Climate Health, Volume 1, Issue 2, Spring 2026: 74-93

Review Article

Climate Change, Health, and Resilience: A Comprehensive Review of Adaptation Strategies

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Article info:
Received: 22 November 2025
Revised: 18 January 2026
Accepted: 05 February 2026

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ABSTRACT

Climate change is increasingly recognized as one of the greatest threats to human health, environmental sustainability, and socioeconomic stability in the twenty-first century. Rising temperatures, altered precipitation patterns, extreme weather events, ecosystem degradation, and the spread of climate-sensitive diseases are placing unprecedented pressures on communities worldwide, particularly among vulnerable populations. This review synthesizes current evidence and practical approaches for strengthening climate resilience across multiple sectors, including healthcare systems, water, sanitation and hygiene (WASH), agriculture, food security, occupational health, urban environments, and public health protection. The review further examines adaptation strategies for addressing droughts, heatwaves, wildfires, dust storms, air pollution, and climate-sensitive infectious diseases, while emphasizing the specific needs of children, women, older adults, and other at-risk groups. Key resilience measures identified include climate-smart infrastructure development, early warning and surveillance systems, ecosystem-based adaptation, sustainable resource management, digital health technologies, community engagement, and cross-sectoral governance. Particular attention is given to integrating environmental, social, economic, and health dimensions of resilience to enhance adaptive capacity and reduce climate-related vulnerabilities. The findings highlight that effective climate adaptation requires coordinated action among governments, healthcare institutions, researchers, communities, and international organizations. Strengthening resilience through evidence-based policies, technological innovation, equitable resource allocation, and inclusive participation can substantially reduce climate-related risks while promoting sustainable development. This review provides a comprehensive framework to guide policymakers, practitioners, and public health professionals in designing integrated strategies that protect human health and support resilient communities in an era of accelerating climate change.

Keywords: Climate; Climate Resilience; Climate Change Adaptation; Public Health; Health Sector

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Citation: Abedini A, Tohidi Sardasht A, Layeghi B, Davari Touchahi E, Taherkhani F, Dalaei H, et al. Climate Change, Health, and Resilience: A Comprehensive Review of Adaptation Strategies. Climate Health. 2026;1(2):74-93.

https://doi.org/***

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Introduction

Climate change represents one of the most pressing challenges of our time, affecting every aspect of human life and natural systems. Rising temperatures, shifting precipitation patterns, extreme weather events, and environmental degradation are creating unprecedented risks to public health, food security, water resources, and community well-being. Vulnerable populations, including children, the elderly, women, marginalized groups, and outdoor workers face disproportionate impacts from these changes.

Building climate resilience requires integrated, multi-sectoral approaches that address the complex interconnections between environmental health, social equity, economic stability, and infrastructure systems. This review presents practical, evidence-based strategies for enhancing community resilience across diverse climate-related challenges. These abstracts span critical domains, including health systems, water and sanitation, food security, vector-borne diseases, extreme weather events, air quality, and vulnerable population protection.

The strategies presented emphasize the importance of combining traditional knowledge with modern science, fostering cross-sectoral collaboration, investing in resilient infrastructure, strengthening early warning systems, and ensuring equitable access to resources and services. Together, these approaches provide a comprehensive framework for communities, policymakers, and practitioners working to build adaptive capacity and protect human health in an era of accelerating climate change. The integrated conceptual framework, including the relationships among climate hazards, health threats, resilience strategies, and expected outcomes, is presented in Figure 1.

Methods

This study was conducted as a narrative review. Relevant literature on climate change, health, and community resilience was identified through searches of major scientific databases, including PubMed, Scopus, Web of Science, and Google Scholar. Keywords such as "climate change", "health", "resilience", "adaptation", "community resilience", "public health", and related terms were used to identify relevant publications.

Peer-reviewed articles, review papers, and reports from reputable international organizations were reviewed. The selected literature was examined to identify key themes and practical adaptation strategies related to climate change and health. Findings were then organized into major thematic areas, including health systems, water and sanitation, food security, climate-sensitive diseases, extreme weather events, mental health, and vulnerable populations.

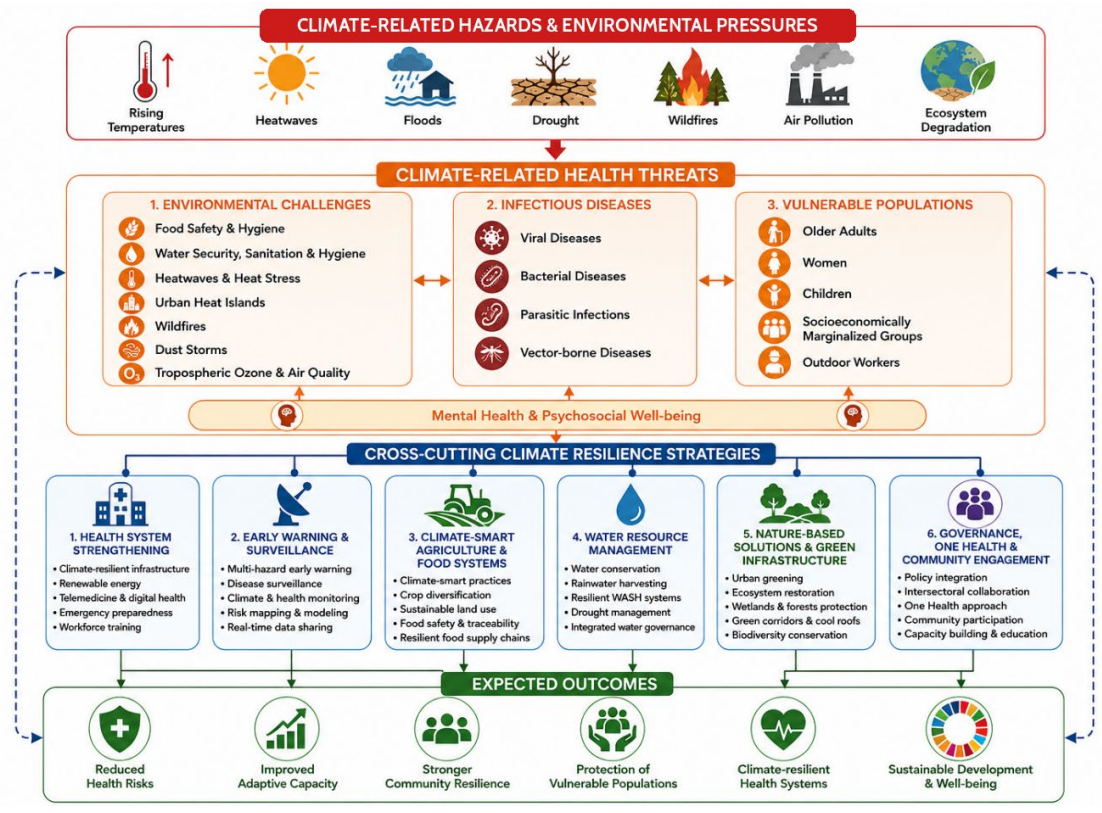

Figure 1: Integrated conceptual framework of climate resilience strategies for protecting human health.

The evidence gathered from the literature was synthesized narratively to provide an overview of current knowledge and practical strategies for strengthening community resilience to climate change and protecting human health.

Results and Discussion

Healthcare Facilities

Climate change is increasing the frequency and intensity of events such as heatwaves, floods, and storms, disrupting healthcare infrastructure and services [1] Such impacts threaten the functionality of health systems, especially in regions with limited resources. Integrating innovative technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and renewable energy into healthcare planning can significantly enhance resilience [2].

Ensure continuous power supply: Install solar photovoltaic systems with battery storage and integrate AI based energy management to reduce dependence on unstable grids. Optimized energy use ensures critical equipment remains operational during outages [3].

Implement AI driven early warning systems: Use real time meteorological data, environmental sensors, and predictive analytics to forecast severe weather events. Automated alerts can trigger emergency protocols, resource allocation, and public notifications, reducing disaster response time [4].

Expand telemedicine and remote diagnostics: Develop telehealth platforms and AI powered diagnostic tools to maintain care access during extreme weather or air pollution events. This approach reduces unnecessary hospital visits and supports vulnerable populations in remote areas [5].

Strengthen climate smart waste management: Use AI enabled medical waste sorting and smart routing for collection to prevent environmental contamination during crises. Integrated inventory systems can predict shortages and reduce waste of essential supplies [6].

Provide technology based staff training: Deliver Virtual Reality [VR] crisis simulations and Chabot based learning modules to improve readiness for climate related health emergencies. Digital training enhances staff confidence and ensures rapid, coordinated responses [7].

Enhance inter institutional coordination: Create secure digital platforms linking healthcare facilities, meteorological agencies, and crisis management authorities for real time information exchange. Effective data sharing improves situational awareness and resource deployment [8].

Water, Sanitation and Hygiene (WASH)

Climate resilient WASH infrastructure: Build and maintain water and sanitation systems designed to withstand extreme weather events, such as flood-proof latrines and raised water storage tanks, reducing service disruption during disasters [9].

Integrated health and climate adaptation planning: Incorporate climate vulnerability and adaptation assessments (V&As) into national health strategies, ensuring that health facility design and location take future climate risks into account [10].

Mental health support: Establish targeted mental health programs in disaster-prone areas to address climate-related trauma, with community-based counseling and emergency psychosocial support [9].

Alternative livelihood programs: Support income diversification in climate-affected regions to reduce dependence on climate-sensitive occupations, thereby increasing community adaptation capacity [9].

Cross-sectoral collaboration: Foster partnerships between health, water, education, and environmental agencies to ensure integrated disaster preparedness and resource sharing for resilience building [11].

Investment in low-carbon, sustainable health systems: Commit to reducing health sector greenhouse gas emissions while maintaining resilience, following global targets such as achieving net zero by 2050 [10].

Improved data and monitoring: Use early warning systems, climate modelling, and WASH service tracking to anticipate and respond quickly to emerging risks, prioritizing high-risk populations.

These measures align with findings from systematic reviews showing that primary healthcare systems play a pivotal role in enhancing resilience by providing accessible, responsive, and reliable services [11]. Political commitments made under the COP26 Health Program now require urgent operationalization to achieve progress on a large scale. Without durable, climate-resilient WASH and healthcare systems, vulnerable populations will remain “on the brink of the climate crisis” [12].

Enhancing Climate Resilience in Food Safety and Hygiene

Climate change is reshaping food systems by shifting temperature, humidity, and precipitation patterns, which raises risks to food safety and hygiene. More frequent extreme weather alters pathogen ecology and mycotoxin formation, elevating contamination risk at both pre-harvest and post-harvest stages, while supply chains in resource-limited regions face temperature excursions and infrastructure failures[13, 14]. Addressing these risks requires coordinated action that bridges scientific tools, policy reform, and local adaptive capacity. The following interventions outline a practical, evidence-based framework.

Climate-smart agriculture: Monitoring and decision-support systems enable timely field interventions, while controlled-environment and vertical farming stabilize production independent of external extremes[15, 16].

These approaches reduce exposure to climate-driven yield and contamination shocks.

Cautious gene editing: CRISPR-Cas9 can accelerate development of heat-, drought-, and toxin-tolerant crop varieties [17]. Deployment must follow transparent regulatory, ethical, and biosafety frameworks [18].

Renewable-powered cold chains: Strengthening cold-chain infrastructure with renewable energy reduces spoilage and pathogen proliferation. This is especially critical in regions prone to power instability [19].

Active packaging: Validated antimicrobial films, including safe nanoparticle-based solutions, extend shelf life under humid conditions [20]. These technologies help maintain product quality across longer supply routes.

Predictive surveillance: Machine-learning models integrating meteorological, environmental, and microbial data enable early detection of elevated risk, including aflatoxin dynamics that inform harvest and storage decisions [21, 22]

Portable biosensors: Validated colorimetric gold-nanoparticle assays and rapid tests provide near-real-time field data to guide interventions [18]. Mobile alert platforms disseminate concise advisories to farmers, processors, and distributors.

Advanced inspection: Nanosensor-based intelligent packaging systems can support continuous monitoring in food storage and processing facilities, while non-thermal methods such as cold plasma can reduce fungal and mycotoxin contamination without compromising quality [23, 24]. Coupling these with traceability systems enables targeted recalls [25]

Climate-responsive governance: Integrating food safety into climate adaptation policy and aligning standards with Codex Alimentarius and HACCP can improve policy coherence [14, 26]. Capacity-building for regulators and inspectors strengthens institutional readiness [14].

Community-based measures: Local projects upgrading storage, introducing low-cost antimicrobial filtration, and providing solar cooling reduce post-harvest loss [27]. Training, mobile outreach, and public–private partnerships improve equitable access to adapted technologies [15].

Strengthening food safety under climate change requires integrated action across innovation, governance, and community engagement. Priority next steps include operational pilots and multi-site validation across diverse agroecological settings, alongside economic and social evaluations to ensure affordability and adoption by smallholders. Combined with clear biosafety oversight and inclusive policies, these strategies can substantially reduce climate-related food safety risks and protect public health.

Agriculture and Food Production

Climate resilience in agriculture refers to the ability to anticipate, adapt to, and recover from climate-related hazards while sustaining productivity [28]. The sector is vulnerable to drought, floods, temperature extremes, salinity, and pests, all of which threaten yields. Climate-resilient agriculture addresses these challenges through sustainable land and water management, enhanced productivity, and reduced greenhouse gas emissions [29]. Key strategies include selecting climate-adapted crops, using advanced technologies, managing resources efficiently, and applying community-level adaptation initiatives [30, 31]. Proposed solutions include:

Site-specific crop choice: Selecting crops and varieties adapted to local climate conditions increases resilience to drought, heat, and pest extremes [32].

Smart technology integration: Using forecasting tools, decision-support systems, and tailored equipment helps farmers respond swiftly to weather changes [31].

Zero tillage systems: Reducing soil disturbance saves energy, maintains soil health, and limits greenhouse gas emissions [33]

Diversified farming systems: Combining crops, livestock, and agroforestry spreads risk and optimizes resource use [34]

Efficient water management: Adopting precision irrigation and rainwater harvesting enhances water-use efficiency and reduces vulnerability to drought [29]

Balanced fertilization and soil re carbonization: Applying nutrients according to soil tests and incorporating organic matter improves productivity and resilience [35].

Renewable energy adoption: Replacing fossil fuels with solar or wind power reduces emissions and improves sustainability [34].

Community-level adaptation strategies: Coordinating resource management, contingency planning, and disaster preparedness enhances local capacity to face climate risks [36].

Improved crop breeding: Developing heat-, drought-, and pest-resistant varieties strengthens long-term productivity under climate stress [32].

Policy and institutional support: Implementing policies that incentivize sustainable practices and provide financial safety nets fosters adoption of resilient farming methods [35].

Food Security

Climate change threatens global food security by lowering crop yields, increasing pest and disease risks, and worsening water scarcity [37]. While agriculture is vulnerable, it can also mitigate climate impacts through climatesmart strategies. Agricultural biodiversity improves resilience by conserving soil and water and enhancing ecosystem services [38]. Rural poor and smallholder farmers face the greatest risks due to limited adaptive capacity, making integrated environmental, economic, and social solutions essential [39]. Proposed strategies include:

Promoting crop genetic diversity: Growing a variety of crop genotypes reduces vulnerability to pests, diseases, and extreme weather, ensuring more stable yields and improving food security [38].

Enhancing species and ecosystem diversity: Integrating multiple species and maintaining healthy ecosystems supports soil fertility, water retention, and pest regulation, which collectively increase resilience to climate stressors [38].

Implementing climate-smart agriculture (CSA): CSA practices, such as conservation tillage, integrated pest management, and efficient irrigation, improve productivity, reduce greenhouse gas emissions, and strengthen adaptation capacity [40].

Adopting sustainable land management: Avoiding deforestation, restoring degraded land, and improving soil health help preserve ecosystem services needed for long-term agricultural productivity [37].

Strengthening smallholder farmer support systems: Providing access to credit, insurance, and climate-resilient inputs empowers small farmers—who supply much of the world's food but are highly vulnerable to climate change [39].

Developing market and price stabilization mechanisms: Reducing market volatility through cooperative models, fair-trade systems, and storage facilities can protect farmers' incomes during climate-related disruptions [37].

Improving rural infrastructure and services: Expanding access to roads, clean water, education, and healthcare strengthens community resilience and reduces vulnerability to livelihood shocks [41].

Integrating livelihood diversification: Encouraging non-agricultural income sources reduces dependence on climate-sensitive crops, enhancing adaptive capacity for rural households [39].

Drought and Water Crises

Drought and water scarcity threaten public health, economic stability, and food security worldwide [42]. As climate change intensifies these events, communities need coordinated strategies combining technology, governance, and public engagement to sustain water resources [43]. Building resilience depends on optimizing resource use, preparing for shortages, and ensuring fair, effective responses [44]. Practical solutions include:

Efficient water management: Promote conservation by reducing demand and waste in all sectors. Use smart meters and tiered pricing to encourage responsible consumption, install water efficient fixtures, and upgrade infrastructure to detect and fix leaks [42].

Sustainable landscaping and irrigation: Encourage xeriscaping with drought resistant plants and smart irrigation systems that adjust watering based on weather and soil moisture. In agriculture, adopt drip and micro sprinkler systems to deliver water directly to plant roots, reducing evaporation [45].

Early warning systems: Implement integrated drought monitoring combining satellite data, forecasts, and ground measurements of soil moisture and reservoir levels. Use indices such as PDSI and SPI to trigger timely alerts and public advisories [42, 43].

Climate smart agriculture: Introduce drought tolerant crop varieties and soil building practices such as no till farming and cover cropping to improve water retention. Apply precision agriculture tools to optimize irrigation and reduce waste [46].

Community engagement: Conduct workshops, school programs, and public campaigns to increase awareness of conservation practices. Involve citizens in leak detection, rainwater harvesting, and community gardens to foster shared responsibility [47, 48].

Policy and governance: Enforce water conservation ordinances, establish clear water rights, and develop drought contingency plans with defined triggers and response measures. Provide incentives such as rebates for efficient appliances and landscaping [42, 49].

Infrastructure investment: Expand water recycling and reclamation facilities, develop rainwater harvesting systems at residential and municipal scales, and invest in aquifer storage and recovery to build reserves for dry periods [46].

Inter jurisdictional cooperation: Strengthen coordination between municipalities, regions, and countries that share water resources to ensure equitable and sustainable allocation [42, 43].

Resilient communities plan ahead, conserve resources, and work together to manage water equitably. Combining local action with institutional support offers the best defense against the growing threat of drought and water crises.

Heatwaves

Climate change is intensifying the frequency and severity of heat waves, posing risks to public health, food security, and community well-being. Many cities lack adequate preparation, making it essential to combine technology, policies, and community-based actions to protect vulnerable populations. Effective resilience-building requires addressing environmental, social, and infrastructural dimensions [50, 51]. Proposed solutions include:

Urban greening and shaded spaces: Expanding tree cover, green roofs, and shaded public spaces can significantly reduce local temperatures, mitigate heat islands, and improve air quality [52].

Heat wave early warning systems: Implementing timely alerts and forecasts enables individuals and organizations to take preventive measures, reducing risks to health and safety [50].

Community-based volunteer programs: Training and mobilizing volunteers to support vulnerable groups during extreme heat events enhances response capacity at the neighborhood level [51].

Public awareness and education: Educating residents, especially older adults, about the signs of heat-related illnesses, prevention strategies, and available resources helps reduce health impacts [53].

Climate-adapted building codes: Updating urban planning and construction regulations to include thermal comfort standards, reflective materials, and ventilation improvements strengthens resilience [52].

Digital tools for heat adaptation: Utilizing mobile applications, social media, and real-time mapping platforms can improve communication, monitor risk areas, and coordinate relief actions [54].

Strengthening social capital: Encouraging cooperation and trust between citizens, local authorities, and NGOs facilitates more effective collective action against extreme heat [55].

Multidimensional resilience assessment: Evaluating socio-economic, health, demographic, ecological, and political capacities helps target interventions where they are most needed [56].

Urban Heat Islands (UHIs)

Urban heat islands (UHIs) are a growing challenge in the context of climate change, exacerbating heat stress, energy demand, and public health risks. Their mitigation requires integrated solutions involving government, private sectors, NGOs, and citizens in a coordinated effort. The strategies below provide practical pathways for enhancing community resilience [57].

Promoting Public Transportation: Expanding public transport corridors and improving accessibility can significantly reduce single-occupancy vehicle use and associated heat generation [58].

Encouraging Electric Vehicles: Incentives for electric vehicle adoption can reduce both air pollution and the waste heat that contributes to UHIs [59].

Facilitating Teleworking and Compact Urban Form: Remote work opportunities and planning workplaces near residences ease traffic congestion and lower heat emissions [58].

Expanding Renewable Energy Use: Installing solar panels or solar water heaters on urban surfaces harnesses abundant solar energy while cutting fossil fuel use and waste heat output [59].

Increasing Green Spaces and Green Roofs: Vegetation provides shading and evapotranspiration cooling, reducing urban temperatures by up to 40% from shade alone[60].Recycled water can be used to irrigate these spaces in water scarce regions.

Providing Shade Infrastructure: Shading streets, public spaces, and building entrances using trees, artificial structures, or solar canopies improves outdoor thermal comfort [59].

Using Light Reflective and Low Conductivity Materials: High albedo surfaces and materials with low thermal conductivity reduce heat absorption, while building designs that encourage ventilation further decrease cooling needs [58].

Planning Green Corridors and Building Layout: Urban design that maintains air flow paths between green areas can enhance ventilation and heat exchange, reducing local temperature [58].

Applying Smart Urban Management: Artificial intelligence and monitoring systems can optimise urban heat mitigation strategies and guide sustainable development [59].

Raising Public Awareness: Educational campaigns in schools, communities, and media increase understanding of UHIs and foster citizen participation in mitigation [58].

Fostering Inclusive Cooperation: Collaboration among governments, NGOs, and community groups encourages sharing of successful policies and joint implementation of climate resilience measures [59].

Promoting Waste Recycling: Waste separation, recycling, and the use of non recyclable waste for fuel or fertilizer reduce landfill emissions and contribute to sustainable urban systems [59].

Outdoor Workers' Safety and Health

Outdoor workers face heightened occupational health risks due to climate change, which amplifies heat waves and related illnesses. In areas like sub Saharan Africa and West Asia, rapid urbanization and poor air quality worsen these hazards. Urban Heat Island effects intensify heat stress and pollution, and without targeted adaptation measures, productivity, health, and survival rates among these workers are expected to decline [61-65]. Proposed solutions include:

Review and enhance workplace regulations: Amending labor laws to include occupational heat exposure standards ensures legal protection for workers in extreme climates [66].

Climate-resilient infrastructure: Introducing shaded work areas, reflective building materials, and natural ventilation reduces direct heat exposure and improves worker safety [59].

Heat stress monitoring systems: Deploying wearable sensors and workplace monitoring stations enables early detection of heat stress symptoms, allowing timely interventions [67].

Targeted worker training: Providing education on hydration, rest cycles, and recognizing symptoms of heat related illness increases workers' ability to self manage risks [68].

Shift scheduling adjustments: Implementing early morning or night shifts during heat waves helps minimize peak heat exposure and related productivity losses [69].

Insurance and emergency funds: Supporting climate related occupational insurance programs offers financial resilience for workers affected by heat related health issues [65].

Integration of green spaces in urban planning: Expanding green corridors and tree cover in industrial

and urban work zones mitigates UHI effects and improves air quality for workers [64].

Evidence based adaptation policies: Employing data from sector specific studies to inform worker protection policies ensures that adaptation is context specific and sustainable [70].

Heat Stress as an Occupational Hazard

Heat stress is an increasingly critical occupational hazard as climate change intensifies the frequency, duration, and severity of extreme heat events [71]. Outdoor sectors such as construction, agriculture, transport, and mining face significant risks, while indoor environments without adequate cooling like warehouses and manufacturing facilities are also vulnerable. Preventing heat stress requires integrated, context-specific measures combining engineering, administrative, educational, and legal approaches [72]. Practical strategies may include:

Proactive hazard identification: Recognize heat stress as a preventable risk, integrate it into workplace safety assessments, and develop tailored heat management plans using seasonal forecasts [73].

Engineering controls: Reduce heat through shade structures, reflective materials, insulation, and ventilation. Use evaporative coolers, air conditioning, or spot fans where possible [72].

• Outdoor cooling solutions: Provide portable shade, misting stations, and mobile cooling units. Re design work layouts to reduce time in hot zones and automate high heat tasks [73]. Work organization adjustments: Apply flexible schedules, rotate tasks between hot and cool areas, and shift heavy work to cooler times of day. Ensure shaded rest breaks and constant access to potable water [74].

Training and awareness: Train workers and supervisors to recognize early symptoms, maintain hydration, follow acclimatization protocols, and administer first aid. Incorporate worker feedback for cultural relevance [75].

Community engagement: Partner with local organizations for public health campaigns and resilience workshops [76].

Monitoring and surveillance: Track temperature, humidity, and WBGT on site; in high risk conditions, use wearable sensors. Regularly review prevention programs [69].

Emergency preparedness: Maintain trained responders, rapid cooling equipment, and clear medical protocols [69].

Legislative measures: Set legal exposure limits, mandate employer controls, and enforce compliance through inspections. Use ILO and WHO frameworks as benchmarks [72].

Climate integrated planning: Include heat resilient workplace design in broader climate adaptation plans, applying green infrastructure and climate projections [76].

Wildfires

Forests are vital for biodiversity, water regulation, and carbon storage, yet they face increasing threats from destructive wildfires intensified by climate change. Rising temperatures, prolonged droughts, and erratic rainfall have amplified fire frequency and severity, altering ecosystems and undermining resilience [77]. Strengthening community resilience requires integrated strategies that combine prevention, preparedness, ecosystem restoration, and climate informed governance.

Fire Management and Prevention: Creating firebreaks, managing vegetation by removing dry fuel, and using controlled grazing or pruning can slow fire spread. The introduction of resilient plant species, supported by satellite and drone monitoring, aids early detection and targeted suppression [78].

Community Preparedness and Planning: Public education on fire safety, safe evacuation routes, and regular drills increase readiness. Fire resistant construction materials and improved access to firefighting water resources reduce structural vulnerability, while fire insurance can mitigate economic losses [79].

Post Fire Management and Ecosystem Restoration: Replanting native vegetation, preventing soil erosion, and safeguarding watersheds help ecosystems recover. Engaging Indigenous communities and integrating traditional ecological knowledge, such as controlled burns, can enhance restoration effectiveness [80].

Climate Smart Governance: Reducing greenhouse gas emissions, supporting afforestation, and fostering regional and global cooperation in fire management address underlying climatic drivers while promoting shared resources and expertise [81].

Protection of Wetland Ecosystems: Restoring wetlands, particularly peatlands and coastal habitats like mangroves and seagrass meadows, enhances resilience by storing carbon, regulating water, and serving as natural firebreaks. Actions such as rewetting peatlands and rehabilitating floodplains deliver multiple ecosystem services alongside climate protection [77].

Dust Events

Dust storms, intensified by climate change, are increasingly impacting urban and rural communities, threatening health, livelihoods, and ecosystems. These events can strain healthcare systems, reduce air quality, and disrupt daily life. Building climate resilience requires integrating traditional knowledge with modern science, technology, and participatory approaches to protect vulnerable populations and reduce long term impacts [82].

Integrating Indigenous Knowledge with Science: Combine local ecological knowledge such as traditional signs of wind and sand shifts with system dynamics models to create accurate forecasting tools that communities understand and trust [82].

Multidisciplinary Planning: Bring together health

experts, economists, sociologists, and meteorologists to design strategies addressing air quality, cardiovascular and respiratory health, and economic stability in an integrated manner [83].

Real Time Early Warning Systems: Install IoT sensor networks and integrate them with satellite data to issue alerts through mobile apps, radio, and community networks. These measures enable timely actions such as adjusting school hours or activating clean-air shelters [84].

Targeted Health Interventions: Implement community health protocols, including mask distributions for high risk patients and temporary clinics during severe dust episodes, to reduce hospitalization rates [84].

Regional Data Sharing and Policy Coordination: Collaborate across regions to share meteorological data, issue unified alerts, and coordinate emergency responses, ensuring faster and more consistent protective measures [85].

Nature Based Solutions: Restore forests and plant dust resistant vegetation around urban areas to filter airborne particles and reduce PM2.5 and PM10 concentrations during storms [86].

Strengthening Healthcare Facilities: Equip hospitals and clinics with high efficiency filtration systems, train staff in dust specific protocols, and establish outreach programs targeting vulnerable populations [87].

Community Engagement and Education: Establish neighborhood dust response committees, encourage information sharing via social platforms, and promote practical household measures such as sealing windows and rescheduling outdoor work [87].

Ecosystem Restoration for Long Term Resilience: Rehabilitate wetlands, such as Hoor Al Azim, and create agricultural windbreaks and greenbelts to act as natural dust barriers around communities [86].

International and Cross Border Cooperation: Develop joint diplomatic and technical programs with neighboring countries to address transboundary dust sources, coordinate funding, and implement joint land restoration projects [88].

Parasitic Infections in Vulnerable Communities

Climate change, one of the greatest health challenges of the 21st century, threatens not only natural resources and food security but also public health by increasing the spread of parasitic diseases in vulnerable regions[89]. Rising temperatures, altered rainfall, and extreme events enable parasites and their vectors to expand into new areas, overwhelming existing health systems [90]. In Iran, conditions have facilitated the spread of diseases such as cutaneous leishmaniosis into provinces where they were previously rare [91].

Climate-resilient WASH infrastructure: Developing flood-resistant latrines, ensuring safe drinking water sources, and promoting hygiene behaviors such as regular handwashing interrupt parasite transmission [92].

Mass drug administration: Implementing regular deworming programs in schools or communities using effective antiphrastic medications reduces infection prevalence, especially when combined with hygiene education and follow-up [93].

Community health education: Training communities about parasite transmission and prevention encourages safer practices such as proper waste disposal and latrine usage, leading to sustainable behavior change [94].

Environmental management: Reducing habitats for disease vectors for example, clearing aquatic vegetation harboring snail hosts limits parasite life cycles and can also benefit local livelihoods [95].

Surveillance and early warning: Applying satellite imagery, GIS mapping, and predictive climate modeling supports targeted prevention, while mobile-based community reporting improves timely response [96].

Integrated governance and One Health: Coordinating policies across health, agriculture, and environmental sectors fosters comprehensive control strategies, addressing human, animal, and environmental health together [97].

Ongoing research and monitoring: Investing in cross-disciplinary studies and establishing national networks for climate-sensitive disease data ensures updated risk assessments and informed decision-making [98].

Regional and international cooperation: Sharing epidemiological and climate-related data across borders enhances preparedness for parasite outbreaks in areas with similar climate vulnerabilities [92].

Bacterial Diseases

Climate change is heightening bacterial disease risks by altering transmission patterns, accelerating antimicrobial resistance, and burdening public health systems. Rising temperatures, extreme weather, and water system changes foster bacterial growth, particularly in vulnerable regions [99, 100]. Warmer conditions increase outbreaks of waterborne pathogens, and a 10 °C rise significantly boosts resistance in E. coli and S. aureus [101]. Floods and other extreme events worsen water contamination, amplifying health threats, which calls for urgent, adaptive, and evidence-based strategies [102]. Proposed strategies may include:

Rapid diagnostics: Implement diagnostic systems at healthcare and national levels to enable early detection and targeted treatment of bacterial infections, reducing unnecessary antibiotic use and slowing resistance trends [102].

Predictive disease modeling: Integrate meteorological and climate data into predictive models to anticipate outbreaks, inform public health responses, and prioritize resources in high risk seasons or regions [100].

One Water management approach: Coordinate governance across drinking water, wastewater, and stormwater systems to prevent contamination, particularly in flood-prone areas, thereby minimizing

bacterial exposure risks [103].

Strengthened water infrastructure: Invest in climate resilient infrastructure, including water treatment facilities and flood resistant systems, to ensure consistent delivery of safe water during extreme weather events [104].

Community education: Promote public awareness about the links between climate change, bacterial diseases, and hygiene practices to encourage preventive behaviors, especially in vulnerable communities [103].

Surveillance networks: Establish or expand integrated disease surveillance systems capable of monitoring bacterial disease trends, antimicrobial resistance, and climate indicators in real time [101].

Viral Diseases

Climate change alters ecological and environmental conditions in ways that can affect viral transmission dynamics, vector and host distributions, and the resilience of public health systems. Rising temperatures, shifting precipitation patterns, and environmental degradation can amplify the spread of infectious diseases and strain health infrastructure [105]. Strengthening climate resilience in communities is critical to prevent and mitigate such health impacts. Proposed solutions include:

Strengthen environmental surveillance and health informatics: Develop integrated systems to monitor environmental variables such as temperature, humidity, and air quality alongside vector presence and disease incidence. Pairing these systems with rapid response platforms enables early outbreak detection and timely public health interventions [106, 107].

Create healthier urban environments: Design cities with natural ventilation, abundant green spaces, and reduced crowding in high risk areas. Such interventions can lower urban heat and improve air quality, reducing conditions that favor virus persistence and transmission [105, 108].

Strengthen primary health systems and community engagement: Expand universal access to vaccines, diagnostics, and credible health information. Support community health teams and rapid response units to improve service reach, and promote clear, transparent risk communication to counter misinformation during climate linked health events [109, 110].

Safeguard food and water security and protect ecosystems: Implement sustainable management of water, soil, and food systems to reduce malnutrition, thereby improving immunity against infections. Protecting biodiversity and conserving ecosystems can help prevent zoonotic spillovers by minimizing disruption to wildlife habitats [111].

Foster cross disciplinary and multi level collaboration: Build networks linking researchers, policymakers, clinicians, and communities to share resources, best practices, and data. Coordinating climate adaptation and health financing priorities helps create integrated and sustained responses [112].

Integrate climate health evidence into policy and planning: Incorporate climate indicators into public health strategies, urban development plans, and budget allocations. Using scenario based analyses can help prioritize vulnerable populations and ensure preparedness through stockpiling, surge staffing, and scalable healthcare facilities resilient to weather related disruptions [105].

Vector-Borne Diseases

Climate change is accelerating environmental shifts that affect the prevalence and distribution of vector borne diseases. Rising temperatures, altered rainfall patterns, and extreme events such as floods are changing vector habitats and transmission dynamics, placing additional stress on public health systems [113, 114]. Strengthening resilience against these challenges requires integrating evidence based prevention, surveillance, policy, and community action.

Enhance early warning and surveillance systems: Establish integrated monitoring of vector populations, environmental changes, and disease incidence. Using geographic information systems (GIS) and climate linked forecasting can enable rapid response to emerging threats [115].

Improve health infrastructure and rapid response capacity: Strengthen primary health facilities to ensure timely diagnosis, treatment, and outbreak containment. Investing in mobile clinics and surge staffing improves coverage during crises [89].

Expand vector control measures: Implement targeted vector control, including insecticide treated nets, indoor residual spraying, and habitat modification. Combining chemical, biological, and environmental approaches can reduce transmission risks sustainably [115].

Foster interdisciplinary and community engagement: Integrate the expertise of epidemiologists, ecologists, and local leaders in decision making. Public participation improves adoption of protective behaviors and facilitates culturally appropriate interventions [115].

Promote environmental management and ecosystem health: Address deforestation, water mismanagement, and poor waste disposal practices that create breeding grounds for disease vectors. Healthy ecosystems provide natural barriers to vector proliferation [114].

Strengthen policy integration and governance: Align climate adaptation policies with health sector strategies to ensure coordinated action and avoid fragmented efforts. Resilient governance can maintain services during climate driven health emergencies [113].

Increase research and innovation investment: Support applied research on climate vector disease linkages and the development of new diagnostics, vaccines, and control technologies. Sustainable funding can bridge gaps between scientific advances and national programs [89].

Tropospheric Ozone Levels

Ground-level ozone (tropospheric O_3) is a harmful secondary pollutant formed by the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) under sunlight. Elevated concentrations especially during heat waves and stagnant air conditions pose severe threats to human health, ecosystems, and agriculture [116]. Mitigating ozone formation and improving community resilience require an integrated effort across technical, regulatory, and societal domains.

Reducing Nitrogen Oxide Emissions: Transitioning to cleaner transport technologies such as electric, hybrid, or compressed natural gas vehicles, installing selective catalytic reduction technologies in industries, and banning the burning of agricultural and waste residues can significantly limit NO_x emissions [116].

Reducing VOC Emissions: The use of low-VOC paints and solvents, installing gasoline vapor recovery systems at fueling stations, and enforcing strict VOC controls in refineries and chemical plants help minimize precursor gases [117].

Expanding Pollution-Resistant Green Spaces: Selecting ozone-resistant species, such as elm, acacia, ash, and myrtle, and developing urban green belts can mitigate ozone levels. Proper irrigation and monitoring ensure optimal environmental performance [118].

Improving Urban Ventilation: Designing wind corridors through open urban layouts, preventing construction that obstructs airflow, and using computational fluid dynamics to identify low-flow areas can enhance dispersion of pollutants [4].

Strengthening Monitoring and Early Warning: Deploying stationary and mobile monitoring stations to track ozone and its precursors, combined with satellite data and air quality models, enables timely forecasts. Multi-tiered alert systems can notify the public via mobile apps, SMS, and public displays [5].

Promoting Clean Transportation Policies: Gradual replacement of public fleets with low-emission vehicles, restricting traffic during high-ozone days, and improving fuel quality can reduce pollution sources [116].

Enhancing Industrial Regulations: Establishing emission limits compliant with international standards, mandating the use of control technologies, and enforcing online monitoring with strict penalties can lower industrial contributions [117].

Fostering Regional Coordination: Coordinating monitoring networks, aligning emission-reduction policies, and implementing joint emergency plans strengthen cross-boundary resilience [118].

Empowering Public Awareness and Participation: Educating residents on ozone risks, peak pollution times, and exposure reduction through schools, media, and digital platforms promotes safer behaviors. Citizen science programs can engage communities directly [119].

Supporting Vulnerable Populations: Identifying at-risk groups, creating clean-air shelters, providing protective equipment, and subsidizing these measures help reduce health impacts [120].

Mental Health

Climate change affects not only physical environments but also mental well being. Extreme weather events such as heatwaves, floods, wildfires, and forced migration increase anxiety, depression, trauma, and feelings of loss, particularly among vulnerable groups like children, the elderly, and displaced populations [121, 122]. Despite the growing threat, mental health integration into climate adaptation planning remains limited, demanding targeted and inclusive strategies.

Promote individual coping mechanisms: Encourage evidence based coping strategies, including problem focused actions [e.g., advocacy, preparedness], emotion focused practices [e.g., mindfulness, self care], and meaning focused approaches [e.g., fostering hope and spiritual connection]. Such actions help reduce eco anxiety and build personal resilience [123].

Increase access to mental health services: Expand affordable and timely psychological support, especially in underserved areas, to address climate related distress. Accessible services strengthen community capacity to recover from climate shocks [124].

Develop community based psychosocial programs: Support initiatives like peer support groups, climate cafés, and youth dialogues that offer safe spaces to share experiences, process emotions, and build trust. These programs reduce isolation and promote collective resilience [125].

Integrate mental health in climate adaptation policies: Incorporate psychological support into disaster risk reduction frameworks and Nationally Determined Contributions. Policy integration ensures mental well being is prioritized alongside physical health during climate planning [122].

Invest in green infrastructure for psychological benefits: Promote urban parks, reforestation, and community gardens that provide restorative environments. Contact with nature is associated with reduced stress, improved mood, and stronger social connections [124].

Train local leaders and professionals: Equip teachers, health workers, and community leaders with skills in psychosocial support, enabling culturally sensitive and sustainable responses to climate related mental health challenges [124].

Foster cross sector partnerships: Build collaborations among climate, health, and education sectors to share resources, coordinate interventions, and ensure inclusive approaches to mental health resilience [121].

Vulnerable Populations: Elderly People

Climate resilience refers to the capacity of individuals, communities, and systems to anticipate,

prepare for, and respond to the impacts of climate change while minimizing damage and maintaining essential functions [126]. Older adults are among the most vulnerable groups due to physiological decline, chronic health conditions, and limited adaptive capacity [127]. Climate change intensifies these risks, especially during extreme events such as heatwaves and cold spells, which worsen existing illnesses and can raise mortality rates [128]. Strengthening the climate resilience of the elderly requires coordinated, targeted, and proactive measures.

Education and risk awareness: Providing older adults and their caregivers with clear, accessible information on preventive actions against heat stress, air pollution, and other climate-related hazards improves early response and reduces health risks [126].

Access to essential equipment: Ensuring availability of cooling systems, ventilation, and air filtration devices in households helps mitigate the health impacts of extreme heat and poor air quality [127].

Healthy nutrition and regular activity: Encouraging balanced diets and moderate physical exercise supports immune function and increases the ability to withstand climate-related stressors [129].

Stress management and emotional support: Offering training in relaxation techniques and stress management skills reduces anxiety and depression linked to climate-related challenges [130].

Social connections and support networks: Facilitating regular contact with family, friends, and community groups mitigates isolation and fosters resilience during climate emergencies [131].

Elder-friendly urban design: Developing accessible public spaces, shaded walkways, and proximity to essential services ensures that older residents can safely navigate their environment during extreme weather events [132].

Resilient infrastructure: Strengthening buildings, transport systems, and utility networks against hazards such as floods or storms reduces disruptions and safeguards elderly populations [133].

Improved healthcare access: Expanding availability of high-quality medical care and integrating emergency health services into local systems enables timely intervention during climate-induced health crises [134].

Community climate education: Organizing public awareness campaigns that highlight climate risks and protective measures helps communities collectively support their older population [135].

Formal support networks: Building structured systems for emotional, financial, and logistical assistance during crises enhances preparedness and recovery for elderly individuals [136].

Active participation opportunities: Involving older citizens in community decisions and local adaptation planning increases their sense of agency and ensures that their needs are addressed in resilience strategies [137].

Mental well-being promotion: Providing enjoyable and engaging activities boosts morale, fosters positive outlooks, and strengthens coping abilities during prolonged climate stressors [138].

Vulnerable Populations: Women

Women's resilience to climate change is a skill that can be developed through awareness, learning, and adaptive strategies [139]. Climate change disproportionately affects women particularly in rural and resource-dependent communities due to their caregiving roles, economic disadvantages, and exclusion from decision-making [140, 141]. These impacts include greater domestic burdens, increased gender-based violence, reduced employment, and limited access to resources, education, and healthcare. Social and cultural norms exacerbate vulnerabilities, while women's leadership remains underutilized in climate responses. Strengthening resilience requires gender-inclusive policies, equitable access to resources, education, protection against violence, support for women-led initiatives, resilient infrastructure, and inclusive governance. Integrating these strategies can create more equitable, effective, and sustainable climate action. Proposed strategies include:

Mainstream gender in climate policies: Integrate gender perspectives into all levels of climate adaptation and mitigation policies to ensure women's needs and priorities are recognized, promoting fair access to resources and decision-making forums [141].

Enhance women's access to resources: Provide equitable access to financial services, technology, and climate-resilient agricultural inputs to strengthen women's adaptive capacity and economic security [142].

Invest in women's education and skills training: Expand programs that offer climate-related vocational training, literacy, and leadership development, enabling women to actively engage in adaptation planning [140].

Strengthen protection against climate-related gender-based violence: Incorporate gender-sensitive risk assessments into disaster preparedness plans, ensuring safe environments for women and girls before, during, and after crises [143].

Support women-led climate initiatives: Fund and promote community projects led by women that address local climate challenges, creating role models and enhancing social cohesion [144].

Improve infrastructure and basic services: Develop resilient water, sanitation, health, and energy systems to reduce the domestic and caregiving burden on women during climate shocks [143].

Foster inclusive governance: Ensure women's representation in climate negotiation and policy-making bodies to shape adaptation strategies that reflect diverse experiences and knowledge systems [142].

Vulnerable Populations: Children's Health and Malaria

Climate change poses one of the most urgent global health threats, disproportionately affecting children due to their developing immune systems and heightened sensitivity to environmental changes [145, 146]. Among the major diseases influenced by a shifting climate, malaria has shown increases in transmission in tropical and subtropical regions as rising temperatures and changing rainfall patterns favor mosquito proliferation [147]. Strengthening resilience in children requires targeted, practical, and coordinated interventions [148, 149].

Environmental management and removal of breeding sites: Draining stagnant water, improving drainage networks, and optimizing irrigation practices reduce habitats for mosquito larvae and significantly lower malaria risk [150, 151].

Use of insecticide-treated bed nets: Providing and promoting consistent use of insecticide-treated bed nets, especially for children during nighttime, acts as a protective barrier against mosquito bites and is proven to decrease malaria incidence [152].

Education and awareness: Training families and communities to recognize malaria's early symptoms and teaching preventive behaviors accelerate diagnosis and improve treatment outcomes. Communicating the connection between climate change and shifting disease patterns fosters community engagement [145, 153].

Strengthening local healthcare systems: Enhancing the availability of essential medications and medical facilities, coupled with training healthcare workers in high-risk regions, ensures timely and effective treatment for infected children [147].

Nutrition and immune system support: Promoting balanced diets with sufficient vitamins and minerals strengthens children's ability to fight infections and supports recovery after illness [145].

Vegetation and microclimate improvement: Planting shade trees and creating green spaces help reduce localized ambient temperatures, which can make conditions less suitable for mosquito breeding, thereby indirectly lowering exposure risks [151].

A comprehensive approach that integrates environmental control, preventive tools, education, capacity-building in health services, and nutritional support is essential to reducing vulnerability. These strategies, when implemented in synergy, not only protect children's health but also promote sustainable and climate-resilient communities [146, 148].

Investments in these measures serve the dual purpose of safeguarding present health and preparing for future climatic shifts.

Vulnerable Populations: Socio-economically Marginalized Group

Climate change disproportionately affects socioeconomically marginalized populations due to increased exposure to environmental hazards, limited access to resources, and systemic inequalities that hinder effective adaptation [154]. Poverty, social exclusion, and geographic isolation interact to intensify vulnerability, requiring integrated strategies that combine immediate relief with long-term resilience building.

Adaptive Social Protection (ASP): ASP blends traditional social safety nets with proactive climate risk management, enabling timely and flexible assistance before, during, and after climate shocks. Measures such as cash transfers, public works, social insurance, and livelihood diversification reduce poverty and enhance adaptive capacity [155, 156]. A defining trait of ASP is anticipatory risk assessment, which helps pre-position resources for rapid hazard response. Effectiveness depends on multisectoral coordination, political commitment, and adaptation to diverse local socioeconomic conditions [154].

Transformative Community-Based Adaptation (TCbA): TCbA promotes resilience by ensuring marginalized groups actively participate in planning and implementing adaptation strategies. This approach tackles power imbalances, secures local agency, and integrates adaptation into broader social justice agendas [157]. Unlike token consultation, TCbA embeds community voices in decision-making, increasing intervention legitimacy and impact. Examples include citizen science initiatives in informal urban settlements, where residents collect flood-risk data to strengthen early warning systems and foster ownership [158].

Ecosystem-Based Disaster Risk Reduction (Eco DRR): Eco DRR leverages natural ecosystems such as wetlands, forests, and coastal vegetation for their protective functions against climate hazards. Restoration, afforestation, and buffer creation provide risk mitigation alongside biodiversity benefits [121] .When combined with indigenous ecological knowledge, community engagement, and sustained funding, Eco DRR delivers economically efficient and socially equitable results. Its success hinges on aligning interventions with local ecological and economic realities [154]. The climate-related health challenges, evidence-based resilience strategies, and expected public health outcomes identified in this review are synthesized in Table 1.

Conclusion

Climate change presents complex and interconnected risks that affect environmental systems, human health, economic stability, and social equity. The strategies presented in these abstracts demonstrate that climate resilience is not limited to a single sector but requires integrated action across healthcare, agriculture, water management, urban planning, occupational safety, infectious disease control, and social protection systems.

Investing in resilient infrastructure, strengthening early warning systems, protecting vulnerable populations, promoting sustainable environmental practices, and

Table 1: Summary of climate-related health challenges, evidence-based resilience strategies identified in the reviewed literature, and their expected public health outcomes.

Climate-related challenge	Health impact	Key resilience strategies identified in the literature	Expected outcome
Climate-resilient healthcare systems	Disruption of healthcare services during extreme weather	AI-supported early warning systems, renewable energy, telemedicine, resilient infrastructure, digital health, workforce training	Continuity of essential health services and improved emergency preparedness
Water, sanitation and hygiene (WASH)	Waterborne diseases, sanitation failures	Climate-resilient WASH infrastructure, integrated adaptation planning, monitoring systems, cross-sector collaboration	Improved access to safe water and reduced climate-related disease burden
Food safety	Food contamination and supply-chain disruption	Climate-smart agriculture, renewable cold chains, predictive surveillance, intelligent packaging, traceability systems	Safer food systems and reduced foodborne disease risks
Agriculture and food security	Reduced crop productivity and food insecurity	Climate-smart agriculture, crop diversification, efficient irrigation, drought-resistant crops, sustainable land management	Improved food security and agricultural resilience
Drought and water crises	Water scarcity and livelihood disruption	Water conservation, rainwater harvesting, drought early warning systems, integrated water governance	Sustainable water resources and improved adaptive capacity
Heatwaves and urban heat islands	Heat-related illness and mortality	Heat-wave early warning systems and coordinated response planning, urban greening, cooling infrastructure, public education, resilient urban planning	Reduced heat-related morbidity and mortality
Occupational heat stress	Heat illness and reduced labor productivity	Heat monitoring, engineering controls, work-rest cycles, hydration, occupational regulations	Safer workplaces and improved worker resilience
Wildfires and dust events	Respiratory and cardiovascular health effects, reduced air quality, and increased healthcare burden	Early warning systems, ecosystem restoration, community preparedness, regional collaboration	Reduced environmental exposure and disaster impacts
Climate-sensitive infectious diseases	Increased risk, altered transmission patterns, and geographic expansion of climate-sensitive infectious diseases	Surveillance systems, One Health approach, GIS-based monitoring, vaccination, integrated vector management	Earlier outbreak detection and improved disease control
Tropospheric ozone and air pollution	Respiratory and cardiovascular diseases	Emission reduction, clean transportation, green infrastructure, air-quality monitoring	Improved air quality and lower health risks
Mental health	Eco-anxiety, trauma, depression	Community psychosocial support, accessible mental healthcare, green spaces, policy integration	Improved psychological resilience
Vulnerable populations	Disproportionate climate-related health impacts	Targeted adaptation for older adults, women, children, outdoor workers, and socioeconomically marginalized populations; social protection and inclusive governance	Reduced inequalities and enhanced community resilience

fostering inclusive governance are essential components of adaptive capacity. By combining technological innovation, community engagement, scientific research, and policy reform, societies can reduce climaterelated risks and build healthier, more sustainable, and more equitable communities for the future.

Financial Support

This work received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests

The authors declare no competing interests

Authors' Contributions

A.F. conceptualized the library-based narrative review, designed the review methodology, synthesized and interpreted the literature, and drafted the original manuscript. A.M. contributed to the review design and methodology, supported the literature synthesis, and

reviewed and edited the manuscript. A.T. contributed to the review methodology, supervised the work, and critically revised the manuscript. A.A. contributed to the literature search and source review and reviewed and edited the manuscript. B.L., E.D., F.T., H.D., H.N., L.P., M.M., M.Mo., M.So., M.A., M.T., M.Ta., M.B., S.K., S.H., S.A.H., S.B., and Z.N. contributed to the literature search, source review, extraction of relevant information from selected references, and reviewing and editing the manuscript. A.A.K. contributed to conceptualization, supervised the project, critically revised the manuscript, and approved the final version for submission. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Ethical Considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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