural and urban settings differ, thereby influencing the vulnerability of respective groups.

3.2.1. Demographic and Socio-economic Factors

Urban areas exhibit diverse populations in terms of socio-economic conditions, age, ethnicity, and race. The vulnerable demographic, comprising the elderly, low-income groups, and individuals with pre-existing health conditions, who are more susceptible to heatwaves, is prominent in urban areas (Macintyre et al., 2018). On the other hand, rural populations are characterized by lower socio-economic status and a higher proportion of older individuals, factors collectively contributing to heightened vulnerability to heat-related illnesses and fatalities (Haskins, 2018). These conditions may limit the capacity to afford essential resources, including cooling systems, suitable housing, or healthcare services, particularly during periods of extreme heat. Rural areas often have a higher concentration of elderly individuals, inherently more susceptible to the adverse effects of extreme heat, necessitating additional care and support during such events (Rebetez et al., 2009).

3.2.2. Community Dynamics

Despite the assumption of high social connectedness in densely populated urban areas, urban residents, especially the vulnerable minorities (Tigges et al., 1998) may experience social isolation, thereby intensifying the impact of heat stress. This phenomenon is especially relevant for individuals lacking robust social networks or support systems. In contrast, rural communities often exhibit stronger social networks, fostering cooperation and mutual support during challenging periods, such as heatwaves. This enhanced social cohesion plays a pivotal role in helping individuals cope with the adversities posed by extreme temperatures. The interconnectedness within rural social structures often results in a communal response to heat-related challenges, providing a support system that extends beyond individual capacities. The strength of these social networks in rural areas not only contributes to the resilience of the community but also underscores the importance of considering social dynamics as a vital component in comprehensive strategies for mitigating the impacts of heatwaves (Cassidy & Barnes, 2012).

Furthermore, rural communities often possess traditional knowledge and practices that contribute to adaptive strategies in dealing with heat stress. This is particularly evident in agricultural practices, where longstanding local expertise is leveraged to navigate extreme weather conditions. The incorporation of such traditional knowledge into contemporary adaptive measures not only enhances the ability of rural populations to withstand heat stress but also highlights the importance of acknowledging and integrating indigenous practices in broader climate resilience initiatives (Fischer et al., 2021).

3.3. Environmental Factors

In general, rural areas are located in geographically distinct environments characterized by higher elevations and more extensive vegetation or forest cover compared to urban areas. These geographical features significantly influence precipitation patterns and temperatures. The higher elevation and augmented vegetation in rural areas foster a more favorable climate for precipitation. The conjunction of elevated terrain and increased vegetation cover in rural areas leads to decreased temperatures and cleaner air. The existence of forests and vegetation additionally affects local microclimates, offering shade and promoting cooling (Zeleňáková et al., 2015). Consequently, rural regions typically encounter lower temperatures and higher air quality in contrast to their urban counterparts. This factor compares the environmental factors that affect vulnerability in both settlements.

3.3.1. Natural Environment

Urban environments, characterized by dense infrastructure and minimal green spaces, face specific challenges during heatwaves. The scarcity of vegetation, parks, and green areas limits the presence of natural cooling mechanisms, including shade and evapotranspiration. Vegetation, green areas, and natural corridors are crucial sources of a cooling effect. The deficient greenery in urban locales results in a decreased capacity for natural cooling, ventilation, contributing to elevated temperatures, particularly evident during heatwaves (Oke, 1982; Ge et al., 2020; Okumuş & Terzi, 2021; Mueller et al., 2017; He et al., 2020; Yin et al., 2018; Yang & Li, 2015).

Rural areas have a distinctive natural environment characterized by abundant green spaces, encompassing diverse features such as forests, fields, and expansive landscapes. Unlike urban areas, rural settlements are less densely built, a characteristic that plays a pivotal role in cooling the environment. The natural features of rural areas, varying across geographies, contribute significantly to temperature regulation. The presence of green and blue structures together, including water bodies like lakes, rivers, and ponds, enhances the cooling effect. These bodies of water act as heat sinks, absorbing and dissipating excess heat, thereby influencing the surrounding air temperature. The natural cooling systems in rural areas offer multifaceted benefits, extending beyond temperature moderation. Dense vegetation, including forests, fields, and natural landscapes, contributes to cooler microclimates through the shading effect. The combination of green spaces, water bodies, and open layouts collectively creates a more comfortable and thermally regulated environment in rural areas, enhancing overall resilience to the impacts of elevated temperatures (Li et al., 2015; Wu & Zhang, 2019).

3.3.2. Air Quality

Urban areas frequently contend with elevated levels of air pollution, a factor that can exacerbate heat stress and contribute to respiratory issues, particularly during extreme heat events (Cohen et al., 2004). The confluence of increased temperatures and heightened air pollution poses significant health risks for urban residents (Jacob, & Winner, 2009; Brugha & Grigg, 2014). Elevated levels of pollutants, such as particulate matter and ground-level ozone, intensify the physiological impact of extreme heat, compromising respiratory function and exacerbating heat-related health concerns (Kalisa et al., 2018; Kinney, 2008).

In the context of air quality during heatwaves, rural areas are characterized by inherently lower levels of pollution compared to their urban counterparts. This disparity arises from a combination of factors that collectively contribute to a more favorable air quality profile in rural regions. One key determinant is the diminished concentration of industrial activities in rural settings, leading to a reduction in emissions associated with manufacturing processes. Furthermore, the lower prevalence of vehicular traffic in rural areas results in reduced emissions from transportation, particularly notable for urban air quality challenges. Moreover, the expansive natural landscapes and green spaces characteristic of rural areas play a pivotal role in mitigating air pollution during heatwaves. The presence of extensive vegetation serves as a natural filter, capturing pollutants and promoting improved air quality. This symbiotic relationship between rural landscapes and air quality underscores the ecological benefits offered by the rural environment, especially during periods of heightened temperatures (Tecer, & Tagil, 2014; Majra, 2011).

However, in contrast to urban areas, rural regions frequently contend with a scarcity of air quality monitoring stations and a relatively limited regulatory framework. Moreover, even they have the regulatory framework, rural authorities are not as experienced as urban ones (Ing et al., 2001). This discrepancy poses challenges in promptly identifying and effectively addressing air quality issues, particularly when exacerbated by the intensifying conditions of heatwaves. The consequence of this limited monitoring infrastructure is a reduced capacity to systematically track variations in air quality, hindering the timely detection of emerging issues related to heatwaves. Identifying pollution sources and understanding the dynamics of air quality during heatwaves becomes intricate without a well-established monitoring infrastructure (Beattie et al., 2002).

3.4. Structural Factors

The land use within and around settlements, including materials and construction density, is intricately linked to the microclimate impacts that may induce either cooling or heating effects during heatwaves. Rural and urban areas exhibit distinct construction patterns, with urban areas experiencing the Urban Heat Island (UHI) effect due to dense built-up areas and specific materials used. Conversely, rural areas tend to derive more benefits from ecological services (Nuruzzaman, 2015). This structural contrast extends to services and infrastructure, presenting different patterns in urban and rural areas, influencing the capacity for mitigation and adaptation to heatwaves, as well as flexibility, accessibility and information access in health-related emergencies. These variations contribute to divergent vulnerabilities between rural and urban areas, a topic explored within this factor (Kapucu et al., 2013).

3.4.1. Building Design and Materials

Traditional rural architecture often demonstrates a thoughtful integration of design elements aimed at harnessing natural cooling strategies. These considerations are rooted in the use of local materials, specific architectural features, and ventilation strategies tailored to the climatic conditions of rural environments (Yao et al., 2020). Traditional rural architecture frequently relies on locally sourced materials with high thermal mass. These materials possess the ability to contribute to temperature moderation. Examples include adobe, stone, or rammed earth construction, which, due to their thermal properties, help in maintaining a more stable indoor temperature (Gou et al., 15Benmarhnia15; Beckett et al., 2018).

Certain rural housing structures may exhibit vulnerabilities to extreme temperatures due to factors such as inadequate insulation and a lack of modern cooling systems. These limitations can render these homes more susceptible to the adverse impacts of climatic extremes, particularly during periods of extreme heat. Many traditional or older rural homes might lack proper insulation, which is crucial for regulating indoor temperatures. During extreme heat, insufficient insulation can lead to higher indoor temperatures, making these homes less resilient to temperature extremes (CDKN, 2018; Klok & Kluck, 2018).

The absence of modern cooling systems, such as air conditioning or efficient ventilation mechanisms, in some rural housing further compounds the vulnerability to extreme temperatures. Cooling systems play a pivotal role in maintaining comfortable indoor environments during heatwaves. Without these systems, residents may face challenges in mitigating the impact of elevated temperatures, leading to potential health risks. Rural communities often face challenges in accessing electricity, and the affordability of cooling technologies becomes a critical concern. This energy poverty intensifies the susceptibility of rural residents to the adverse effects of extreme heat (CDKN, 2018).

Urban areas exhibit higher concentrations of buildings, roads, and other heat-absorbing infrastructure, contributing to elevated temperatures in comparison to the surrounding rural areas (Oke, 1973). Urban environments feature extensive impervious surfaces such as asphalt and concrete, which have high thermal mass and absorb solar radiation. These surfaces store heat during the day and release it at night, contributing to elevated nighttime temperatures. The increased prevalence of impervious surfaces intensifies the UHI effect. Urbanization often results in the reduction of green spaces, such as parks and vegetation, which play a crucial role in cooling through evapotranspiration (Mueller et al., 2017). The diminished presence of greenery decreases the overall capacity of the urban area to dissipate heat, further amplifying the UHI effect (Lapola et al., 2019). The density and height of buildings in urban areas influence the UHI effect. Tall structures create canyons that trap heat, restricting air circulation and exacerbating temperature extremes (Yin et al., 2018). The UHI effect alters the local microclimate, leading to temperature differentials between urban and rural surroundings (Ge et al., 2020; Okumuş & Terzi, 2021). This can impact weather patterns, precipitation, and overall climatic conditions in the urban area, influencing the resilience of the environment to extreme heat events.

3.4.2. Connectivity

The limited availability of public transportation and access to essential services in rural areas accentuates the impact of heat stress, particularly for individuals who face challenges in reaching cooling centers or accessing emergency aid. Rural areas often experience limited public transportation options, and the reliance on personal vehicles becomes more pronounced (Kamruzzaman & Hine, 2011). This poses challenges for individuals who do not own vehicles or face mobility issues. The lack of convenient transportation exacerbates the isolation of certain segments of the population during heatwaves. The isolation of rural communities poses significant challenges to their resilience during extreme heat events, impacting access to information, resources, and support networks. The lack of connectivity in rural areas can hinder the timely dissemination of early warnings and crucial information related to heat stress, exacerbating the vulnerabilities of these communities (Putzer er al., 2012). This lack of information can impede the ability of residents to proactively prepare for and respond to heat-related challenges. Rural communities may face challenges in accessing vital resources needed to cope with extreme heat, such as emergency supplies, medical assistance, and cooling facilities. Connectivity issues can hinder the efficient coordination and distribution of these resources, further amplifying the vulnerability of rural populations during heatwaves. The lack of connectivity disproportionately affects vulnerable groups within rural communities, including the elderly, individuals with pre-existing health conditions, and those with limited mobility. These individuals may be more dependent on external support networks and services, making them particularly susceptible to the adverse effects of heat stress in the absence of reliable communication channels (Gutierrez & LePrevost, 2016).

Urban areas, on the other hand, characterized by high connectivity and accessible services. Although there might be uneven distribution of public transportation services (Ricciardi et al., 2015) and information dissemination, they have advantage of stronger infrastructure compared to rural areas.

3.4.3. Infrastructure and Technology

Energy poverty in rural communities presents a formidable challenge (Kaygusuz, 2010), limiting access to reliable cooling systems and exacerbating the impact of extreme heat indoors. This issue is further compounded by inefficient and aged housing, collectively magnifying the vulnerabilities of rural residents during periods of elevated temperatures. The limitations on solutions for heat mitigation are evident in the predominant focus on strategies tailored to urban areas, resulting in the under-prioritization of solutions suitable for rural contexts. This imbalance in emphasis has significant implications for the effectiveness and appropriateness of heat mitigation efforts, as certain solutions designed for urban environments may not be readily applicable or effective in rural areas. Certain heat mitigation solutions which may be effective in densely populated urban areas, encounter limitations when applied to rural settings. The lower population density in rural areas diminishes the feasibility and efficiency of certain mitigation efforts, leading to challenges in providing widespread relief during heatwaves (Nicholas Institute, 2023).

3.4.4. Health Care Access and Services

In the event of a heatwave, access to emergency aid and medical services is paramount. The limited availability of these services in rural areas can delay or impede timely responses to heat-related emergencies (Pristaš et al., 2009). Residents facing health issues aggravated by heat may experience heightened vulnerability due to delays in accessing essential medical support. This lack of access to medical care presents a multifaceted challenge, making it more difficult for rural residents to manage chronic conditions and receive necessary care, especially during periods of crisis (Nicholas Institute, 2023). The ongoing trend of rural health facility closures has intensified the health disparities experienced by rural populations (Xu et al., 2019). Rural residents face heightened challenges in accessing timely medical assistance and preventive services, leaving them more vulnerable to the health impacts of extreme heat (Gohlke et al., nd).

Although health service is more accessible in physical terms in urban areas, the socio-economic disparities among social groups (low income) in urban areas create economic barriers in access to health service (Pristaš et al., 2009). The inequalities in urban areas heightens the vulnerabilities in urban areas during heatwaves and emergency situations. The vulnerable groups may lack of consistent treatment in the pre-existing health issues that will be more dangerous in extreme heat situations.

3.5. Governance

The resilience of urban and rural communities to extreme heat events is intricately linked to local governance and policies. The formulation and implementation of policies in areas such as land use planning, building codes, and emergency response strategies play a pivotal role in shaping how communities prepare for and respond to heat stress.

3.5.1. Policy and Governance

Effective policies encourage collaboration across various sectors, including agriculture, health, and infrastructure. Multi-sectoral approaches promote a holistic understanding of the interconnected challenges posed by extreme heat and facilitate coordinated efforts to enhance resilience. Policies that incentivize collaboration and information sharing among different sectors contribute to a comprehensive and integrated approach to heat stress management. The influence of local governance and policies on urban and rural resilience to extreme heat is profound. Well-designed and implemented policies provide the framework for creating adaptive, sustainable, and community-centric solutions. By addressing the unique challenges of urban and rural areas, these policies play a crucial role in building the capacity of communities to withstand and thrive in the face of increasing heat stress (Martin et al., 2018).

4. Evaluation

Rural and urban areas exhibit distinct advantages and disadvantages concerning climate change, specifically in the context of heatwaves. Table 1 provides a comprehensive summary of the factors influencing the resilience and vulnerabilities of rural and urban areas. The outlined categories encapsulate the nuanced examination conducted within this research.

The literature review reveals that urban areas face challenges during heatwaves due to heat-generating economic activities, leading to elevated temperatures and posing risks to outdoor workers. On the other hand, urban areas benefit from economic diversity, providing adaptive advantages. Rural areas leverage natural landscapes, yet economic development poses a threat, altering land use. A significant concern arises from the dominance of the agricultural sector in rural areas, making them highly susceptible to climatic variations. Consequently, rural citizens experience economic stress, compounded by heat exposure during hot summer days. The limited range of economic activities in rural areas serves as an impediment to effective adaptation strategies.

Urban areas exhibit a diverse population in terms of age, gender, race, and socio-economic status, resulting in the concentration of various vulnerabilities. Additionally, the anonymity prevalent in urban settings may lead to the isolation of individuals from their communities. Consequently, a thorough examination of the urban social structure is crucial. Rural areas predominantly house socio-economically disadvantaged or elderly populations. Despite these disadvantages, rural areas benefit from stronger social networks and traditional shared knowledge on coping mechanisms during stressful situations.

In the realm of environmental factors, rural areas hold evident advantages attributed to their natural landscapes and their harmonious integration with the environment. Rural settings facilitate the efficient utilization of ecosystem services, providing benefits such as natural cooling and air purification. Conversely, in urban areas characterized by dense urbanization and industrialization, reaping the benefits of ecosystem services becomes challenging, hindering the potential for cooling and air cleaning.

While the Urban Heat Island (UHI) poses a formidable challenge to urban areas during heatwaves, they boast a robust advantage in terms of strong connectivity. This connectivity facilitates swift access to health services, efficient dissemination of information, and the implementation of early warning systems. Additionally, the enhanced infrastructure and widespread adoption of technology contribute to the effectiveness of adaptation and mitigation actions, ensuring their accessibility to the entire population. In contrast, rural areas, despite potentially leveraging traditional materials and housing styles for climate adaptation, encounter challenges. These areas often grapple with poor connectivity, inadequate infrastructure, and limited technology integration. The absence of robust infrastructure becomes particularly problematic during emergencies, impacting the overall response capacity. Furthermore, accessing health services emerges as a critical challenge in rural areas, especially during periods of heightened heatwaves.

Finally, local governments play a crucial role in shaping climate change adaptation and mitigation actions. It is imperative that these strategies extend beyond the confines of urban settlements and encompass the surrounding rural areas. Adopting an expansive perspective is paramount, considering the diverse vulnerabilities and advantages inherent in both rural and urban areas. A comprehensive approach that addresses the specificities of each locality is essential for developing effective and inclusive climate resilience measures.

Table 1 The vulnerabilities of rural and urban settlements.

Categories	Sub-categories	Urban Areas	Rural Areas
Economic Factors	Economic Activities	(-) Heat-generating activities (-) Heightened risk for outside workers due to UHI (+) Diversity in economic activities	(-) Landscape changes/deforestation due to economic development (-) Dependency on agricultural production and field work
Social Factors	Demographics and Socio-economic Factors	(-) High concentration of vulnerable populations	(-) Socio-economically disadvantage population (-) Elderly population
	Community Dynamics	(-) Isolation	(+) Stronger social network (+) Traditional knowledge
Environment. Factors	Natural Environment	(-) Lack of green areas and ecosystem services	(+) Green areas and waterbodies (+) Geographic location advantage
	Air Quality	(-) Lack of natural ventilation (-) Dense industrial activities	(+) Natural ventilation (+) Diminished industrial activities (-) Limited monitoring infrastructure
Structural Factors	Building Design and Materials	(-) Urban Heat Island (-) High density of built-up area (-) Heat-keeper materials	(+) Traditional methods and materials (-) Lack of proper isolation and modern cooling system
	Connectivity	(+) Developed transportation network (+) Disseminating information	(-) Poor public transportation (-) Isolation (-) Access to information
	Infrastructure and Technology	(+) Tailored mitigation and adaptation technologies	(-) Energy poverty (-) Unsuitable mitigation policies
	Health Care Access and Services	(+) Economic inequalities	(-) Limited availability (-) Isolation
Governance	Policy and Governance	Local government policy and strategies	Local government policy and strategies

5. Conclusion

Addressing the challenges posed by climate change, particularly those related to extreme heat, necessitates a comprehensive approach that encompasses various types of settlements, economic activities, social groups, and the environment. This study specifically examines rural and urban settlements, considering their economic, social, environmental, structural, and governmental factors. The findings indicate that rural areas possess advantages, particularly in terms of environmental factors and, to some extent, social dynamics. However, these areas exhibit greater vulnerability in terms of infrastructure, connectivity, and economic activities. Urban areas, characterized by diverse contexts, exhibit both vulnerabilities and advantages across all factors. The paper challenges the prevailing notion in the literature that urban areas are more vulnerable, emphasizing significant vulnerabilities in rural areas. To ensure a resilient future, equal importance should be given to both urban and rural areas, necessitating the development of a comprehensive framework that addresses the unique characteristics and challenges of each.

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Resume

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