Structural Inequalities and Heatwave Exposure in Developing Countries: A Structured Review of Socioeconomic and Environmental Vulnerability and Coping Strategies, with a Focus on Pakistan

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ABSTRACT:
Heatwaves are among the most serious manifestations of climate change, affecting health, livelihoods, food security, and environmental sustainability. Their effects are amplified by structural inequalities, socioeconomic disadvantage, and environmental vulnerability, particularly in Pakistan and comparable developing-country settings. This structured review synthesizes evidence on the links among inequality, heat exposure, vulnerability, and adaptation. Scopus, Web of Science, PubMed, ScienceDirect, Google Scholar, and relevant institutional sources were searched between February and April 2025 for English-language material published from January 2011 through April 2025. Because the included evidence varied in design and outcome measures, it was synthesized narratively using the Intergovernmental Panel on Climate Change framework of exposure, sensitivity, and adaptive capacity. Seven themes were identified: income inequality and economic vulnerability; housing and urban infrastructure; occupational exposure and loss of labour productivity; social vulnerability and gender disparities; health-care access and institutional adaptive capacity; environmental degradation and water scarcity; and coping and adaptation. The evidence indicates that low-income households, outdoor and informal workers, women facing resource constraints, residents of informal settlements, and environmentally marginalized communities often face greater exposure or fewer resources to adapt. Inadequate housing, weak service provision, limited health-system preparedness, insecure livelihoods, and declining environmental resources can compound risk. Effective adaptation therefore requires integrated, equity-focused policies that address poverty, gender inequality, health-care access, resilient infrastructure, environmental sustainability, occupational protection, and institutional preparedness.

Keywords: structural inequalities, heat stress, environmental vulnerability, socioeconomic status, developing countries, heatwave exposure

1.0. Introduction

Climate change is one of the most pressing challenges to global health and development in the twenty-first century. Human influence has warmed the climate, and hot extremes have become more frequent and intense across most land regions; further warming is expected to increase the frequency and severity of extreme-heat events (IPCC, 2021, 2023). South Asia is highly exposed to these changes. Within the region, Pakistan's geographic exposure, rapid population growth, reliance on climate-sensitive economic sectors, fragile urban infrastructure, and limited institutional capacity contribute to substantial socioeconomic and environmental risks from extreme heat (World Bank Group & Asian Development Bank, 2021).

Heatwaves can cause substantial excess mortality and morbidity, although their effects may be less immediately visible than those of sudden-onset disasters (Benmarhnia et al., 2015; Campbell et al., 2018). Heat stress occurs when environmental and metabolic heat exceed the body's capacity to dissipate heat, and risk is influenced by temperature, humidity, solar radiation, air movement, physical exertion, and clothing (World Health Organization, 2018). Under a high-emissions scenario, some densely populated agricultural areas of South Asia are projected to approach or exceed critical wet-bulb thresholds late in the twenty-first century (Im et al., 2017). Even lower levels of warming would increase exposure to dangerous heat in urban and rural populations (IPCC, 2021).

Heatwaves do not affect populations equally. Social, economic, environmental, and institutional inequalities shape exposure, sensitivity, and adaptive capacity. Evidence reviews identify age, health, income, housing, occupation, social isolation, and access to protective resources as recurring dimensions of heat vulnerability (Mayrhuber et al., 2018; Niu et al., 2021; Arsad et al., 2022). Informal or low-income settlements may combine dense construction, inadequate ventilation, unreliable water and electricity, and limited access to cooling, thereby increasing indoor heat exposure and restricting residents' ability to respond.

The relationship between structural inequality and heat exposure is especially relevant in Pakistan. The 2015 Karachi heatwave caused a sharp increase in mortality and exposed gaps in preparedness, public awareness, health-care capacity, electricity and water provision, and institutional coordination (Government of Pakistan, Ministry of Climate Change, 2015; Ghumman & Horney, 2016; Hanif, 2017). Rapid urban development can also intensify exposure by increasing impervious surfaces and reducing vegetation. Studies in Lahore show that urban form and socioeconomic conditions produce marked spatial differences in heat vulnerability (Zuhra et al., 2019; Iqbal et al., 2022).

Heat stress in Pakistan is intertwined with other socioeconomic and environmental risks. Agriculture, forestry, and fishing accounted for 37.4% of employment in the Labour Force Survey 2020–21 (Government of Pakistan, 2023). Local evidence from southern Punjab links farmers' reported climate impacts with lower crop output, reduced soil moisture, pest pressure, and food-security concerns, although these cross-sectional findings should not be read as national causal estimates (Ashraf et al., 2022). Occupational heat can also reduce work capacity and productivity, particularly in physically demanding outdoor jobs with limited access to shade, water, rest, or other protections (Hoa et al., 2013; Kjellstrom et al., 2016; Abokhashabah et al., 2021). These pathways can deepen existing economic disadvantage.

Environmental pressures compound these risks. Rising temperatures contribute to glacier mass loss and alter seasonal runoff in the Hindu Kush–Karakoram–Himalayan region, while changing precipitation and drought affect water availability and demand (IPCC, 2022). Pakistan already faces severe water-management challenges, and climate change is expected to increase variability and pressure on water resources (World Bank Group & Asian Development Bank, 2021). Land degradation, biodiversity loss, and ecological instability may further threaten rural

communities whose livelihoods depend directly on natural resources.

Susceptibility to heat varies with age, health, gender, occupation, disability, housing, and socioeconomic position. Older adults, people with chronic illness or disabilities, outdoor workers, displaced people, and residents of underserved urban areas may face greater exposure, sensitivity, or barriers to adaptation (IPCC, 2022; Mayrhuber et al., 2018; Slesinski et al., 2025). In resource-constrained settings, women's exposure and capacity to respond may also be shaped by unequal access to income, health care, mobility, information, and household decision-making. These overlapping conditions show that heat vulnerability is embedded in wider structural and social inequalities.

Research on climate change and heat-related health has expanded, but it remains dispersed across public health, environmental science, agriculture, urban studies, and economics. Global reviews have emphasized mortality and morbidity while also identifying major geographic and methodological gaps (Benmarhnia et al., 2015; Campbell et al., 2018; Arsad et al., 2022). Fewer studies examine how housing, livelihoods, environmental degradation, institutional capacity, and social inequality interact to shape heat exposure and adaptation in Pakistan and other developing-country contexts.

This review consolidates evidence on the links among structural inequalities, heatwave exposure, socioeconomic and environmental vulnerability, and coping strategies in Pakistan, while drawing cautiously on relevant international evidence.

1.1. Specific Objectives

1. To examine how inequalities in income, housing, occupation, gender, and access to services shape heatwave exposure and vulnerability in urban and rural Pakistan.
2. To examine how socioeconomic and environmental conditions influence exposure, sensitivity, and adaptive capacity during extreme-heat events.
3. To synthesize evidence on the spatial patterns, sectoral effects, and inequities of heat stress among marginalized and vulnerable groups in Pakistan and comparable settings.
4. To assess household-, community-, and institutional-level responses intended to reduce the socioeconomic and health effects of heat stress.
5. To assess the methods and analytical frameworks used to evaluate heatwave vulnerability, inequality, and resilience.
6. To identify research gaps and evidence-informed policy options for strengthening climate resilience and reducing socioeconomic disparities in Pakistan.

2.0. Study Design

This study used a structured literature-review design informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement (Page et al., 2021). The review examined the relationship between structural inequalities and heatwave exposure in developing countries, with particular attention to Pakistan.

2.1. Information Sources and Search Strategy

A structured literature search was conducted to identify studies on the links among structural inequalities, heatwave exposure, and socioeconomic vulnerability in Pakistan and other developing countries. Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar were searched electronically.

Reference lists of eligible publications were also searched, together with relevant reports from the Government of Pakistan, the World Health Organization, the Intergovernmental Panel on Climate Change, the Food and Agriculture Organization, the National Disaster Management Authority, and the World Bank.

Electronic searches were conducted from 15 February to 30 April 2025 and were last updated on 30 April 2025. Eligible sources were published in English between January 2011 and April 2025.

The search combined free-text terms, keywords, controlled vocabulary (including Medical Subject

Headings in PubMed, where applicable), and Boolean operators. Terms covered heat exposure (heatwave, extreme heat, heat stress, temperature increase); structural and socioeconomic inequality (structural inequality, socioeconomic inequality, social determinants, environmental vulnerability); health resilience and adaptive capacity; geography (Pakistan, developing countries, Global South); and health and livelihood outcomes (health, agriculture, labour productivity, water scarcity, urban heat island). Syntax, field tags, truncation, and wildcards were adapted to each database. Reference lists were searched for additional eligible material.

The review protocol was not registered. PRISMA 2020 principles informed the documentation of study selection, data extraction, appraisal, and reporting.

Two members of the review team independently screened titles, abstracts, and full texts against predefined eligibility criteria. Disagreements were resolved by discussion and consensus, with a third reviewer consulted when necessary. No formal inter-reviewer agreement statistic was calculated.

2.2. Eligibility Criteria

Sources were eligible if they met the following criteria:

- Peer-reviewed journal articles or authoritative institutional and government reports.
- Research addressing heatwaves, extreme heat, or closely related climate-vulnerability pathways.
- Studies addressing socioeconomic, environmental, institutional, or structural dimensions of vulnerability.
- English-language systematic reviews, empirical studies, relevant theoretical papers, or authoritative grey literature focused on Pakistan or a comparable developing-country context.

2.3. Exclusion Criteria

Excluded material comprised blogs and opinion pieces; non-authoritative or unverifiable grey literature; studies limited to meteorological processes without a social, health, livelihood, or vulnerability dimension; publications unrelated to inequality or vulnerability; conference abstracts without full text; material published outside the stated date range; and duplicate records.

2.4. Study Selection Process

Retrieved records were imported into EndNote and Mendeley for organization and duplicate checking. Selection proceeded through identification, title-and-abstract screening, full-text eligibility assessment, and inclusion.

1. Identification and Screening

Records were identified through the electronic databases, reference-list searches, and institutional and government sources described above. After duplicate checking, titles and abstracts were screened against the eligibility criteria.

2. Eligibility and Inclusion

Potentially eligible full texts were assessed for relevance to structural inequality, heat exposure, socioeconomic or environmental vulnerability, health or livelihood outcomes, adaptation, and methodological quality.

3. Evidence Base

Eligible evidence was retained for qualitative thematic synthesis. Exact record counts and exclusion totals were removed because the screening log was not available for independent verification and the original totals were internally inconsistent with the stated treatment of grey literature.

Peer-reviewed evidence was supplemented by authoritative government, policy, and institutional sources when these provided necessary national context. Grey literature was appraised for provenance, relevance, and methodological transparency.

To reduce selection bias, two reviewers independently conducted screening and eligibility

assessment. Disagreements were resolved by consensus or, when necessary, by a third reviewer.

2.5. Data Extraction

A standardized data-extraction form was used to record: (a) publication year and source; (b) study setting and location; (c) study design and methods; (d) key variables, including income, housing, occupation, and gender; (e) measures of heat exposure and vulnerability; and (f) principal findings.

2.6. Quality Assessment

Sources were assessed using design-appropriate criteria drawn from the Critical Appraisal Skills Programme and Joanna Briggs Institute appraisal tools. Appraisal considered methodological rigor, validity and reliability, clarity of findings, and risk of bias. Evidence that could not be verified or did not meet minimum quality and relevance standards was excluded from the synthesis.

2.7. Data Synthesis

The included evidence was synthesized narratively because study designs, exposure measures, outcome indicators, methods, and vulnerability dimensions varied substantially. This heterogeneity precluded a statistical meta-analysis.

Findings were organized into seven recurring themes related to heat exposure, structural inequality, socioeconomic vulnerability, environmental stress, and adaptive capacity:

- Income inequality and economic vulnerability
- Housing conditions and urban infrastructure
- Occupational exposure and loss of labour productivity
- Social vulnerability and gender disparities
- Health-care access and institutional adaptive capacity
- Environmental degradation and water scarcity
- Coping strategies and climate-adaptation mechanisms

The synthesis was interpreted through the IPCC framework of exposure, sensitivity, and adaptive capacity. This framework was used to examine how structural inequalities shape differential heat risk in Pakistan and relevant comparison settings.

Quantitative findings were summarized descriptively when measures were sufficiently comparable. No formal meta-analysis was performed because populations, methods, vulnerability indicators, and outcomes differed substantially across studies.

2.8. Ethical Considerations

Because the review used published material and did not involve human participants, institutional ethics approval was not required. Sources were cited in accordance with academic-integrity standards.

3.0. Thematic Results

3.1. Income Inequality and Economic Vulnerability

The evidence reviewed identifies income inequality as a structural factor that shapes all three dimensions of heat vulnerability: exposure, sensitivity, and adaptive capacity. Economic disadvantage can influence where people live and work, how severely heat affects their health and livelihoods, and which protective resources they can access. Heatwaves can therefore amplify existing socioeconomic inequalities, particularly among people with low incomes, insecure employment, or other forms of marginalization.

Economic inequality can increase heat exposure through unequal living and working conditions. Evidence from Karachi and Lahore links vulnerability with poor-quality housing, high-density development, limited vegetation, and unreliable basic services (Hanif, 2017; Zuhra et al., 2019; Iqbal et al., 2022). Low-income workers are also more likely to perform physically demanding outdoor work in agriculture, construction, transport, and street-based occupations, sometimes with limited access to shade, water, rest, or cooling (Hoa et al., 2013; Abokhashabah et al., 2021). Structural inequality thus operates through both place of residence and conditions of employment.

Economic disadvantage may also heighten sensitivity by limiting nutrition, health care, savings, and livelihood security. Evidence from rural Pakistan links climate vulnerability with food security, human health, and gendered access to resources, while accounts of the 2015 Karachi heatwave describe the particular exposure of poor and outdoor-working populations (Iqbal et al., 2015; Hanif, 2017). In District Lodhran, farmers reported adverse effects of changing climatic conditions on crop output, soil moisture, pest pressure, and food security; because the study was cross-sectional and local, these findings should not be generalized as national causal estimates (Ashraf et al., 2022). Smallholder households may be especially sensitive when they have limited financial buffers or few opportunities to diversify climate-sensitive livelihoods.

Poverty also constrains adaptive capacity. Low-income households may be less able to afford cooling, housing improvements, health care, insurance, or relocation, and they may depend more heavily on public infrastructure and social protection. Reviews and qualitative studies show that adaptation is shaped not only by individual behaviour but also by housing, neighbourhood resources, social support, and institutional provision (Mayrhuber et al., 2018; Maller & Strengers, 2011; Guardaro et al., 2022; Palinkas et al., 2022). Unequal adaptive capacity therefore reflects unequal access to social, economic, physical, and institutional resources.

Taken together, the evidence indicates that heat risk is socially distributed rather than determined by temperature alone. Heat is the physical hazard, but housing, income, health, occupation, social isolation, and access to services influence who is exposed, who is most sensitive, and who can respond (Mayrhuber et al., 2018; Niu et al., 2021; Slesinski et al., 2025). Heat vulnerability is therefore produced through the interaction of climatic exposure with structural inequality.

The synthesis suggests a reinforcing relationship between poverty and heat vulnerability. Economic disadvantage can place people in hotter homes or hazardous outdoor jobs; heat exposure can then reduce work capacity and income, disrupt livelihoods, and further limit adaptive resources. Occupational research supports the work-capacity pathway, and evidence from rural Pakistan links heat-related income losses with increased long-term male migration (Kjellstrom et al., 2016; Mueller et al., 2014). This feedback pathway is an interpretation across studies rather than a single uniformly tested causal model.

Economic disadvantage also intersects with gender, age, health, occupation, disability, and place. Reviews identify multiple groups—including older adults, people with pre-existing illness or disabilities, outdoor workers, socially isolated people, and residents of disadvantaged neighbourhoods—whose exposure, sensitivity, or adaptive capacity may be affected by overlapping conditions (Mayrhuber et al., 2018; Slesinski et al., 2025). Evidence from urban Pakistan further shows how gender and socioeconomic status interact with housing, service provision, and governance (Sawas et al., 2020). An intersectional perspective helps explain why similar heat exposure can produce different outcomes.

Overall, income inequality shapes exposure, sensitivity, and adaptive capacity. Reducing heat risk therefore requires action on poverty, housing, social protection, health care, safe employment, and equitable public services.

TABLE 1. Selected Literature Supporting the Thematic Synthesis

Thematic Variable (Aligned with Results Section)	Representative Sources	Setting	Integrated Evidence
1. Income Inequality and Economic Vulnerability	Iqbal et al. (2015); Hanif (2017); Rahut and Ali (2018); Abbasi et al. (2019); Mueller et al. (2014); Ashraf et al. (2022); Ngcamu (2023)	Pakistan; Global South review	Economic disadvantage can increase exposure through unsafe housing and work, heighten sensitivity through insecure livelihoods and poor health, and constrain access to protective resources. In rural Pakistan, heat and climate stress are also linked with productivity, household welfare, food security, and migration.
2. Housing Conditions and Urban Infrastructure	Maller and Strengers (2011); Zuhra et al. (2019); Ehsan et al. (2021); Laranjeira et al. (2021); Niu et al. (2021); Guardaro et al. (2022); Iqbal et al. (2022); Soomar and Soomar (2023)	Pakistan; Australia; Germany; United States; international reviews	Housing design, ventilation, neighbourhood form, access to electricity and water, and availability of shade or cooling resources shape exposure and adaptive capacity. The relative importance of these factors varies by place and study design.
3. Occupational Exposure and Labour Productivity	Hoa et al. (2013); Mueller et al. (2014); Kjellstrom et al. (2016); Hanif (2017); Rahut and Ali (2018); Abokhashabah et al. (2021)	Pakistan; Vietnam; international evidence	Outdoor and physically demanding work can expose workers to dangerous heat where water, shade, rest, and formal protections are limited. Heat can reduce work capacity and income; in rural Pakistan, heat-related income losses have also been associated with long-term male migration.
4. Social Vulnerability and Gender Disparities	Abbasi et al. (2019); Sawas et al. (2020); Habib (2021); Daraz et al. (2024); Anjum and Aziz (2025); Slesinski et al. (2025)	Pakistan; international review	Gender, poverty, health, occupation, age, and geographic marginalization can interact to shape exposure, sensitivity, and adaptive capacity. The cited studies differ in hazard and population, so broad intersectional conclusions are treated as synthesis rather than uniform causal findings.

Thematic Variable (Aligned with Results Section)	Representative Sources	Setting	Integrated Evidence
5. Health-Care Access and Institutional Adaptive Capacity	Hanif (2017); Rauf et al. (2017); Khan et al. (2021); Razzak et al. (2022); Palinkas et al. (2022); Arsad et al. (2022); Ullah et al. (2024)	Pakistan; United States; international review	Preparedness, risk communication, access to health care, reliable basic services, and community interventions influence adaptive capacity. A Karachi trial found improved heat literacy and fewer unscheduled all-cause hospital visits after a community education intervention.
6. Environmental Degradation and Water Scarcity	Malik et al. (2012); Iqbal et al. (2015); Iqbal (2020); Sawas et al. (2020); Anjum and Fraser (2021); Ashraf et al. (2022); World Bank Group and Asian Development Bank (2021); IPCC (2022)	Pakistan; regional and global assessments	Water stress, changing precipitation, glacier loss, land degradation, and urban development can compound heat vulnerability, especially where livelihoods depend on climate-sensitive resources and adaptive capacity is limited.
7. Coping Strategies and Climate Adaptation	Rauf et al. (2017); Ehsan et al. (2021); Maller and Strengers (2011); Razzak et al. (2022); Guardaro et al. (2022); Palinkas et al. (2022); Ullah et al. (2024)	Pakistan; Australia; United States	Household behaviours, housing improvements, public education, access to cooling resources, early warning, and institutional preparedness can reduce risk, but their feasibility and effectiveness depend on resources and local context.

3.2. Housing Conditions and Urban Infrastructure

Housing quality, neighbourhood form, and urban infrastructure are important structural determinants of heat exposure and the ability to adapt. Rapid urbanization, weak planning, and unequal infrastructure investment can concentrate heat risk in disadvantaged neighbourhoods while limiting access to water, electricity, shade, health services, and affordable cooling.

A study of 52 low-income homes in Faisalabad found that orientation, ventilation, and building design were associated with reported thermal discomfort and identified practical heat-mitigation options (Ehsan et al., 2021). A Pakistan-focused review likewise identifies housing, social, economic, environmental, and health factors as relevant to heat-vulnerability assessment (Soomar and Soomar, 2023). These sources support concern about poorly ventilated and thermally uncomfortable housing, but they do not establish that indoor temperatures are always higher than outdoor temperatures or that the same building conditions prevail in every informal settlement.

In Lahore, spatial studies show that urban-development patterns, population density, housing materials, vegetation, water access, health, education, and other socioeconomic indicators are associated with marked differences

in heat vulnerability (Zuhra et al., 2019; Iqbal et al., 2022). The evidence supports targeted urban planning and neighbourhood-level assessment. Comparable data for other Pakistani cities are less complete, so Lahore findings should not be generalized to Karachi, Faisalabad, Multan, or the country as a whole without local evidence.

Housing and infrastructure can influence both exposure and sensitivity. Poor ventilation and thermally unsuitable design can increase discomfort and restrict relief from heat, while limited income and unreliable services can reduce the feasibility of household coping measures (Ehsan et al., 2021; Soomar and Soomar, 2023). Broader reviews identify age, pre-existing illness, and socioeconomic disadvantage as recurrent vulnerability factors (Arsad et al., 2022). The magnitude of these effects depends on the population, building type, climate, and outcome measured.

Adaptive capacity also depends on reliable electricity and water, accessible health services, transport, and affordable cooling. Accounts of the 2015 Karachi event describe how power and water shortages, constrained health services, and limited preparedness compounded risk (Government of Pakistan, Ministry of Climate Change, 2015; Hanif, 2017). International qualitative studies similarly show that low-income households' access to shade, trees, air conditioning, and other cooling resources is shaped by housing and financial constraints (Guardaro et al., 2022; Palinkas et al., 2022).

Housing vulnerability is therefore not solely a physical attribute of a building. It emerges through interactions among infrastructure, technology, everyday practices, resources, and institutions (Maller and Strengers, 2011). Housing quality, energy access, neighbourhood conditions, and urban planning jointly influence both exposure and the capacity to adapt.

The synthesis suggests a feedback relationship among inadequate housing, environmental disadvantage, and poverty. Poor households may be concentrated in neighbourhoods with weak infrastructure and limited green space; repeated heat exposure can affect health and work, while constrained income limits the ability to improve housing or purchase cooling. Because few studies directly test this full pathway over time, it should be treated as a conceptual synthesis rather than a demonstrated longitudinal effect.

Housing-related vulnerability often overlaps with other disadvantages. Low-income households, older adults, people with disabilities, residents of informal settlements, and women with heavy unpaid domestic workloads may face different combinations of exposure, sensitivity, and constrained resources. Effective urban heat policy therefore requires attention to safe housing, public services, energy reliability, accessibility, and climate-resilient neighbourhood design.

Overall, housing and urban infrastructure can increase exposure by concentrating people in heat-prone environments, heighten sensitivity through poor living conditions, and reduce adaptive capacity by restricting access to essential services and cooling. The evidence supports place-specific improvements in housing, planning, energy, water, public space, and service delivery alongside wider efforts to reduce socioeconomic inequality.

3.3. Occupational Exposure and Labour Productivity Loss

Occupational exposure is a direct pathway through which inequality shapes heat risk. Workers in physically demanding, informal, or outdoor occupations often have greater exposure and fewer opportunities to modify schedules, reduce exertion, or access climate-controlled environments. Occupational heat therefore affects health, productivity, household welfare, and economic security.

Outdoor work in agriculture, construction, transport, livestock production, and street-based occupations can involve prolonged physical exertion in high temperatures. Reviews and field studies identify water, shade, rest, work scheduling, acclimatization, and worker education as important protections (Hoa et al., 2013; Kjellstrom et al., 2016; Abokhashabah et al., 2021). Accounts from Sindh also describe dehydration, heat illness, and income risks among

day labourers and outdoor workers during severe heat (Hanif, 2017). The available sources support concern about occupational protection but do not establish a single nationwide level of regulatory enforcement across all sectors.

Heat-related reductions in work capacity and income can influence household livelihood strategies. In rural Pakistan, temperature-related declines in farm and non-farm income were statistically associated with increased long-term male migration (Mueller et al., 2014). Research on livestock-dependent households also shows that climate-risk coping strategies can affect productivity and household welfare, although it does not establish migration as the outcome (Rahut & Ali, 2018). Occupational heat thus has consequences beyond immediate illness, but the form and scale of those consequences vary by livelihood and study design.

3.4. Social Vulnerability and Gender Disparities

Social vulnerability shapes how heat and other climate stressors are experienced. Unequal access to income, education, health care, political participation, social protection, and decision-making can affect exposure, the severity of impacts, and the capacity to adapt. Gender is one important dimension of this broader pattern, but evidence differs across populations and is not uniformly heat-specific.

Studies from Pakistan describe women's responsibilities in agriculture, household work, water collection, and caregiving, together with constraints on mobility, resources, and decision-making (Abbasi et al., 2019; Anjum & Aziz, 2025). These studies address climate vulnerability broadly and do not show that every reviewed study found the same heat-specific maternal or reproductive outcome. Qualitative research with pregnant women reports perceived health and well-being concerns and barriers to adaptation, while a rural study from Malakand links climate-related stress with anxiety, depression, and the availability of social support (Batool & Zulfiqar, 2024; Daraz et al., 2024). These findings should be interpreted within their limited samples and settings.

Women in low-income urban and rural settings may face overlapping disadvantages related to income, services, environmental quality, and social norms (Anjum & Fraser, 2021; Sawas et al., 2020). Existing inequalities can reduce adaptive capacity before an extreme event, while climate stress can increase care burdens or livelihood pressure. The literature supports an intersectional interpretation, but it does not establish a universal causal cycle for all women or all heatwaves.

Evidence from rural and mountain communities suggests that education, access to resources, livelihood options, and women's participation in household or community decisions can strengthen adaptive capacity (Iqbal et al., 2015; Habib, 2021). These studies are mainly qualitative or observational; they do not support a claim that every empowerment measure was positively and significantly correlated with reduced heat vulnerability.

3.5. Health-Care Access and Institutional Adaptive Capacity

Access to health care and institutional preparedness can influence the consequences of extreme heat. Qualitative evidence from pregnant women points to perceived barriers in obtaining care during climate-related stress, but it cannot establish population-wide rates of severe heat illness or death (Batool & Zulfiqar, 2024). The 2015 Karachi heatwave illustrates how limited preparedness, health-system strain, power and water disruption, and gaps in risk communication can compound an environmental hazard (Government of Pakistan, Ministry of Climate Change, 2015; Ghumman & Horney, 2016; Hanif, 2017). Governance and service provision therefore form part of adaptive capacity, although the available studies do not quantify every institutional pathway.

Risk communication, public awareness, and community-based intervention can strengthen preparedness, but the evidence should be stated precisely. A Pakistan survey found that demographic, socioeconomic, health-access, and Health Belief Model factors were associated with heat-risk perceptions and protective intentions

(Rauf et al., 2017). In Karachi, the Heat Emergency Awareness and Treatment intervention improved heat literacy and reported protective practices and was associated with a 38% adjusted reduction in unscheduled hospital visits for any cause; it did not produce a statistically significant mortality reduction (Razzak et al., 2022). A separate Pakistan study found that perceived benefits, barriers, cues to action, and self-efficacy predicted different levels of adaptive behaviour (Ullah et al., 2024). Comparative evidence from the Indian Sundarbans suggests that social networks can help communities share information and mobilize support (Mondal et al., 2024). Occupational evidence from Vietnam and broader reviews also emphasizes practical workplace protections rather than assuming that health services alone determine risk (Hoa et al., 2013; Kjellstrom et al., 2016).

The synthesis points to a possible feedback relationship between institutional weakness and social vulnerability. Heat-related illness can strain services that already have limited capacity, while weak public-service delivery can further disadvantage low-income communities. Because this complete feedback loop has rarely been tested longitudinally, it is best understood as an evidence-informed conceptual pathway.

3.6. Environmental Degradation and Water Scarcity

Environmental degradation and water scarcity can compound heat vulnerability through their effects on exposure, sensitivity, and adaptive capacity. Urban form affects local heat accumulation, while water availability shapes both daily coping and longer-term livelihood security. These environmental processes interact with socioeconomic conditions rather than operating independently of them.

3.6.1. Exposure

In Lahore, heat-vulnerability mapping links higher risk with urban form, density, housing materials, vegetation, water access, health, education, and related social indicators (Zuhra et al., 2019; Iqbal et al., 2022). These studies support concern about urban heat islands and unequal neighbourhood vulnerability, but not a multi-city attribution involving every proposed driver. At the national scale, climate change is expected to increase pressure and uncertainty in already stressed water resources through changing precipitation, glacier loss, drought, and rising demand (Iqbal, 2020; World Bank Group & Asian Development Bank, 2021; IPCC, 2022). Water scarcity can in turn reduce households' ability to use water-based coping measures during extreme heat.

3.6.2. Sensitivity

Environmental stress can heighten sensitivity by affecting livelihoods, food security, and ecosystem services. In District Lodhran, farmers reported lower crop output and soil moisture, greater pest pressure, and food-security concerns in association with changing climatic conditions (Ashraf et al., 2022). These findings illustrate a plausible livelihood pathway but are local perceptions from a cross-sectional study, not proof of uniform effects across Pakistan.

Smallholder farmers and resource-dependent households may be particularly sensitive because they rely on natural resources and often have limited financial buffers. Reviews of rural Pakistan describe links among climate exposure, food security, health, gender, and livelihood vulnerability (Iqbal et al., 2015; Fahad & Wang, 2020; Anjum & Fraser, 2021). More broadly, environmental degradation can reduce the services on which households depend, but the cumulative mechanism described here is a synthesis across sources rather than a single measured causal chain.

3.6.3. Adaptive Capacity

Environmental and infrastructural conditions influence the options available for adaptation. Evidence on heat-vulnerability indices and low-income urban communities identifies vegetation, shade, water, housing, health, and social resources as relevant factors (Niu et al., 2021; Guardaro et al., 2022). Within Pakistan, a district-level assessment found relatively low adaptive capacity in Balochistan and parts of Punjab and Sindh using indicators such as health services, literacy, and socioeconomic resources (Malik et al., 2012). These differences indicate that

adaptation depends on governance, infrastructure, resource allocation, and development as well as climate.

3.7. Coping Strategies and Climate-Adaptation Mechanisms

Coping and adaptation can reduce exposure and sensitivity or strengthen adaptive capacity, but their feasibility and effectiveness depend on resources, institutional support, and social conditions. Adaptation operates at household, community, institutional, and governmental levels; no single behaviour is sufficient for all settings.

3.7.1. Exposure

Reported household responses include increasing water intake, avoiding the hottest times of day, seeking shade or cooler spaces, adjusting clothing, improving ventilation, and following warnings (Rauf et al., 2017; Ehsan et al., 2021; Palinkas et al., 2022; Ullah et al., 2024). These measures are constrained where housing is crowded or electricity, water, and cooling are unaffordable or unreliable. International evidence also supports neighbourhood shade, vegetation, and equitable access to cooling resources as components of urban adaptation (Guardaro et al., 2022; Niu et al., 2021).

3.7.2. Sensitivity

Education and community intervention can improve protective behaviour. The Heat Emergency Awareness and Treatment programme in Karachi improved heat literacy and reported practices and was associated with fewer unscheduled all-cause hospital visits, without a significant mortality effect (Razzak et al., 2022). Rauf et al. (2017) identified several demographic, socioeconomic, health-access, and belief-related correlates of risk perception and intended action. Ullah et al. (2024) used the Health Belief Model and found that perceived benefits and self-efficacy predicted individual behaviour, while cues to action and self-efficacy predicted household behaviour; risk perception was not significant in the adjusted overall model. Comparative evidence from India indicates that social networks can facilitate information sharing and collective support (Mondal et al., 2024).

3.7.3. Adaptive Capacity

Adaptive capacity includes economic resources, institutions, governance, and long-term planning as well as individual coping. Pakistan-based evidence points to the importance of public awareness, emergency preparedness, reliable water and electricity, health-care readiness, and trained personnel (Khan et al., 2021; Razzak et al., 2022). Access to adaptation is unequal: housing improvements, cooling, health care, and relocation may be unaffordable, while women and other marginalized groups may face financial, social, or decision-making barriers (Abbasi et al., 2019; Mayrhuber et al., 2018). In rural Pakistan, heat-related income losses have been associated with long-term male migration, which may represent adaptation, distress, or both (Mueller et al., 2014). Climate-risk coping also affects livestock productivity and household welfare (Rahut & Ali, 2018). Sustainable adaptation therefore requires structural and equitable measures rather than reliance on individual behaviour alone.

Discussion

The reviewed evidence indicates that structural inequalities shape exposure to extreme heat, sensitivity to its effects, and the resources available for adaptation. Poverty, inadequate housing, insecure employment, gender inequality, environmental degradation, uneven service provision, and weak institutional capacity can interact rather than operate in isolation (Hanif, 2017; Mayrhuber et al., 2018; Anjum & Fraser, 2021; Sawas et al., 2020). The strength and scope of evidence vary, however, and many Pakistan studies are local, qualitative, cross-sectional, or focused on climate vulnerability more broadly rather than heat alone.

The findings can be interpreted across the three components of the IPCC framework. Economic disadvantage may increase exposure by concentrating people in thermally unsafe housing or outdoor work. It may increase sensitivity through poor health, food insecurity, or unstable livelihoods, and it may reduce adaptive capacity

by limiting access to cooling, health care, finance, education, infrastructure, and social protection. These pathways are supported to different degrees across the literature and should not be treated as a single universally demonstrated causal model.

The seven thematic domains form a system of potential cumulative disadvantage. Housing affects indoor exposure; employment determines whether workers can avoid peak heat; reduced work capacity can lower income; and low income can restrict access to health care, cooling, or housing improvements. Institutional conditions can either mitigate or compound these pathways. Much of this cumulative framework is a synthesis across studies, so longitudinal research is needed to test how the proposed feedback mechanisms unfold over time.

The evidence is consistent with a possible feedback relationship between poverty and heat vulnerability. Structural disadvantage can increase dependence on climate-sensitive livelihoods and reduce access to protective resources, while heat can disrupt work, health, and household security. Evidence on occupational productivity and heat-related migration supports parts of this pathway (Kjellstrom et al., 2016; Mueller et al., 2014), while gender-focused research in urban Pakistan supports an intersectional perspective on access to resources and decision-making (Sawas et al., 2020). The complete feedback loop remains an inference from the combined literature.

Housing and urban infrastructure emerged as important determinants, but the geographic reach of the evidence should be kept clear. Studies in Faisalabad and Lahore document thermal discomfort, building-design concerns, and spatial differences in heat vulnerability (Ehsan et al., 2021; Zuhra et al., 2019; Iqbal et al., 2022). International studies show that access to shade, trees, cooling, and good-quality housing is also socially unequal (Guardaro et al., 2022; Niu et al., 2021). Together, these findings support place-specific investment in housing, energy, water, public space, and urban planning; they do not establish identical conditions in every Pakistani city.

Occupational exposure is another important pathway. Outdoor and physically demanding workers may experience high heat loads where rest, shade, water, schedule control, and formal protections are limited (Hoa et al., 2013; Kjellstrom et al., 2016; Abokhashabah et al., 2021). Evidence from Sindh describes health and income effects among outdoor and day labourers during severe heat (Hanif, 2017), while rural Pakistan evidence links heat-related income losses with long-term male migration (Mueller et al., 2014). These sources support effects on work capacity, productivity, and household security, but not every claimed outcome in every occupational group.

Vulnerability is multidimensional. International reviews identify age, health, disability, income, occupation, social isolation, and housing as intersecting factors (Mayrhuber et al., 2018; Slesinski et al., 2025). Pakistan studies add context on gender, rural livelihoods, resource access, and mental health among particular communities (Abbasi et al., 2019; Habib, 2021; Daraz et al., 2024). Because these studies do not compare every vulnerable group directly, the conclusion is that disadvantages may overlap—not that people facing multiple disadvantages were uniformly proven to fare worse than those facing one.

Institutional preparedness can moderate heat risk. Evidence from the 2015 Karachi event and subsequent research highlights public awareness, emergency training, reliable water and electricity, and health-service readiness (Government of Pakistan, Ministry of Climate Change, 2015; Hanif, 2017; Khan et al., 2021). Intervention evidence is narrower but encouraging: community education improved heat literacy and protective practices and reduced unscheduled all-cause hospital visits in one Karachi trial (Razzak et al., 2022). Behavioural research also identifies perceived benefits, barriers, cues to action, and self-efficacy as predictors of adaptation (Ullah et al., 2024). Claims about nationwide Heat Action Plan effectiveness or interagency performance require further direct evaluation.

Environmental conditions can compound social vulnerability. Urban form and vegetation influence local heat patterns, while water stress, changing precipitation, glacier loss, land degradation, and agricultural pressure affect livelihoods and coping options (Zuhra et al., 2019; Iqbal et al., 2022; World Bank Group & Asian Development Bank, 2021; IPCC, 2022). Poor households may be more affected when they depend on climate-sensitive livelihoods or have fewer resources to respond. The resulting cascade across health, food security, income, and ecosystems is a synthesis of several evidence streams rather than a single measured pathway.

The findings align with international reviews while underscoring evidence gaps in Pakistan. Slesinski et al. (2025) found that socially disadvantaged groups generally experience greater heat exposure and lower adaptive capacity. Mayrhuber et al. (2018) identified recurring social and resource-related vulnerabilities, and Niu et al. (2021) documented the factors and methods used in heat-vulnerability indices. Arsad et al. (2022) synthesized mortality, morbidity, and associated vulnerability factors. The present review suggests that, in Pakistan, these dimensions interact with insecure livelihoods, rapid urban development, water stress, and variable institutional capacity, but the strength of evidence is uneven across themes.

This review proposes a cumulative vulnerability pathway within the IPCC framework. Structural inequality can increase exposure through housing, employment, and environmental conditions; it can heighten sensitivity through health and livelihood insecurity; and it can reduce adaptive capacity by limiting access to services, cooling, information, finance, and institutional support. Repeated heat exposure may then reinforce disadvantage. This pathway is a conceptual synthesis intended to organize the literature, not a causal model validated by a single study.

The synthesis suggests that technology, emergency response, and individual behaviour are necessary but insufficient on their own. Longer-term resilience also depends on safe housing, reliable services, occupational protection, health-system readiness, water security, gender equity, social protection, and accountable governance. The balance of interventions should be adapted to local evidence and evaluated for both effectiveness and distributional equity.

4.0. Conclusion and Recommendations

This structured review examined relationships among structural inequality, socioeconomic and environmental vulnerability, heat exposure, and adaptation in Pakistan, supported by carefully identified international evidence. Heat risk is not distributed evenly: housing, income, occupation, health, gender, infrastructure, and institutional support influence exposure, sensitivity, and adaptive capacity.

Seven thematic dimensions were identified: income inequality and economic vulnerability; housing and urban infrastructure; occupational exposure and productivity loss; social vulnerability and gender disparities; health-care access and institutional adaptive capacity; environmental degradation and water scarcity; and coping and climate adaptation. These domains can interact and compound one another, although the evidence base is stronger for some pathways than for others.

Low-income households, outdoor and informal workers, women facing resource constraints, residents of thermally vulnerable housing, and environmentally marginalized communities may face disproportionate risk. Policies should therefore combine heat-specific preparedness with wider action on poverty, public services, urban planning, safe work, health care, gender equality, and environmental management.

Priority options include locally evaluated Heat Action Plans, reliable early-warning and risk-communication systems, health-care preparedness, enforceable occupational heat protections, resilient housing and infrastructure, equitable access to water and cooling, urban shade and vegetation, and community-based adaptation. Interventions should be designed with affected communities and assessed for reach, effectiveness, affordability, and unintended inequalities.

Future research should use longitudinal, mixed-methods, and intervention designs; report exposure and outcome measures transparently; distinguish heat-specific effects from broader climate impacts; and evaluate whether adaptation reaches the groups at greatest risk. Standardized indicators and comparable local data would improve evidence-informed policy across Pakistan.

5.0. Limitations and Future Research

This review was limited to English-language material and relied partly on grey literature located through Google Scholar and institutional websites, which may introduce language, publication, and retrieval bias. Many included studies were local, qualitative, cross-sectional, or focused on climate vulnerability rather than heat specifically, limiting causal inference and generalizability. The evidence was too heterogeneous for meta-analysis. The available screening documentation did not permit independent reconciliation of the original record counts; exact flow totals are therefore not reported.

Future reviews should preregister a protocol, preserve a reproducible search and screening log, report complete study-level extraction and appraisal tables, and update the search before publication. Primary research should prioritize comparable heat-exposure measures, disaggregated outcomes, and rigorous evaluation of household, occupational, urban, and institutional interventions.

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