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A Bibliometric and Qualitative Synthesis on Climate Change and Occupational Health Research

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ABSTRACT

Research on climate change and occupational health has grown as climatic risks increasingly threaten workers. Despite this growth, the literature remains dispersed, and there is still limited clarity on how the field has evolved conceptually and methodologically. This study, therefore, aims to map the global trajectory of publications on climate change and occupational health while also synthesising the dominant themes and modelling practices that underpin current knowledge. This study employs an integrated approach that combines bibliometric analysis with interpretive qualitative synthesis. Publications from Scopus and the Web of Science (WoS) were retrieved using Title, Abstract, and Keyword searches, cleaned, and merged using ScientoPy, and then refined to a final dataset of 571 records. The bibliometric phase examined annual publication output, major contributing countries and institutions, keyword patterns and modelling approaches. The qualitative phase involved examining studies associated with the ten most frequent keywords and the models identified in ScientoPy's extended results. The findings reveal a clear and sustained increase in scientific attention, with publication activity accelerating sharply after 2016 and peaking in 2024. The United States, Australia, the United Kingdom, Canada, and Italy appear to be the most active contributors, supported by several leading institutions. Heat-related terms dominate the keyword landscape, though recent years have seen growing interest in adaptation and broader environmental health concerns. The modelling review identifies Distributed Lag Non-Linear Models as the most widely used tool, supported by building simulations, human thermal models, regional climate models and socio-ecological frameworks. The current study suggests that research on climate change and occupational health is maturing. Nevertheless, the subject remains fragmented, suggesting that future studies should rely more on epidemiological, engineering, physiological, and socio-ecological insights to protect workers better as climate constraints intensify.

Keywords:
Climate change; occupational health; worker vulnerability; bibliometric analysis; knowledge evolution

1. Introduction

In recent years, the conversation about climate change has gradually moved beyond its earlier focus on ecosystems and atmospheric processes. More people now recognise that environmental shifts are beginning to shape everyday life [1]. One of the most tangible places where these changes

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are felt is the world of work [2]. Whether on farms, construction sites, factory floors, or even in indoor commercial spaces, workers are increasingly encountering conditions quite different from what their jobs once entailed [3]. Many workers now find themselves in environments that require fresh forms of adaptation and resilience [4]. Episodes of extreme heat arrive earlier and linger longer. Air quality worsens abruptly during haze periods. Unpredictable storms and shifting rainfall patterns disrupt routines and start new hazards [5]. The view that climate change is distant has faded; for many workers, it has become an integral part of their daily working life.

As concerns about climate change have become more visible, scientific interest in climate-related occupational risks has grown. Early research often centred on physical heat stress and heat-related injuries [6], particularly among workers engaged in physically demanding outdoor labour [7]. These foundational studies clarified the physiological pathways connecting heat exposure to fatigue, dehydration, reduced productivity and heightened injury rates. Over time, however, the scope of inquiry has widened considerably. Researchers are now exploring the intersection of climate stressors with chronic illness [8], mental health strain [9], workplace design [10], and economic productivity and organisational practices [11]. This evolution reflects a maturing field, one that recognises that occupational health cannot be separated from the broader environmental shifts reshaping working conditions.

Nevertheless, despite this expanding body of work, the literature remains highly fragmented. Studies are conducted across different climatic regions [12], focusing on varied occupational groups and guided by a range of measurement tools [13], conceptual models, and terminologies [14]. Some scholars emphasise public health pathways [15], others concentrate on micro-level physiological responses [16], and still others examine policy or organisational adaptation practices [17]. The modelling approaches used in this field are similarly diverse, ranging from epidemiological time-series models to building simulations, human thermal models and regional climate projections [18,19,20]. While this methodological and thematic variety reflects the richness of the field, it also makes the broader landscape harder to discern. Policymakers, practitioners and even researchers may struggle to trace the field’s evolution, identify the dominant themes shaping current understanding, or recognise where fresh contributions are most urgently needed.

The literature to date does not offer a unified, integrative mapping of scholarship at the intersection of climate change and occupational health. This absence of consolidation constitutes a substantive epistemic gap. While prior bibliometric investigations have interrogated specific domains such as climate change and non-communicable diseases [21], comparative trajectories within general climate research [22], or heat stress in specialised sectors such as poultry production [23], these studies remain thematically bounded.

The contribution of one study lies in its methodological sophistication, demonstrating how machine-assisted topic modelling can reveal latent thematic clusters within climate-related research [21]. However, the analysis remains anchored in disease outcomes and does not extend its scope to occupational exposures or workplace-level adaptation dynamics. A comparative bibliometric exploration of publications on climate change, global warming, and the climate emergency has similarly clarified discursive shifts and terminological trajectories over time, illustrating how scientific narratives evolve in response to socio-political framing [22]. Nevertheless, that work operates at a macro level of climate research discourse and does not disaggregate occupational health as a distinct analytical domain. In contrast, bibliometric mapping within poultry science has identified global trends, collaborative networks, and emerging research frontiers in heat stress research [23]. While this sector-specific precision is a clear strength, the primary focus on animal physiology and production systems limits its direct relevance to human occupational health, with the occupational dimension remaining implicit rather than analytically foregrounded.

Without such an overview, it becomes easy to overlook emerging trajectories, underestimate the value of specific modelling tools or miss the growing attention to adaptation strategies that extend beyond individual responses. Addressing this gap is particularly important at a time when climatic pressures continue to intensify, and workplaces require robust, evidence-informed approaches to safeguard workers and sustain productivity. Therefore, this study aims to systematically map the global trajectory of climate change and occupational health research between 1990 and 2024 and to synthesise the dominant thematic clusters and modelling approaches shaping the field. By integrating bibliometric structure analysis with interpretive qualitative synthesis, this study contributes a consolidated intellectual overview that clarifies the field's evolution, identifies methodological patterns, and proposes directions for interdisciplinary integration to strengthen evidence-informed occupational adaptation strategies.

2. Methodology

2.1 Study Design and Rationale

This study employs an integrated analysis of bibliometric and qualitative synthesis. This procedure is valuable in examining how climate change has been framed, analysed, and operationalised within occupational health research. The logic for this combined approach is straightforward. Bibliometric techniques map the intellectual structure of a field, yet they do not always reveal how ideas are interpreted within individual publications [24,25]. The qualitative component fills this gap by providing closer, more reflective engagement with the substance of the literature [26]. As a result, this integrated approach allows us to capture both the scope of scientific activity and the depth of conceptual reasoning that underpins it.

2.2 Data Sources, Search Strategy, and Data Cleaning

Two international indexing platforms, Scopus and Web of Science (WoS), were selected due to their broad disciplinary coverage and robust citation architecture. Their global reach ensures that the dataset captures diverse contributions, including work originating from different climatic regions, occupational contexts and research traditions. In addition, these databases were selected for their extensive coverage of peer-reviewed literature and robust indexing of multidisciplinary research outputs [27], particularly in environmental health, climate-related sciences, and occupational safety research.

To ensure methodological rigour and reproducibility, the search was conducted in August 2025 using the advanced search functions on both platforms. A series of Title-Abstract-Keyword searches was carried out using the combination of terms, as follows: ("climate change" OR "global warming") AND ("occupational health" OR "worker health"). Boolean operators were applied to maintain both sensitivity and inclusiveness. At this stage, no restrictions were applied to years, document types, subject areas or publication languages. This procedure is to maximise the inclusivity of the initial dataset.

The retrieved datasets were exported in comma-separated values (CSV) format from Scopus and in tab-delimited (TSV) format from WoS, containing complete bibliographic metadata, including author names, article titles, source titles, abstracts, keywords, author affiliations, publication years, and citation counts. The data were then merged and cleaned using ScientoPy to eliminate redundancy and ensure accuracy, following a standardised bibliometric procedure previously described in the literature [28]. Duplicates were identified and removed by matching titles and DOIs. In addition, publications that mentioned climate-related terms only in passing or used them in a general, non-technical manner, without any apparent connection to occupational settings or worker health, were excluded after careful manual review of their titles and abstracts.

Table 1 summarises the outcomes of the data cleaning process undertaken for this study. A total of 936 records were initially retrieved from Scopus and WoS. After screening the document types, 117 items were removed because they fell outside the categories retained for analysis: conference papers, journal articles, review articles, and proceeding papers. This left 819 documents for further processing.

Of the remaining records, 352 were sourced from WoS and 467 from Scopus, representing 43% and 57% of the dataset, respectively. Duplicate detection identified 248 duplicate entries, accounting for 30.30% of the combined dataset. A closer inspection showed that 247 of these duplicates originated from Scopus, while only one was identified from WoS. After removing all duplicates, the dataset was reduced to 571 publications. At this point, 351 papers (61.50%) were retained from WoS and 220 papers (38.50%) from Scopus. The final dataset of 571 publications is sufficiently large and diverse to meet the criteria for a robust bibliometric analysis, providing a reliable foundation for the subsequent quantitative and qualitative examination. Following the post-cleaning process, the retained publications spanned from 1990 to 2024, encompassing more than three decades of scholarly work on climate change and occupational health.

Table 1
Data cleaning

Information	Number	Percentage (%)
Loaded publication of year range (retrieved): 1990 to 2024	936	–
Omitted papers by document type (retain conference papers, articles, review papers, and proceeding papers)	117	12.5
Total papers after omitted papers removed	819	–
Loaded papers from WoS	352	43.00
Loaded papers from Scopus	467	57.00
Duplicated papers found	248	30.30
Removed duplicated papers from WoS	1	0.30
Removed duplicated papers from Scopus	247	52.90
Total papers after removing duplicates	571	–
Final papers from WoS	351	61.50
Final papers from Scopus	220	38.50

2.3 Bibliometric Analysis

A bibliometric analysis of the dataset was conducted using ScientoPy, an open-source Python-based tool for evaluating scientific output and research trends [29]. ScientoPy was chosen not only for its ease of use and clear visual dashboards, but also for its capacity to generate a wide range of descriptive indicators across time. These outputs provided a firm empirical base for mapping the global intellectual and thematic development of research at the intersection of climate change and occupational health [30].

Once the dataset had been cleaned, it was imported into ScientoPy for detailed bibliometric processing. The tool's transparency and reproducibility made it particularly suitable for this study, especially in visualising keyword evolution, thematic structures and long-term publication trajectories [31]. The analysis covered several key indicators, namely annual publication output, leading countries and institutions, keyword frequency, and the modelling approaches utilised in earlier research.

2.4 Qualitative Synthesis of Keyword Themes and Modelling Approaches

In the qualitative phase, two strands of analysis were undertaken. First, a thematic synthesis was conducted on publications linked to the top ten most frequently occurring keywords. The top ten keywords were selected because they represent the most influential and recurring themes in the dataset, accounting for the highest cumulative frequency. Second, the study examined the modelling approaches used in earlier research by reviewing the publications listed under the model category in ScientoPy's extended results. For both components, the articles were read closely to understand how the authors framed key concepts, constructed occupational exposure pathways and applied specific analytical techniques. This approach enabled the explanation of why specific themes and models have gained prominence, how they contribute to current understandings of climate change and occupational health, and where conceptual or methodological gaps remain.

3. Results and Discussion

3.1 Bibliometric Patterns in Output, Contributors, Keywords and Modelling Approaches

To understand how climate change and occupational health research have evolved, the findings are unpacked through five indicators. The five indicators are annual publication output, the major contributing countries and institutions, the patterns observed in keywords, and the modelling approaches applied in earlier studies.

The pattern of annual publications shows a steady and meaningful expansion of scholarly interest in climate change and occupational health. Figure 1 offers a clear view of how research on climate change and occupational health has unfolded over the last three decades. For a prolonged period in the 1990s and early 2000s, the field experienced slow growth. Both Scopus and WoS show only a handful of papers each year, and in many years, none are published. This quiet period is not surprising; at that time, climate change was still mainly framed as an environmental or ecological issue [32], and its implications for workers' health had yet to gain serious attention.

A noticeable shift begins to take shape around 2010. The number of publications starts to climb, first modestly and then with increasing consistency. This growth reflects the gradual recognition that climate-related exposures, particularly heat, air quality deterioration, and extreme weather, carry direct and indirect consequences for workers across multiple sectors [33]. The most striking pattern appears from 2016 onwards. Both databases record a pronounced rise in output, with WoS showing sharper peaks. This surge coincides with heightened global concern following key international climate agreements, the spread of heatwaves worldwide, and an expanding research community studying climate-health linkages [34,35,36]. The upward trend also suggests that occupational health scholars are increasingly engaging with climate science, leading to more interdisciplinary work.

In recent years, especially from 2022 to 2024, the trajectory has become even steeper. The number of WoS documents reaches its highest level in 2024, and Scopus also shows elevated activity. This suggests that the topic is no longer peripheral but has matured into a recognised research domain with growing momentum. The fluctuations in certain years, where publication numbers dip and then rise again, likely reflect variations in funding cycles, global events, and the availability of climate-related datasets.

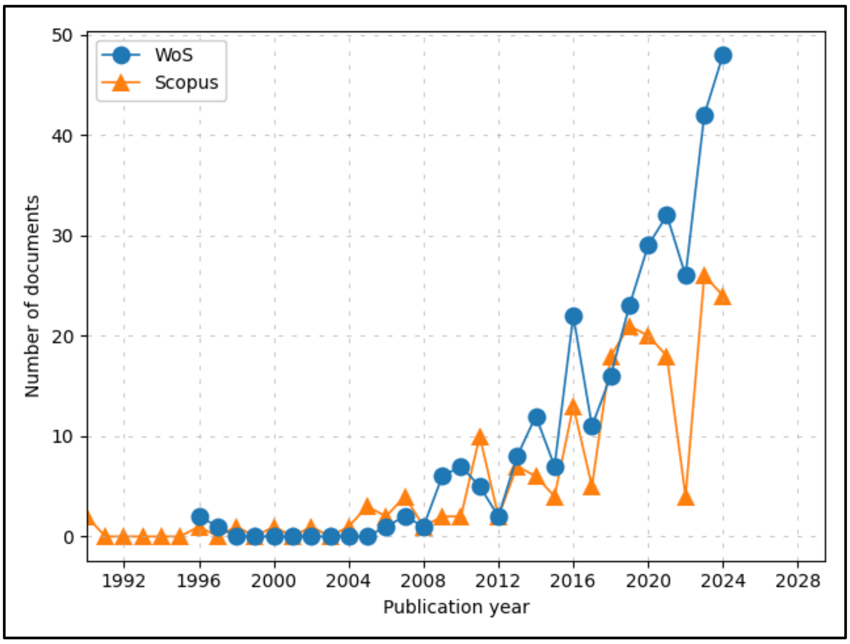

Fig. 1. The annual trend of publications on climate change and occupational health

The country-level distribution shows that research on climate change and occupational health is concentrated in several high-output countries. This suggests that the countries have been actively engaged in climate and occupational health research for a long time. Figure 2 provides a detailed overview of the ten countries that have contributed most actively to research on climate change and occupational health. The graph on the left illustrates cumulative publication growth over time, whereas the panel on the right provides a more recent perspective by comparing the average annual number of documents in 2023 and 2024 with the proportion of total publications produced during those two years.

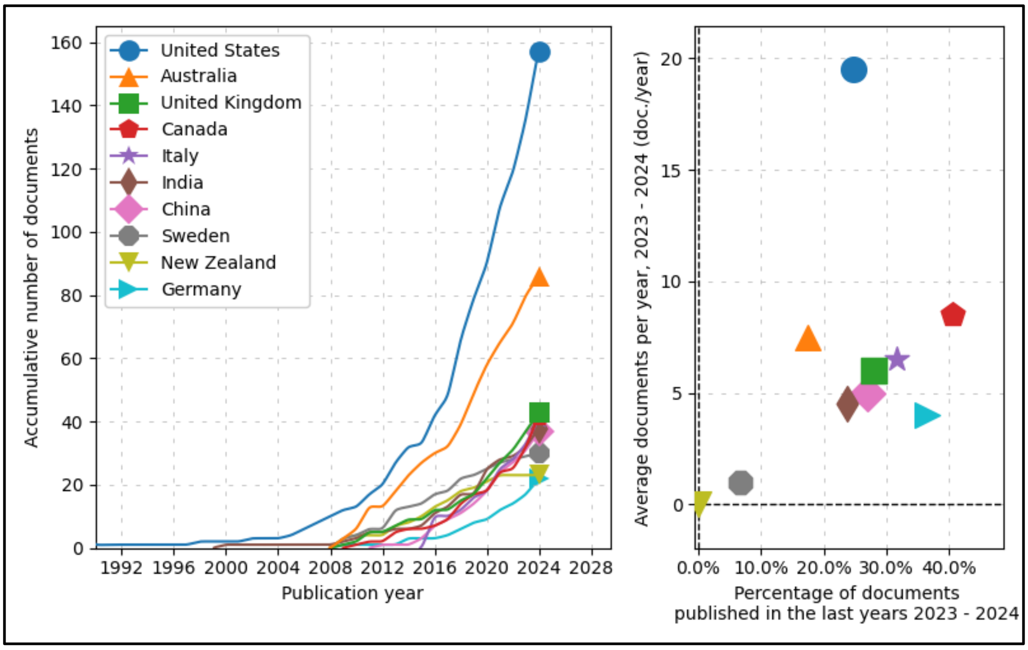

Fig. 2. The top ten countries that have widely researched climate change and occupational health

Across the entire period, the United States stands out as the most dominant contributor. Its cumulative output rises sharply after 2016 and continues to climb at a rate that far exceeds that of other countries. This reflects the strong presence of occupational health research centres in the United States [37] and the growing engagement of environmental and climate science groups with worker safety issues [38]. Australia follows a similar upward trajectory, albeit on a smaller scale, and consistently makes active contributions in both the long term and recent periods.

The United Kingdom, Canada and Italy form a second tier of contributing countries. Their curves reveal steady involvement over the years, with noticeable increases after 2018. These countries often have established scientific communities working in both climate and occupational health, which may explain their sustained presence. India, China and Sweden show more modest cumulative numbers, yet their participation has become more visible in recent years. This may reflect an increasing awareness of climate-related risks in rapidly evolving work environments [39], particularly in countries experiencing frequent heatwaves or deteriorating air quality. New Zealand and Germany contribute smaller volumes overall, but their presence in the dataset indicates that interest in the topic is geographically widespread and not confined to major economies.

The right panel highlights the most active countries during the last two years. Once again, the United States is at the forefront, with a remarkably high average of publications per year in 2023 and 2024, alongside a sizable proportion of recent output. Australia also demonstrates strong recent engagement, confirming a pattern of continued scholarly interest. The United Kingdom, Italy, Canada, India, and China occupy the middle of the scatter plot, suggesting growing but uneven activity. Meanwhile, countries such as Sweden and New Zealand display very low recent averages, hinting at emerging or sporadic rather than sustained research involvement.

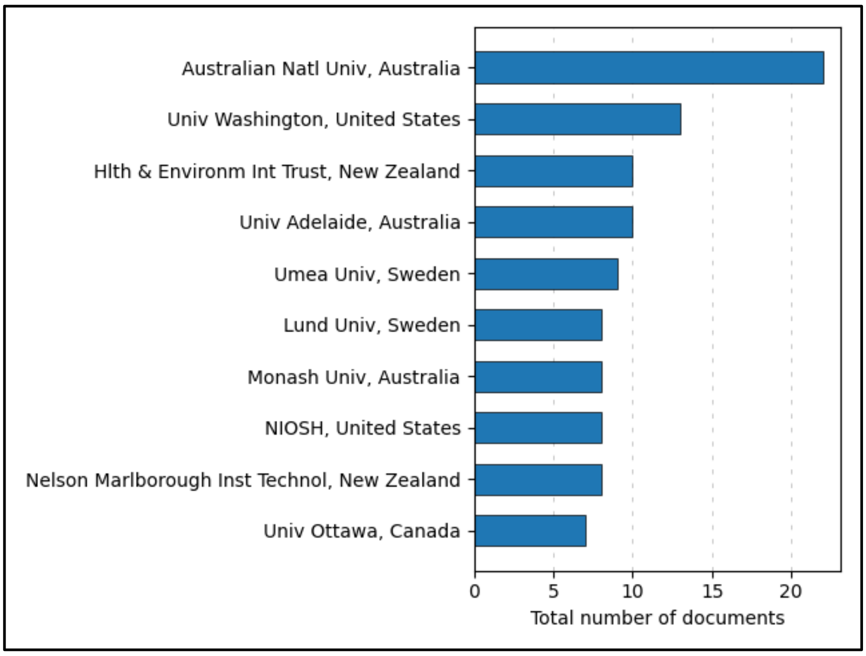

Fig. 3. Leading institutions engaged in climate change and occupational health research

Figure 3 highlights the institutions that have contributed most actively to research about climate change and occupational health. The pattern that emerges is one of concentrated leadership, where a small group of universities and research centres play a central role in advancing this area of study. The Australian National University appears at the top of the list with the highest number of publications. Its strong presence reflects the broader national trend seen in the country-level results, where Australia stands among the most active contributors. The university has long been connected with environmental science and climate-related research, and its engagement with occupational health issues appears to have expanded in parallel with growing national concern about heat exposure and extreme weather events.

The University of Washington in the United States follows closely. This institution is known for its well-established public and environmental health programmes, which may explain its steady engagement in research on how climate change affects worker safety and well-being. The presence of the National Institute for Occupational Safety and Health from the United States further reinforces the idea that American institutions are playing an important role in shaping this field.

Institutions from New Zealand, Sweden and Canada also feature prominently. The Health and Environment International Trust and the Nelson Marlborough Institute of Technology represent New Zealand's contribution, suggesting an emerging interest in climate-related occupational risks within smaller but well-focused research settings. Umea University and Lund University in Sweden reflect the strength of Scandinavian engagement, particularly in areas related to environmental exposures, cold climates and public health. The University of Ottawa adds a Canadian perspective, enriching the field's geographical diversity. Monash University and the University of Adelaide further strengthen Australia's footprint, indicating that the country's involvement is not limited to a single research centre but is distributed across multiple well-established institutions.

The analysis of author keywords reveals the conceptual heartbeat of climate change and occupational health. Figure 4 presents the ten most frequently used author keywords in the publications on climate change and occupational health. Concerns about temperature risks strongly shape the pattern that emerges. The term heat stress appears as the most dominant keyword, reflecting its longstanding position as the core issue in this field. Its high frequency suggests that researchers continue to focus primarily on the direct physiological effects of rising temperatures on workers, especially in sectors that involve physical labour or prolonged outdoor exposure [40].

Closely related terms, such as heat exposure and the Wet Bulb Globe Temperature (WBGT) indicator, also play a prominent role. Their presence signals the growing use of technical measures to quantify thermal risk and link environmental conditions to worker safety outcomes [41,42]. The appearance of global warming among the top keywords indicates that climate change is not treated as an abstract environmental phenomenon, but as a driver of specific occupational hazards.

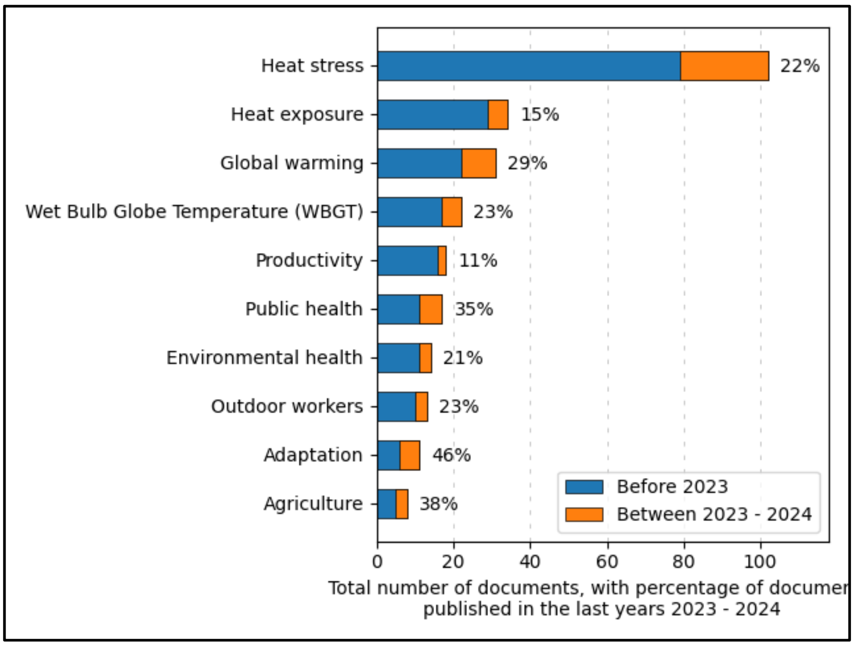

Fig. 4. The top ten used keywords in climate change and occupational health research

The keyword productivity highlights another important strand of the literature, in which scholars have examined the economic and performance implications of working under hotter, more stressful climatic conditions [43-45]. Terms such as public health and environmental health indicate that the conversation is expanding beyond immediate heat-related impacts to include broader health and environmental pathways.

Outdoor workers and agriculture are also represented on the list, highlighting the groups and sectors that are most frequently studied. These terms reflect the reality that workers in agriculture, construction, and similar settings face some of the most direct and severe climate-related exposures [2]. Adaptation stands out as a keyword that has gained more traction in recent years, as indicated by the relatively high percentage of publications from 2023 and 2024. This suggests a growing interest in practical strategies and organisational responses to emerging climate risks [46-48].

The modelling component reveals that researchers have employed a range of analytical tools to investigate the linkages between climate change and occupational health. Figure 5 illustrates the types of models employed in previous studies examining the relationships between climate change and occupational health. The distribution shows that researchers have relied on a range of modelling approaches, each offering different strengths in understanding exposure pathways and worker vulnerability.

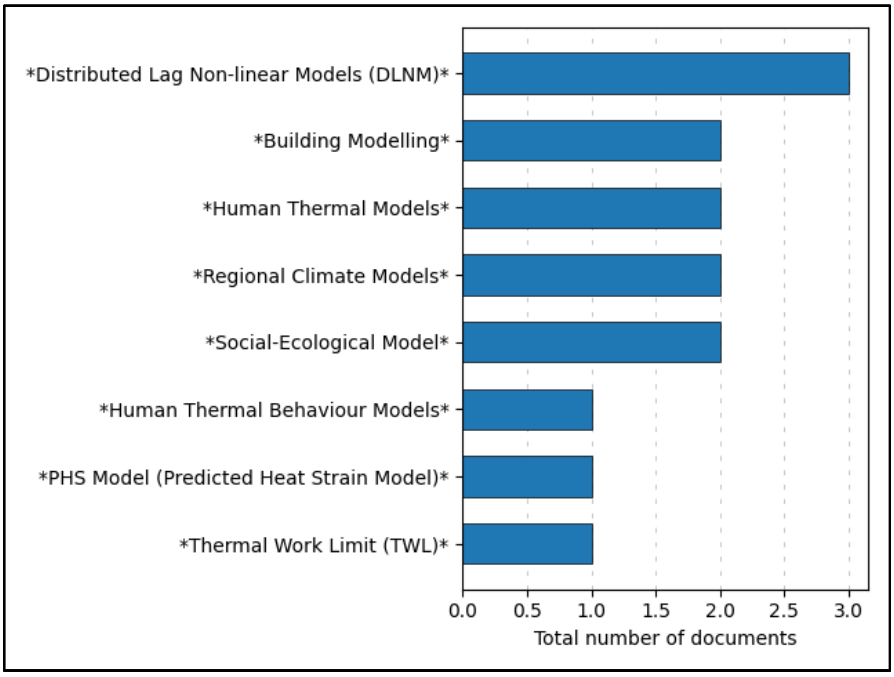

Fig. 5. Modelling approaches used in research on climate change and occupational health

Distributed Lag Non-Linear Models appear as the most frequently applied modelling technique. Their prominence reflects the need to capture delayed and non-linear relationships between climatic conditions and health outcomes, particularly in studies examining heat-related injuries and acute physiological responses [49-51]. These models are commonly used in environmental epidemiology and have been adapted to explore worker-specific risks.

Building modelling, human thermal models and regional climate models form the next group of widely used approaches. Building modelling is often employed to estimate indoor heat accumulation and the effectiveness of ventilation or cooling measures, which is increasingly important as heat risks extend beyond outdoor settings [18]. Human thermal models facilitate the assessment of physiological strain by simulating how the human body responds to various combinations of temperature, humidity, and work intensity [19,20]. Regional climate models contribute by projecting future climatic conditions, enabling researchers to anticipate how occupational risks may evolve [52,53].

The social ecological model appears as another recurrent approach, indicating that some studies frame climate-related occupational risks within a broader system of social, organisational, and environmental factors. This reflects an emerging interest in how worker behaviour, workplace norms, and community-level conditions interact with climatic stressors [54].

A smaller number of studies have used human thermal behaviour models, the Predicted Heat Strain model and the Thermal Work Limit measure. These methods tend to support more specific assessments, such as estimating safe work durations, identifying heat thresholds for different work tasks or understanding behavioural adjustments workers may make during periods of high heat.

The pattern in Figure 5 reveals a field that draws on both epidemiological and engineering-based modelling traditions. While the number of studies for each model type is still modest, the diversity of approaches suggests a growing appreciation that climate-related occupational risks cannot be understood through a single analytical lens. Instead, they require tools capable of capturing physiological processes, environmental conditions and the broader social context in which work takes place.

3.2 Interpretive Qualitative Synthesis of Thematic Keywords and Modelling Practices

A closer examination of the articles associated with the top-ten keywords and the modelling approaches used in earlier research reveals several important thematic patterns. Nevertheless, as indicated in Figure 4, the total of 270 publications assigned to the 10 keywords provides a rich pool. The list of publications was generated by ScientoPy and produced in the extended keyword file. From this pool, representative articles were identified based on citation influence, conceptual relevance and recency. The synthesis below draws directly on those studies to illustrate how each keyword anchors a particular strand of thinking in climate change and occupational health research. This synthesis is summarised in Table 2.

Publications grouped under the term heat stress form the historic core of the field. Early empirical work demonstrated that elevated temperatures impair worker capacity and increase health risks in physically demanding occupations [43]. Subsequent research further established the link between regional climate change and labour productivity losses, underscoring that heat exposure is a public health and economic concern [58]. More recent analyses have consolidated cross-sectoral evidence on the health impacts of occupational heat exposure, reinforcing the centrality of heat stress in discussions of climate-related occupational risk [59].

Studies classified under heat exposure tend to focus on the measurement and epidemiology of thermal conditions in the workplace. Occupational heat-related mortality in the United States has been characterised through analyses that demonstrate clear associations between extreme heat and fatal outcomes in specific industries [55,56]. Rising ambient temperatures have also been linked to population health burdens and occupational impacts in Australia, with evidence highlighting regional differences in exposure and vulnerability [57]. In combination, these studies show how careful exposure assessment provides the empirical foundation for prevention policies.

The keyword global warming marks work that situates occupational health within the context of longer-term climate trajectories. Research on biochar and sustainable agriculture under warming conditions illustrates how climate adaptation strategies in agriculture may alter work tasks and exposure patterns [60]. Empirical studies have also examined the impacts of climate change and heat stress on farm workers, highlighting both current health effects and anticipated future burdens [61].

Sector-specific analyses further link global warming to distinct exposure profiles, including heat stress among construction workers [62]. When examined comparatively, these studies reveal a clear shift in framing: global warming is no longer treated as a peripheral environmental issue but as a structural determinant of occupational risk.

Table 2
Thematic interpretation of the top ten keywords with illustrative studies

Keyword	Main Themes	Representative Studies
Heat stress	Physiological burden; injury risk; reduced work capacity	[43,59]
Heat exposure	Exposure assessment; mortality and morbidity patterns	[55-57]
Global warming	Long term climate trends; sector specific risks	[60-62]
Wet Bulb Globe Temperature	Use and limitations of heat indices in work settings	[63,64]
Productivity	Economic consequences of heat; reduced performance	[43,44]
Public health	Occupational risks linked with population health burdens	[65,66]
Environmental health	Combined environmental exposures and climate stressors	[67,68]
Outdoor workers	Vulnerability of outdoor sectors; heat related risks	[69-71]
Adaptation	Coping strategies; planning and preparedness for extreme heat	[46-48]
Agriculture	Climate sensitive labour; farming sector vulnerability	[72-74]

The Wet Bulb Globe Temperature (WBGT) is a keyword associated with work that applies or critiques this index as a tool for managing heat in the workplace. An extended framework for assessing the effects of climate change on worker safety has been proposed, integrating measures such as WBGT to connect environmental monitoring with prevention strategies [63]. Empirical analyses have also examined the association between extreme weather conditions and occupational injuries in Italy, where WBGT functions as a central exposure indicator [64]. These contributions underscore both the utility and the practical limitations of relying on a single index in diverse climatic and occupational settings.

Under the productivity keyword, the literature links climate-related heat to economic and performance outcomes. A widely cited synthesis has quantified the extent to which excessive heat reduces work capacity and productivity, particularly in outdoor, physically demanding occupations [44]. Earlier empirical work further reinforced these findings by providing initial estimates of productivity loss and the broader economic burden associated with occupational heat exposure in hot environments [43]. Additional analyses have examined excessive occupational heat exposure as a significant health and safety challenge, with clear implications for both performance and injury risk [45].

The public health keyword signals a broader framing that connects occupational risks with wider population health concerns. Comprehensive reviews of the health effects of climate change situate occupational exposure within a continuum linking environmental change to patterns of morbidity and mortality [65]. Critical analyses have also examined how manufactured uncertainty and regulatory practices can obscure or delay recognition of climate-related hazards affecting workers [66]. Viewed holistically, these works position occupational health within a wider public health and policy context.

Environmental health publications highlight the intersection of climatic stressors with other environmental hazards. Commission reports on plastics and human health have emphasised complex exposure pathways in which climate factors, pollution, and material use intersect [67]. Other analyses have proposed sustainable engineering and policy solutions to mitigate occupational heat stress, drawing explicitly on environmental health principles [68]. This strand of the literature underlines that workers are exposed to combined environmental burdens rather than isolated climate variables.

The keyword outdoor workers is closely tied to vulnerability in specific sectors. Research on climate change and occupational health has emphasised agriculture, construction, and other outdoor occupations, where exposure is both frequent and intense [69]. Epidemiological analyses have documented heat-related deaths among construction workers, demonstrating the fatal consequences of inadequate protection in hot climates [70]. Emerging studies have also evaluated wearable sensors for physiological monitoring among outdoor workers, illustrating how new technologies can complement traditional surveillance and prevention strategies [71]. This cluster clearly marks outdoor work as a priority area for adaptation.

Adaptation emerges as a forward-looking theme. Climate change adaptation has been described as a complex public health and development challenge that includes protecting worker health during periods of extreme heat [46]. Research has further examined how healthy working populations are affected by rising temperatures, identifying both individual and organisational strategies to cope with changing conditions [47]. Sector-specific analyses have also questioned whether industries such as construction are adequately prepared for heat-related risks, highlighting gaps in planning and implementation [48]. These studies demonstrate that adaptation extends beyond technical adjustments and requires changes in work organisation, regulation, and long-term planning.

Finally, the agriculture keyword focuses on climate-sensitive industries. Evidence suggests that current work adaptations are insufficient to address the growing risk of heat exposure in agriculture, with rising temperatures threatening both worker health and food production systems [72]. Intervention-based studies have documented workplace measures to mitigate heat stress among agricultural workers, particularly in regions where sugarcane and other labour-intensive crops are cultivated [73]. Additional research has examined the relationships among workplace safety, perceived occupational stress, and well-being among Latino agricultural workers, highlighting the psychosocial dimensions of climate-related labour [74]. This body of work positions agriculture as a focal sector in which climate adaptation, social vulnerability, and occupational health intersect.

While the keyword synthesis highlights the conceptual direction of the field, an equally important layer of insight emerges from the modelling approaches that researchers have employed. This section interprets those modelling practices in greater depth. The extended modelling dataset provides a detailed picture of how researchers have approached quantifying the impact of climate change on occupational health. Several distinct modelling traditions emerge, each offering a different approach to understanding worker exposure and health outcomes (see Table 3).

Reading across the eight groups of models reveals two broad movements in the field. First, there is a strong epidemiological tradition that seeks to quantify injury risks at the population scale using advanced time-series techniques such as Distributed Lag Non-linear Models (DLNM). Second, a more engineering-oriented strand of work uses building simulations, regional climate modelling, and human thermal behaviour models to explore mechanisms and design solutions. These strands reveal a field that is gradually maturing, with improved methodological rigour and increasing attention to micro-environmental and behavioural nuances.

DLNM is the most frequently used modelling approach in this dataset and has become the anchor of quantitative climate-occupational health research. It has been applied to characterise the delayed, cumulative, and non-linear effects of ambient temperature on occupational injuries [49–51]. Empirical analyses demonstrate that extremely hot days are associated with significant increases in compensation claims, with injury risk rising markedly at the upper percentiles of temperature distribution [49]. Multi-city comparisons further indicate that temperature–injury relationships vary across climatic zones, with more substantial heat-related effects observed in temperate cities than in consistently warm regions [50]. Spatial extensions of this modelling framework have incorporated intra-city, grid-level temperature inputs to identify neighbourhood-level hotspots of risk, revealing how micro-environmental features interact with worker characteristics to shape vulnerability [51]. These studies suggest that DLNM is particularly effective for estimating population-level risk profiles, delayed effects, and regional heterogeneity. The approach is epidemiologically rigorous but depends heavily on the availability of long-term administrative or compensation datasets. It is less capable of capturing workplace-specific variables such as task patterns or microclimatic variation.

Table 3
Summary of modelling practices

Model	Purpose in the Literature	Representative Studies	Main Contribution
Distributed Lag Non-linear Models (DLNM)	Quantifying delayed and non-linear temperature–injury relationships	[49-51]	Identifies heat-related injury risks, regional variation, and intra-city hotspots
Building Modelling	Simulating indoor heat mitigation strategies	[18]	Shows the effectiveness of passive cooling retrofits and future climate scenarios
Human Thermal Models	Assessing physiological stress and personal cooling effectiveness	[19,20]	Provides individual-level stress assessment and evaluates local cooling strategies
Regional Climate Models (RCM)	Projecting future WBGT and productivity loss	[52,53]	Forecasts long-term heat stress patterns and productivity impacts
Social-Ecological Model	Explaining multi-level risk factors	[54]	Highlights gender, age, policy and organisational determinants of heat-related injuries
Human Thermal Behaviour Models	Modelling whole-body heat response	[19]	Evaluates thermal comfort and local cooling limits
Predicted Heat Strain (PHS) Model	Physiology-based heat strain prediction	[75]	Identifies model limitations and regional suitability
Thermal Work Limit (TWL)	Practical work-rest and heat tolerance index	[75]	Recommends TWL as suitable for varied environments

A second body of work focuses on how indoor workplaces respond to heat. Simulation-based modelling of a ready-made garment factory in Bangladesh has been used to test the cooling potential of multiple rooftop interventions [18]. The results indicate that passive retrofits can reduce indoor temperatures by approximately 2 degrees Celsius and prevent hundreds of hours of lost worker time associated with unsafe heat exposure. This form of modelling provides a compelling demonstration of how engineering interventions can mitigate climate-related risks without increasing energy consumption. Its strength lies in generating actionable insights for building design and policy, although it depends on detailed assumptions regarding construction materials, occupancy patterns, and projected climate scenarios.

Two distinct applications of human thermal modelling are visible in the literature. Experimental modelling using the FIALA-FE framework has been employed to assess the effectiveness of personal cooling devices, with findings indicating only modest improvements in comfort and limited protection during extreme heat conditions [19]. Complementary reviews have advocated integrating advanced human heat balance models with weather forecasting systems to enable personalised thermal stress warnings, while also highlighting challenges related to microclimates, radiant heat exposure, and vulnerable worker groups [20]. Human thermal models thus function as a bridge between physiological processes and workplace design. However, their methodological complexity and substantial data requirements may constrain widespread implementation.

Regional climate modelling approaches have extended the analytical frame beyond present-day exposures by projecting future WBGT patterns across Western Turkey through 2100 [52,53]. These projections illustrate how climate change is likely to reshape work-rest cycles, labour productivity, and the geographical distribution of occupational heat risk. Such modelling frameworks are particularly valuable for long-term planning and the development of labour policy. However, because they operate at a broader spatial scale, they may overlook workplace-specific variables and microclimatic conditions.

A complementary strand of scholarship adopts the social-ecological model as an interpretive framework rather than a numerical tool [54]. Narrative synthesis within this approach demonstrates how heat exposure interacts with gender, age, industry type, regulatory gaps, and organisational conditions. Although not mathematical in structure, this framework enriches the literature by illuminating the social mechanisms that shape injury risk and by underscoring that climate hazards are deeply intertwined with structural inequalities.

A comprehensive review examined multiple heat stress indices, including the Predicted Heat Strain (PHS) model and the Thermal Work Limit (TWL), highlighting the strengths and limitations of each [75]. The PHS model provides greater physiological precision but is comparatively complex and difficult to operationalise in routine workplace settings. In contrast, TWL offers a more practical, region-specific metric suitable for both indoor and outdoor environments. In concert, this analysis underscores that no single index performs optimally across all climatic contexts, reinforcing the need for context-specific evaluation.

Based on the synthesis of modelling practices, we found that the models reveal a field working towards integration. DLNM captures broad epidemiological risks; building and regional climate models simulate environmental pathways; human heat balance models explore physiological responses; and social-ecological models unpack contextual drivers. Each illuminates a different segment of the climate-health pathway. A future direction suggested by the literature is combining these approaches, particularly by pairing DLNM-based epidemiological insights with engineering and physiological modelling to produce more holistic assessments of worker vulnerability.

The integration of bibliometric trajectory mapping with qualitative modelling synthesis provides a structured understanding of how the climate-occupational health nexus has evolved across three decades. Rather than remaining a collection of heat-related case studies, the field demonstrates a gradual methodological diversification and thematic broadening. However, the continued dominance of heat stress research and reliance on isolated modelling traditions suggest the need for deeper interdisciplinary convergence. Bridging epidemiological time-series modelling with engineering simulations, physiological heat balance models, and socio-ecological frameworks would allow more comprehensive assessment of worker vulnerability. Such integration is essential for translating scientific evidence into adaptive workplace design, regulatory reform, and long-term climate resilience planning.

4. Conclusions

This study demonstrates that research on climate change and occupational health has grown steadily, with heat-related risks remaining the primary concern, and modelling approaches becoming increasingly diverse and refined. The findings highlight important implications. As climatic pressures intensify, there is a clear need for workplaces and policymakers to draw on evidence from epidemiology, engineering, physiology and socio-ecological studies to design more effective protective measures. The emergence of adaptation and environmental health themes suggests that future interventions must move beyond individual coping strategies to include organisational planning and broader public health considerations.

In this study, there were several limitations that should be acknowledged. The analysis relies on publications indexed in Scopus and WoS, which may exclude relevant regional or practice-based studies. Another key limitation is that the chosen search terms shaped the scope of the dataset (“climate change” OR “global warming”) AND (“occupational health” OR “worker health”). Thus, if other researchers use broader or more specific terms or add related concepts, it could lead to a different set of publications and different findings. The following limitation concerns the qualitative synthesis. This approach is guided by the top ten keywords and modelling categories generated by ScientoPy, which means that smaller yet important lines of inquiry may not be fully captured. In addition, bibliometric indicators trace patterns but cannot fully explain the deeper social, economic or regulatory factors driving research trends.

These limitations point to clear directions for future work. More integrated studies are needed to bridge the gaps between modelling traditions, linking epidemiological outcomes with physiological responses, engineering solutions and organisational practices. Research focusing on under-studied sectors, low-income regions and vulnerable worker groups would strengthen global understanding of climate change and occupational health. As climate change continues to alter working conditions, such efforts will be essential for developing coherent, evidence-based strategies that protect workers and enhance workplace resilience.

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