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Do the Core Concerns of Climate Adaptation Policies and Studies Align? —A Comparative Review of Policy Documents and the Literature

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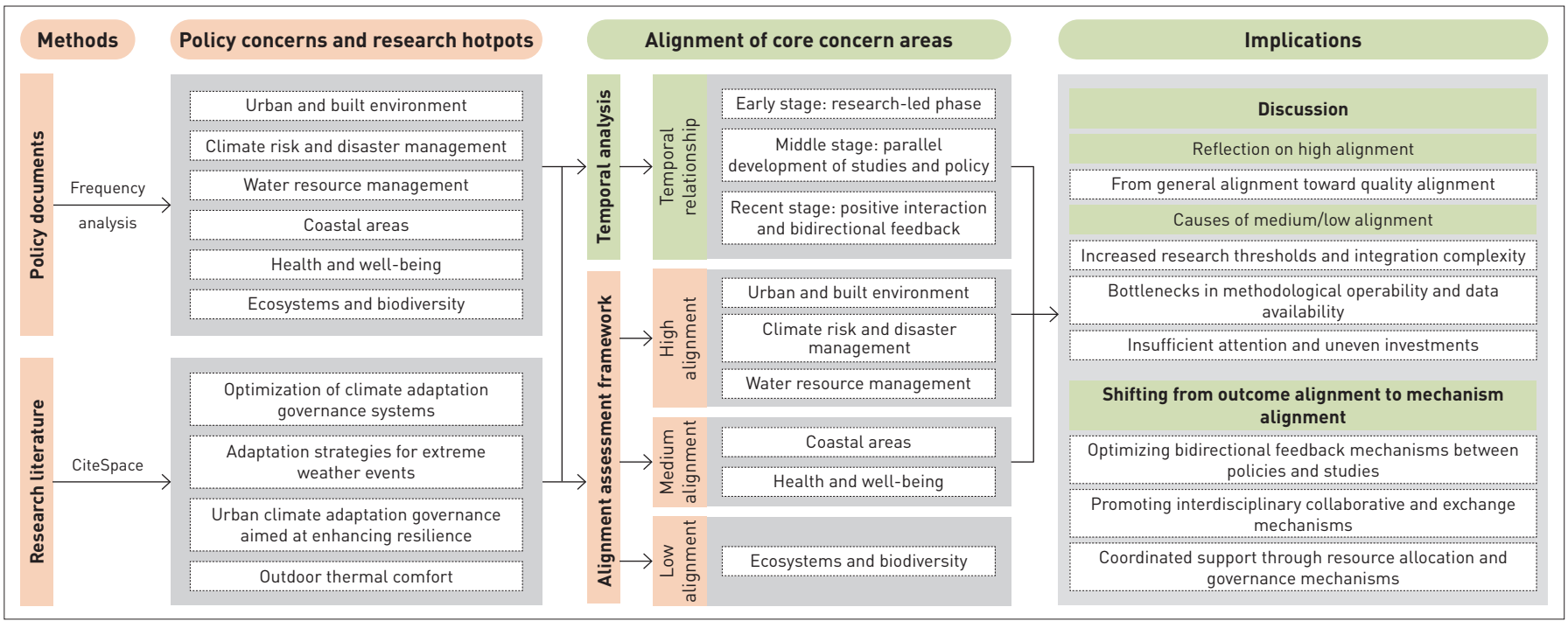
GRAPHICAL ABSTRACT



ABSTRACT

A comparative review of the alignment between climate adaptation policies and studies helps identify and narrow their gaps, thereby enhancing the effectiveness of climate adaptation actions in the human settlements. This study systematically traced the development of policies and studies to reveal the evolution of their interactions. An analytical framework for assessing alignment was constructed across four dimensions—level of attention, adaptation target, adaptation action, and adaptation scale—to evaluate the alignment within core concerns. The results indicate that climate adaptation policies have embraced global coordination, while studies have gradually shifted from a theoretical focus to applied practice. The policy–research relationship has evolved from study-led development through parallel advancement to bidirectional interaction, though the efficiency and depth of their synergy remain limited. Across core concerns, overall alignment was relatively strong. Higher alignment was observed in cities and built environments, climate risk and disaster management, and water resource management; coastal areas and health and well-being showed moderate alignment; and ecosystems and biodiversity exhibited relatively low alignment. Alignment is generally strong in terms of adaptation target and action, but weak in regard to adaptation scale, with future scenario simulations and studies at regional and community scales remaining insufficient. Future studies should move beyond “outcome alignment” to “mechanism

alignment" by optimizing policy–research bidirectional feedback mechanisms, promoting interdisciplinary collaboration and exchange mechanisms, and enhancing coordinated support through resource allocation and governance mechanisms. These findings contribute to the climate adaptation governance theory and provide insights and guidance for the future development of both policies and studies.

KEYWORDS

Climate Adaptation; Climate Change; Literature Review; Policy Framework; Alignment

HIGHLIGHTS

- A comparative review of climate adaptation policies and studies from dual perspectives
- Demonstrates the reciprocal and positive interactions between climate adaptation policies and studies
- Develops an assessment framework covering the level of attention, adaptation target, action, and scale
- Reveals strong overall alignment across core concern areas, with substantial intersectoral differences
- Optimize policy-research feedback, interdisciplinary collaboration, and resource allocation and governance

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1 Introduction

Climate change is affecting the world at an unprecedented pace and intensity. Climate-related hazards, such as extreme heat, flooding, and drought, are occurring with increasing frequency and posing severe threats to human settlements[1]. Since the Intergovernmental Panel on Climate Change (IPCC) formally introduced adaptation strategies in 1990[2], the international community has increasingly recognized the urgency of adapting to climate change.

In recent years, substantial progress has been made globally in climate adaptation policy formulation and theoretical studies. At the policy level, from the Cancun Agreements to the Paris Agreement, climate adaptation has gained increasing priority and become progressively institutionalized. Governments worldwide have accelerated the development of climate adaptation policies to address a wide range of sectors, including urban infrastructure, water resource management, ecosystem conservation, agricultural security, and public health. Specifically, China issued a series of climate adaptation policy documents, such as the *National Climate Change Adaptation Strategy 2035*, explicitly emphasizing the need to strengthen the climate adaptability of the built environment[3]. Simultaneously, extensive research advances have been achieved in fields of cities and built environments, climate risk and disaster management, etc.[4], providing robust theoretical and methodological support for policy formulation and practical action. However, existing studies tend to focus on specific domains, such as spatial planning[5], urban water management[6], and summaries of global policy instruments[7], while relatively few studies have systematically examined the degree of alignment between climate adaptation policies and studies.

To some extent, academic studies are shaped by policy agendas, and both ultimately aim to serve societal needs[8–9]. Scientific studies play a crucial role in informing governmental decision-making; however, research agendas do not always align with the most urgent policy demands, particularly in complex domains, including environmental governance[10]. Consequently, understanding the potential misalignment between climate adaptation studies and policy concerns is essential for narrowing the gap between knowledge production and policy action and enhancing the effectiveness of climate adaptation initiatives for built environments. This study focused on the core question of whether the key concerns of climate adaptation policies and studies are aligned. This study developed an analytical framework to assess the degree of policy–research among the core concerns, thereby identifying opportunities for optimizing both research contents and policy-making. Specifically, this study aimed to 1) trace the evolutionary trajectories and core concerns of global climate adaptation policies and studies across different stages, 2) construct a framework to evaluate the degree of policy–research alignment within core concerns, and 3) propose strategies and recommendations for academia and governments to advance future climate adaptation efforts. Moreover, due to China's large population and its geographical vulnerability to climate change impacts, this study also examines the similarities and differences between Chinese- and English-language climate adaptation policies

and studies, seeking to offer a practical reference for climate adaptation actions in Global South countries like China.

2 Research Framework and Methods

2.1 Climate Adaptation: Definition and Characteristics

In its climate assessment reports, IPCC defines climate adaptation as "in human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects"[11]. This definition emphasizes proactive adjustments in response to both existing and anticipated climate change and extreme weather events. This study conducted sample selection and textual analysis based on this conceptualization and the key characteristics of climate adaptation.

2.2 Sample Collection

For policy samples, this study focused on whether climate adaptation-related content in policy documents conforms to the comprehensive definition of a policy framework, that is, whether it includes clearly articulated objectives, guiding principles, action plans, and policy instruments[12]. Using 1990 as the starting point, a screening process was conducted, resulting in the selection of 45 policy documents by national governments, including China, the United Kingdom, and Japan, and international organizations such as the IPCC (Table 1), with the issued year spanning from 2007 to 2024. This study also identified the years of key milestone events—namely the IPCC Fourth Assessment Report (AR4)[13] and the Bali Road Map[14] in 2007, the Cancun Agreements in 2010[15], and the Paris Agreement in 2015[16]—as the years for dividing the three evolution stages of climate adaptation policies.

English-language studies were retrieved from the Web of Science (WoS) Core Collection, while Chinese-language studies were collected from the China National Knowledge Infrastructure (CNKI), including journals indexed by the database of Core Journal of China, the Chinese Social Sciences Citation Index (CSSCI), and the Chinese Science Citation Database (CSCD). The search keywords included "climate adaptation" (气候适应), "climate adaptability"/"climate adaptiveness" (气候适应性), and "climate adaptive"/"climate-adaptive"(气候适应型) . The disciplinary scope was limited to Area Studies, Regional and Urban Planning, Urban Studies, and Environmental Sciences. Preliminary searches and relevance screening indicated that studies closely related with the urban, regional, and environmental topics began to emerge primarily after 2004. Accordingly, the search period was defined as January 1,

Table 1: Global climate adaptation policies included in this study

Country/ organization	Year	Policy name
Stage 1 (2007–2009): Equal emphasis on mitigation and adaptation		
Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC)	2007	Bali Road Map
European Union	2007	Green Paper of Adapting to Climate Change in Europe—Options for EU Action
	2009	White Paper of Adapting to Climate Change: Towards a European Framework for Action
IPCC	2007	Fourth Assessment Report
Australia	2007	National Climate Change Adaptation Framework
China	2007	National Climate Change Programme
Germany	2008	German Strategy for Adaptation to Climate Change
India	2008	National Action Plan on Climate Change
United Kingdom	2009	Scotland's Climate Change Adaptation Framework
Stage 2 (2010–2014): Systematization of adaptation frameworks		
COP to the UNFCCC	2010	Cancun Agreements
	2013	Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts
European Union	2013	EU Strategy on Adaptation to Climate Change
IPCC	2014	Fifth Assessment Report
Canada	2013	The Adaptation Platform
China	2013	National Strategy for Climate Change Adaptation
	2014	China National Plan for Tackling Climate Change (2014–2020)

(Continued)

Table 1: Global climate adaptation policies included in this study (Continued)

Country/ organization	Year	Policy name
Stage 2 (2010–2014): Systematization of adaptation frameworks		
Germany	2011	Adaptation Action Plan (APA I) of the German Strategy for Adaptation to Climate Change
United Kingdom	2013	National Adaptation Programme I
United States	2011	Federal Agency Climate Change Adaptation Plans
	2013	President's Climate Action Plan
Stage 3 (2015–present): Globalization of adaptation actions		
COP to the UNFCCC	2015	Paris Agreement
	2023	UAE Framework for Global Climate Resilience
European Union	2021	New EU Strategy on Adaptation to Climate Change
International Federation of Landscape Architects (IFLA)	2021	Climate Action Commitment
IPCC	2018	Global Warming of 1.5°C
Australia	2015	National Climate Resilience and Adaptation Strategy
	2018	National Disaster Risk Reduction Framework
	2021	National Climate Resilience and Adaptation Strategy
	2022	AILA Climate Positive Design
Brazil	2016	National Adaptation Plan
Canada	2023	Canada's National Adaptation Strategy
	2024	Government of Canada Adaptation Action Plan
China	2022	National Climate Change Adaptation Strategy 2035
Germany	2015	Adaptation Action Plan II (APA II), included in the Initial Progress Report
Germany	2020	Adaptation Action Plan III (APA III), included in the Second Progress Report
	2024	2024 German Strategy for Adaptation to Climate Change
Japan	2015	National Plan for Adaptation to the Impacts of Climate Change
	2018	Climate Change Adaptation Act
	2021	Climate Change Adaptation Plan
South Africa	2019	National Climate Change Adaptation Strategy
United Kingdom	2018	National Adaptation Programme
	2023	Third National Adaptation Programme (NAP3)
United States	2023	National Climate Resilience Framework
	2025	ASLA Climate and Biodiversity Action Plan (2026–2030)

(Continued)

2004, to July 1, 2024. Subsequently, a manual screening process was conducted to retain studies on planning and design, engineering technologies, territorial and landscape conservation, ecological restoration, and historical and heritage conservation. It is worth noting that during manual screening, the term "适应" (response) used in early Chinese studies (in 2004 and 2005) was found to differ conceptually from "adaptation" as defined in this study, thus excluding such literature. After deduplication and final verification, 1,967 publications were retained, including 1,589 English articles and 378 Chinese articles.

For the literature content analysis, CiteSpace (version 6.3. R3) was used to quantify publications and keyword frequencies. Keyword clustering and timeline analyses were conducted using the log-likelihood ratio (LLR) algorithm to delineate developmental stages and identify core concern domains. Subsequently, the top 5% of the most cited publications in each cluster were manually reviewed in depth, with particular attention given to influential seminal studies and recent research advances. The results indicate that the clustering quality was robust for both English and Chinese studies.

Specifically, the modularity value (Q) for English studies was 0.768, with an average silhouette score (S) of 0.891, while the corresponding values for Chinese studies were 0.930 (Q) and 0.978 (S), respectively, suggesting statistically significant and well-structured clustering outcomes.

2.3 Alignment: Definition, Analytical Framework, and Assessment Indicators

"Alignment" is defined as the degree to which the missions, objectives, and plans of two related elements or systems mutually support each other[17], that is, the extent to which they correspond in terms of objectives and action arrangements. Based on this definition, alignment in this study refers to the degree to which academic studies correspond with core policy concern domains in terms of overall attention, adaptation targets, adaptation actions, and adaptation scales. To ensure the objectivity and rigor of the alignment assessment, this study follows the "key questions–sub-questions–assessment parameters" evaluation logic proposed by Elisabeth Conrad et al.[18]. Accordingly, an alignment assessment framework was constructed (Table 2), which consists of three components—primary dimensions, sub-dimensions, and assessment indicators—and includes four main dimensions: level of attention, adaptation target, adaptation action, and adaptation scale, with specific sub-dimensions accordingly. Alignment was assessed through a procedure from sub-dimensions to primary dimensions, and finally to overall alignment degree. To balance coverage and comparability, the number and proportion of studies corresponding to each sub-dimension were used as assessment indicators and were classified into low, medium, and high levels using the natural breaks method. The average degree of every sub-dimension was calculated to determine the alignment of the corresponding primary dimension and subsequently aggregated to derive overall alignment degree.

Table 2: Alignment assessment framework

Primary dimension	Sub-dimension	Assessment indicator
Level of attention	—	Proportion of studies in each domain to the total number of studies
Adaptation target	Defined according to policy content (e.g., the vulnerable groups such as the elderly and children)	Proportion of studies aligned with each sub-dimension to the total number of studies in that domain
Adaptation action	Defined according to policy content (e.g., Nature-based Solutions [NbS] and management strategies based on local knowledge)	
Adaptation scale	Coverage of different spatial scales	Number and proportion of studies across five key spatial scales: global/transnational, national, regional, urban, and local/community
	Coverage of different temporal scales	The number of studies addressing future time scales and their proportion to the total number of studies in that domain

3 Climate Adaptation Policies and Studies: Evolution and Core Concern Domains

3.1 Climate Adaptation Policies: Evolution and Core Concern Domains

3.1.1 Policy Evolution

The characteristics of climate adaptation policy development across the different stages were examined. In total, contemporary climate adaptation policies are characterized by multi-sectoral coverage, multi-level collaboration, regular monitoring, dynamic adjustment, and international cooperation. In terms of core concern domains, based on high-frequency themes identified in policy documents and classification schemes commonly adopted in academia[19], 11 major domains were identified: water resource management, ecosystems and biodiversity, coastal areas, agriculture, forestry, health and well-being, fisheries, infrastructure, cities and built environments, climate risk and disaster management, and energy. Together, these domains constitute a diverse and coexisting policy concern landscape. In terms of institutional arrangements, climate adaptation policies increasingly emphasize implementation through legal instruments and regulatory frameworks to ensure effectiveness and accountability[20]. In terms of governance and cooperation, policy actions span multiple levels, ranging from global, regional, city to community scales as well as individual actors. Compared with the overall characteristics in developed countries, adaptation policy systems in Global South countries, including China, remain

relatively weak in planning enforceability and legal support, and in institutionalizing or translating supporting mechanisms into operational pathways.

3.1.2 Core Concern Domains

Among the 11 core concern domains, six were selected for in-depth analysis based on their relevance to spatial form, natural ecosystems, and human needs. Domains of agriculture, forestry, fisheries, infrastructure, and energy were not included in the detailed analysis, as related policy measures are largely concentrated on engineering and technical aspects, such as transportation, communication, and breeding technologies.

Analyses revealed that the adaptation targets and actions across different domains shared several common characteristics (Table 3). First, an increasingly pronounced ecological orientation is observed. A growing number of organizations recognize that adaptation is not merely a short-term response but also a long-term process, for which no-regret measures centered on NbS are particularly effective in addressing sustained adaptation needs[21]. Second, climate adaptation and risk assessment are being progressively integrated into spatial planning systems[22], reflecting a shift toward a proactive and preventive approach[23]. For example, Germany has incorporated climate risk maps into spatial and territorial planning, restricting development in high-risk areas and adjusting population distribution away from vulnerable regions[22]. In addition, a stronger human-centered orientation has emerged among the policies, with increasing attention paid to the impact of climate risks (e.g., heatwaves) on human health[24]. Countries, such as Canada, have proposed targeted measures to enhance the adaptive capacity of vulnerable groups and integrated indigenous and local knowledge through public participation mechanisms, thereby improving social equity and inclusiveness of adaptation policies[25].

3.2 Climate Adaptation Studies: Evolution and Hotspots

3.2.1 Research Evolution

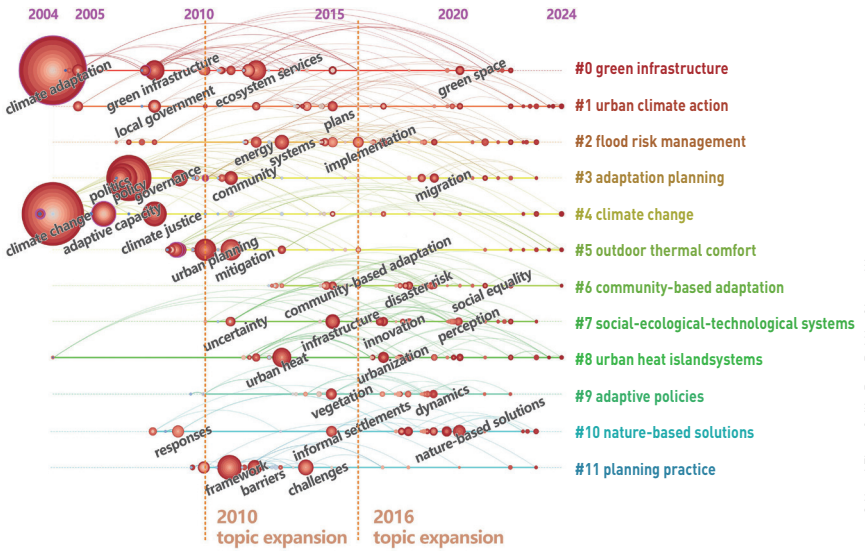
English-language literature on climate adaptation have begun to diversify research themes since 2010 (Fig. 1-1). Then by 2016, the extent of research topics and volume of publications increased significantly. Accordingly, the evolution of English studies can be divided into three distinct stages. Similarly, the developmental trajectory of Chinese studies during the past two decades can be broadly classified into three stages: from around 2010 onwards, research topics gradually diversified (Fig. 1-2), and after 2018, research themes expanded further, accompanied by a substantial increase in publication output (Fig. 2).

Table 3: Number of research publications and alignment analysis across core concern domains

Core concern domain	Number of publications	Level of attention	Adaptation target	Adaptation action	Adaptation scale	Overall alignment
Cities and the built environment	1,020	●●●	●●	●●	●	●●●
Climate risk and disaster management	557	●●	●●	●●●	●●	●●●
Coastal areas	207	●	●	●●●	●●●	●●
Ecosystems and biodiversity	188	●	●●	●	●	●
Water resource management	182	●	●●●	●●●	●●●	●●●
Health and well-being	108	●	●●	●●●	●●	●●
Total (after deduplication)	1,686	—	—	—	—	—
Proportion	85.7%	—	—	—	—	—

NOTES

●●● means high alignment; ●● means medium alignment; and ● means low alignment.



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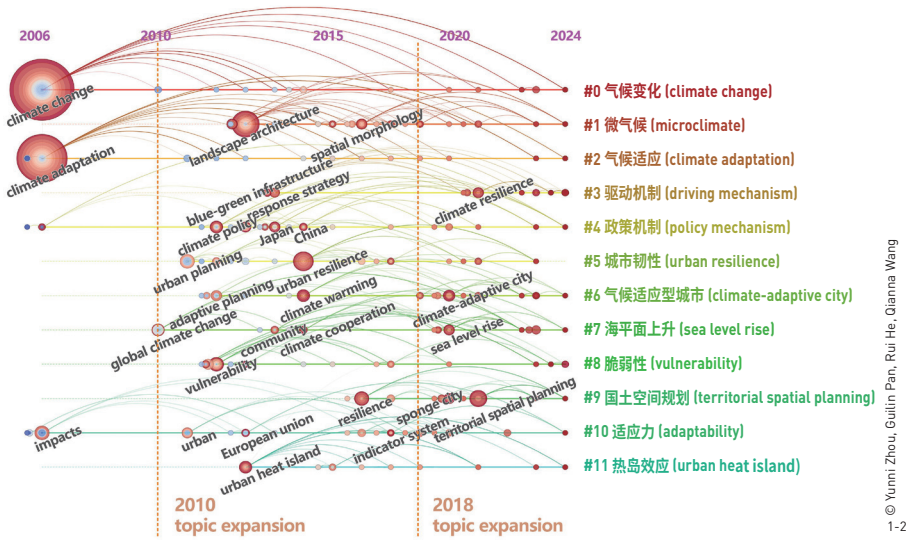

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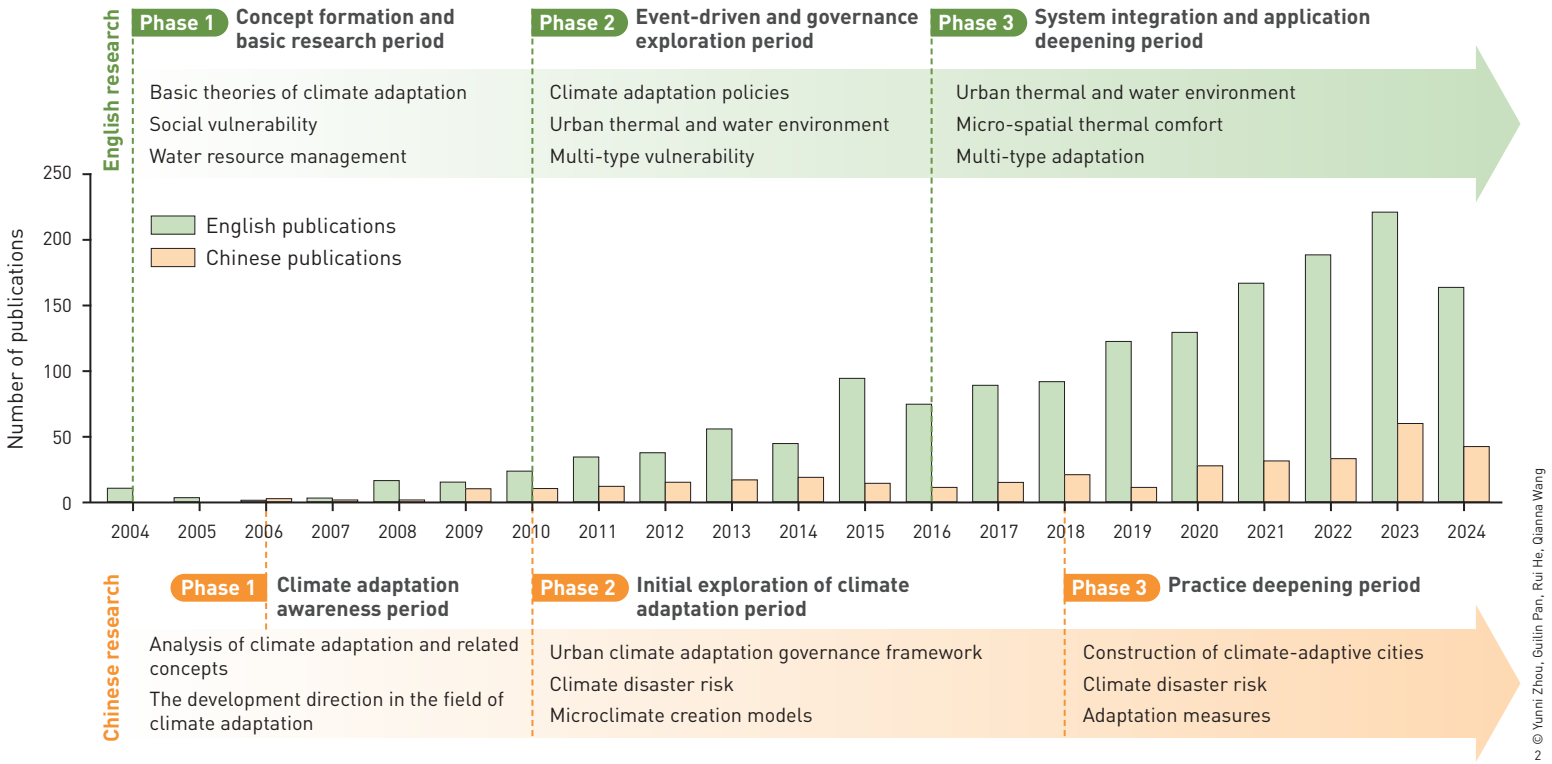

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Fig. 1 Timeline of English- and Chinese-language climate adaptation studies.
Fig. 2 Development stages of English- and Chinese-language climate adaptation research.

3.2.2 Research Hotspots

Based on the analysis of high-frequency keywords and clustering results generated by CiteSpace (Fig. 3), global climate adaptation studies exhibited a high degree of consistency in their core themes. Studies have largely focused on the optimization of policy and governance systems, as reflected in clusters, such as “adaptive policies” and “政策机制” (policy mechanism), as well as on spatial planning and design strategies, including clusters related to “green infrastructure” and “国土空间规划” (territorial spatial planning). Current research hotspots can be summarized into four main areas: 1) optimization of climate adaptation governance systems; 2) adaptive strategies for extreme weather events; 3) urban climate adaptation governance aimed at enhancing resilience; and 4) outdoor thermal comfort. Although emerging topics, such as climate justice (e.g., de-climate gentrification) and climate risks to cultural heritage (e.g., conservation of historic buildings), have gained increasing attention in recent years, their overall study volume remains relatively limited.

Overall, climate adaptation studies have continued to expand and deepen by engaging with policy and governance mechanisms,

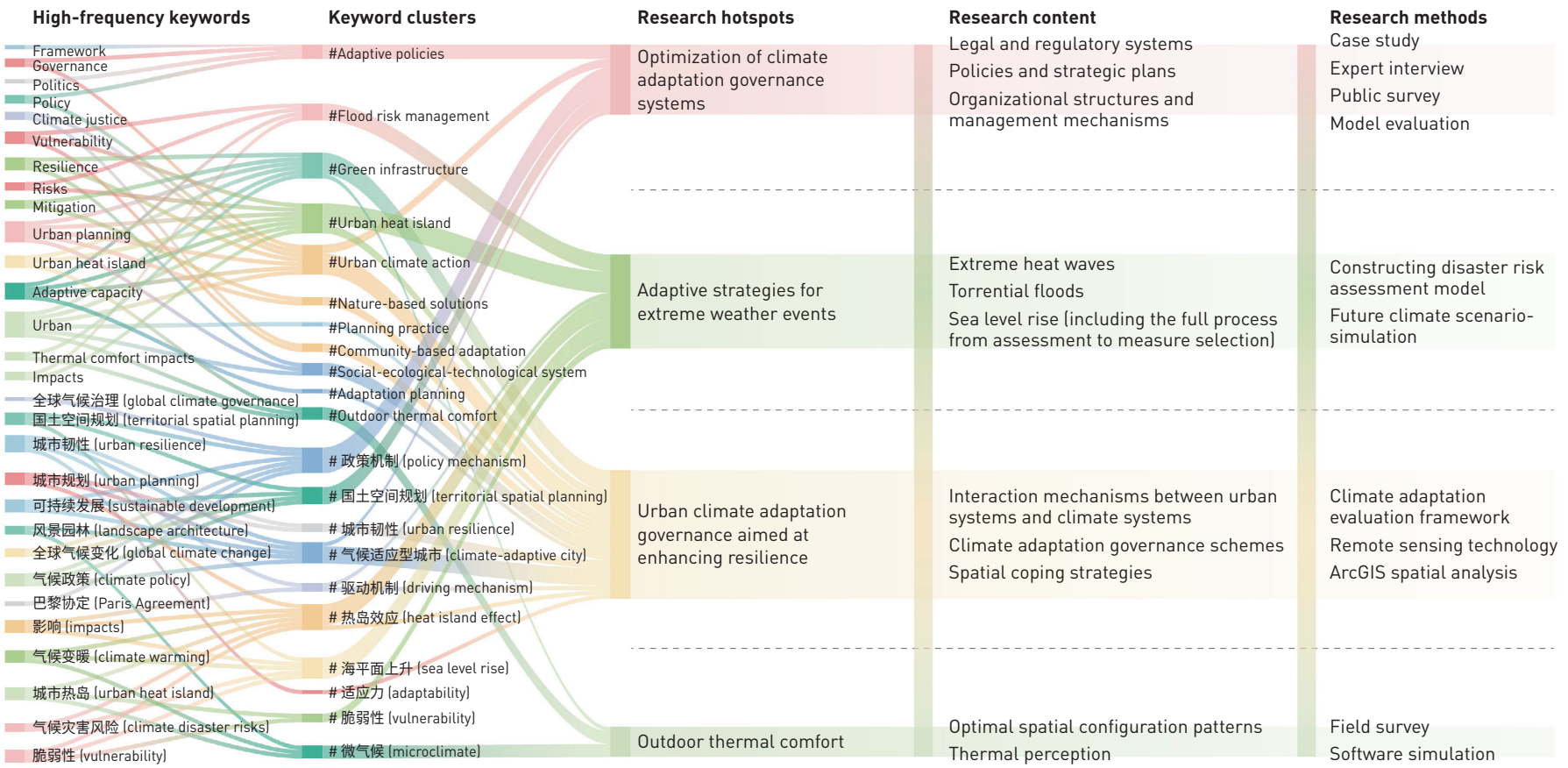

Fig. 3 High-frequency keywords, clusters, and research hotspots among climate adaptation studies.

incorporating ecological measures, embedding adaptation considerations in spatial planning and design, responding to human-centered needs, and increasingly addressing multisystem coupled adaptation. These developments have contributed to advancements in climate adaptation actions. In comparison, English studies have expanded extensively into areas of social equity, public health, ecosystem services, etc., demonstrating a greater diversity of perspectives and stronger interdisciplinary integration. In contrast, Chinese studies still require further strengthening of adaptation studies related to natural ecosystems and human well-being, particularly regarding the development of localized climate adaptation strategies grounded in local environmental and socioeconomic conditions.

4 Alignment Analysis of Core Concern Domains Between Policies and Studies

4.1 Temporal Analysis of Core Concern Domains in Policies and Studies

A comparative analysis of the historical trajectories of climate adaptation policies and studies identified key temporal milestones, clarified thematic similarities and differences, and examined evolving interaction patterns, thereby revealing the dynamic relationship between them. Furthermore, the temporal comparison indicates that the development of policies and studies are characterized by synchronized turning points, increasing thematic convergence, and evolving interaction patterns. Although policies and studies have adopted different criteria for stage division, both identified 2010 as their critical year. In addition, the enactment of the Paris Agreement in 2016 coincided with a major growth observed in English studies since the same year. This temporal correspondence confirms an underlying linkage between the policy evolution and academic studies. Accordingly, 2010 and 2016 can be regarded as milestone years of the development of climate adaptation policies and studies.

In the early stages, academic studies led policy development, providing conceptual foundations and signaling emerging adaptation needs. As policy frameworks matured, their guiding influence on research strengthened, resulting in increasingly evident positive interactions and enhanced alignment. The policy–

research alignment was particularly evident in urban adaptation planning, where policies prioritized cities and infrastructure, while studies addressed specific issues, such as land-use optimization. However, a comparative analysis revealed that the efficiency and depth of coordination and feedback remain limited. For instance, discussions on maladaptation and climate justice often face difficulties in effectively translating into policy practices across different political contexts. Since 2016, predominantly positive interaction and bidirectional feedback between policies and studies further increased their alignment. Studies proactively aligned with policy demands, using policy agendas as drivers for study topics and impact objectives, contributing to continuous policy improvement by evaluating policy quality, verifying implementation outcomes, and identifying policy barriers. Policies, in turn, have increasingly incorporated scientific findings, translating frontier theories into practical operational tools.

4.2 Alignment Analysis

4.2.1 Overall Overview

To assess the alignment across the six core concern domains, this study applied the alignment assessment framework and used R 4.4.2 to extract keywords from article abstracts for literature classification, followed by the calculation of multi-dimensional assessment indicators (Table 3). The results showed that 85.7% of the global studies address one or more policy core concern domains. In total, notable differences existed in the comprehensive alignment across the domains. Alignment is relatively high in the domains of cities and built environments, climate risk and disaster management, and water resource management; moderate in coastal areas and health and well-being; and comparatively low in ecosystems and biodiversity. Specifically, the alignment, in regard to adaptation targets, is generally strong across domains, and is relatively high in adaptation actions. In terms of spatial scale, most studies have focused on the city scale, followed by community and regional scales, whereas global and national scales are the least represented. In regard to the temporal scale, relatively few studies have incorporated future scenario simulations, indicating a limited capacity to address uncertainties associated with future climate change.

4.2.2 High-alignment Domains

(1) Cities and built environments

Climate adaptation policies in this domain have increasingly adopted an ecological orientation, advocating the development of interconnected, eco-based infrastructures and the enhancement of urban adaptive capacity through no-regret measures. Academic efforts have responded actively to these policy directions, generating substantial findings. For example, some studies have elucidated the interaction mechanisms between climate and urban systems, exploring the relationships between urban spatial structure, land use, and climatic processes[26]. Other studies have applied frameworks, such as the IPCC adaptation indicator system, Pressure-State-Response model[27], and Notre Dame Global Adaptation Index[28] to comprehensively assess urban adaptive capacity. In addition, urban spatial zoning and management frameworks have been proposed to reshape land-use structures and promote the development of blue–green infrastructure[29]. Overall, alignment regarding adaptation targets and actions in this domain is moderate, with study efforts largely concentrated on governance and institutional aspects, whereas empirical spatial practice cases remain relatively limited. Alignment in terms of adaptation scale was also insufficient, indicating the need for further studies at the regional scale, such as urban agglomerations and metropolitans, as well as for enhanced simulation and early warning of future climate risks.

(2) Climate risk and disaster management

Climate adaptation policies in this domain generally emphasize the establishment of end-to-end frameworks covering the entire process, from early warning to response. Correspondingly, studies have developed systematic climate risk adaptation processes encompassing three monitoring and evaluation stages: risk and vulnerability assessment, selection of adaptation measures, and assessment of adaptation actions. Among the various risk types, water-related risks have received the most attention, particularly extreme precipitation-induced flooding and sea-level rise. Related studies have employed multitemporal and multi-scenario simulations to reveal potential risks arising from climate uncertainty[30]. Extreme heatwaves constitute another major study focus, with proposed adaptation measures, including the establishment of heat warning and response systems[31] and adjustments to the urban spatial structure[32]. At the microscale, studies have increasingly examined outdoor thermal comfort and recommended measures such as using linear green spaces aligned with prevailing wind directions[33], deploying appropriate vegetation types and water bodies[34], and regulating building orientation and layout[35]. Although the comprehensive and dimension-specific alignments in this domain were relatively strong, further studies are required to address compound disaster risks and to improve the evaluation and monitoring of adaptation measures.

(3) Water resource management

Climate adaptation policies in this domain emphasize the integrated consideration of natural and social water systems to

ensure the safety, quality, and sustainable supply of water resources. Studies have contributed to the development of innovative approaches and technologies, including low-impact development (LID) practices[36], green infrastructure, and sustainable drainage systems[37]. These advances have also supported institutional transitions toward decentralized management and stakeholder participation in decision-making processes[38–39], responding to governance challenges associated with droughts, floods, and other water-related risks in major river basins, such as Mekong River and Yellow River[40–41]. Generally, the comprehensive alignment of this domain was strong. Future studies could further enhance the alignment with respect to adaptation targets in water supply systems by strengthening the integration of disciplines (e.g., landscape planning and water supply and drainage engineering) and applying NbS to ensure water quality and security of water supply under extreme weather conditions.

4.2.3 Medium-alignment Domains

(1) Coastal areas

Climate adaptation policies in coastal areas emphasize responses to sea-level rise and other coastal hazards through measures, such as coastal protection infrastructure and ecosystem restoration, with the objective of ensuring the ecological, social, and economic sustainability of coastal regions. Compared with water resource management, this domain places a greater emphasis on the adaptive capacity of coastal populations and socioeconomic systems. Existing studies have largely focused on managed retreat planning[42]. Commonly adopted approaches include dynamic adaptive policy pathways[43], backcasting[44], multi-criteria analysis[45], and contextualized analyses that integrate future climate simulations and public participation[46]. However, with respect to the alignment of adaptation targets and actions, ecosystem-related issues remain relatively underrepresented. Future studies should strengthen the exploration of coastal ecosystems and promote the development of integrated grey–blue–green protection systems. In terms of spatial scale, studies in this domain are predominantly concentrated at the city scale, particularly in economically developed coastal cities. Vulnerable villages and community-level contexts have received limited attention, requiring further efforts.

(2) Health and well-being

Policies in the domain of health and well-being emphasize strengthening the adaptation capacity of healthcare systems, vulnerable regions, and population groups to the health impacts of climate change, including air pollution, vector-borne diseases, and mental health risks. However, existing studies have predominantly focused on heat stress[47], whereas other areas remain comparatively underdeveloped, particularly studies on vector-borne disease transmission[48] and spatial configuration of healthcare facilities. Notably, in terms of the level of attention, the alignment in this domain is relatively weak, as reflected by the limited volume of relevant literature. Regarding the adaptation actions, further exploration is needed for the application of scientific data in disease surveillance, prevention, and early warning systems. In terms of adaptation scale, a greater emphasis on fine-grained, small-scale analyses is required to ensure that adaptation measures effectively benefit individuals.

4.2.4 Low-alignment Domain

This study identified ecosystems and biodiversity as the only domains characterized by low alignment. Although the American Society of Landscape Architects (ASLA) has explicitly stated that "solutions to the climate and biodiversity crises are intertwined,"[49] alignment in this domain remains the weakest. Climate adaptation policies generally emphasize expanding the ecosystem extent and enhancing ecosystem resilience[3,50], as well as conserving species habitats to maintain biodiversity. In contrast, existing studies have largely concentrated on urban ecosystems, focusing on enhancing adaptive capacity through NbS, such as rain gardens, green roofs, and urban parks[51]. Studies addressing natural ecosystems are relatively limited, particularly those focusing on biodiversity. Existing studies have approached biodiversity adaptation from various perspectives, including ecosystem restoration, ecological network development, the establishment of protected areas, adaptive capacity analysis of focal species[52], and improvements in habitat quality. Emerging concepts, such as "climate connectivity," have also provided new analytical tools for biodiversity adaptation studies[53]. However, the number of such studies remains insufficient to form a robust scientific basis and provide actionable guidance for policy implementation. In terms of adaptation scale, predictive and simulation-based studies on the future trajectories of natural ecosystems are also limited, constraining the ability of existing studies to effectively support policy demands for sustainable adaptation.

5 Implications

In total, the alignment analysis revealed that the current research landscape is characterized by imbalances in research focus and weak coverage of spatio-temporal scales, limiting its capacity to meet policy demands for full-chain implementation, long-term planning,

and sustainable actions. Accordingly, the high-, medium-, and low-alignment domains are discussed, with the aim of providing critical reflections and insights for future climate adaptation efforts.

5.1 High-alignment Domains

Benefiting from ample financial support and lower disciplinary barriers, the domains of cities and built environments, climate risk and disaster management, and water resource management exhibit relatively high levels of alignment, achieving mature technical approaches and a substantial body of studies. However, the high overall alignment between policies and studies should not be regarded as the sole or unequivocally ideal objective[54]. On the one hand, policy agendas may lag behind rapidly evolving climate realities, such that research narrowly responding to existing policies risks losing forward-looking capacity and academic value. On the other hand, high alignment may result from uneven resource allocation of academic investment, coming at the expense of ignoring other critical issues. For example, within the domain of cities and built environments, 59.1% of the studies focus on governance frameworks, whereas the development and application of smart technologies account for only 1.4%. Moreover, most such studies rely on case-based approaches and exhibit homogeneity in research topics, methods, and outcomes, which may lead to path dependence in the long term[55]. Therefore, future efforts should promote a shift from "general alignment" toward "quality alignment." This entails reallocating research resources to address key challenges; developing practical decision-support models, indicators, and policy tools; and strengthening knowledge translation by validating their feasibility in economic and engineering practice contexts.

5.2 Medium- and Low-alignment Domains

Owing to the combined effects of multiple factors, medium- and low-alignment domains (i.e., coastal areas, health and well-being, ecosystems and biodiversity) exhibited both generally weak alignment and imbalanced development across sub-topics. First, the highly interdisciplinary nature and strong multisystem coupling of these domains substantially increase the research thresholds and integration complexity[56]. For example, studies on health and well-being require the integration of disciplines such as spatial planning, psychology, and medicine, resulting in disciplinary barriers that enlarge the delays and fragmentation in knowledge production. Second, limitations in methodological operability and data availability are critical bottlenecks. For instance, studies on ecosystem services that rely on relatively straightforward methods account for 48.4% of the total, whereas biodiversity-focused research that requires advanced interdisciplinary knowledge and technical capacity accounts for only 17.0%. Specifically, research progress in coastal areas is constrained by the complexity of sea-level rise modeling; health-related studies are often limited by ethical considerations that restrict data access[57]; and biodiversity studies face persistent data scarcity owing to the high costs of long-term monitoring[58]. Finally, limited academic resources tend to be prioritized for domains with immediate visible risks[59], whereas medium- and low-alignment domains often involve long-term and latent risks, such as ecosystem degradation and potential health threats. This dynamic contributes to insufficient attention and uneven investments. The *Fourth Review of the Adaptation Fund* reports that disaster risk-related sectors receive the highest levels of funding, whereas the forestry sector receives the least, with an approximate thirtyfold difference between the two[60]. Nevertheless, these challenges also have substantial potential, as cross-sectoral and cross-system approaches can generate synergistic benefits. For example, coastal protection strategies can integrate grey–blue–green infrastructure to jointly address ecological and social adaptation needs; for ecosystems, the development of climate-adaptive ecological networks can provide a foundation for species persistence and water and coastal protection.

5.3 From Outcome Alignment to Mechanism Alignment

The analysis indicates that the policy–research misalignment is not merely in content, but rather the result of the combined influence of internal and external mechanisms. This implies that the effectiveness of future climate adaptation efforts depends on fundamental improvements at the mechanism level. Knowledge co-production systems that emphasize dynamic interaction and iterative optimization have been widely validated as effective[61–62] and can serve as a core strategy for bridging the policy–research gap in the field of climate adaptation.

1) Optimizing policy–research bidirectional feedback mechanisms. Establishing sustained, in-depth dialogue platforms between policymakers and researchers is essential for embedding bidirectional feedback into the process of knowledge production and policy application. Regular policy briefings and study dissemination sessions should be institutionalized, and policymakers should be engaged at the early stages of major study initiatives to jointly clarify policy needs and priorities. At the same time, boundary organizations, such as scientific advisory bodies, should be introduced to act as "translators," distilling complex research findings into accessible policy-relevant conclusions. For

example, uncertainties in climate modeling can be translated into multiple policy options to support flexible decision-making[62]. The policy-formulation process should similarly incorporate feedback mechanisms, whereby insights from pilot projects, monitoring efforts, and evaluation reports can in turn inform research agendas. This iteration allows for the continuous recalibration of research directions and fosters a virtuous cycle from knowledge generation to real actions.

2) Promoting interdisciplinary collaborative and exchange mechanisms. To address the systemic nature of climate adaptation, it is necessary to break down disciplinary barriers and establish mechanisms for interdisciplinary collaboration, as well as data and technology sharing. Experiences from initiatives, such as the EU's Climate-KIC and the USA's NOAA (National Oceanic and Atmospheric Administration) Climate Data Portal, provide useful references for developing interdisciplinary open-data platforms and shared standards, thereby facilitating collaboration between research institutions, academia, and industry. Also, priority should be given to addressing crosscutting challenges among the domains or developing shared technical approaches[54,63]. Examples include integrating machine learning with remote-sensing technologies, standardizing interdisciplinary research paradigms, promoting NbS across multiple spatial scales to achieve synergistic benefits, and developing tools for future climate scenario simulations.

3) Enhancing coordinated support through resource allocation and governance mechanisms. First, funding distribution should address existing imbalances. Priority should be given to domains that face urgent real-world challenges and strong policy demands but exhibit insufficient alignment (e.g., ecosystems and biodiversity), as well as to high-value but underrepresented areas (e.g., climate justice). At the governance level, reforms in research evaluation systems can increase the recognition of policy relevance and societal impact[62], thereby incentivizing studies that address critical and complex challenges. On the policy side, the establishment of binding regulatory instruments, regular monitoring requirements, and adaptive management tools can strengthen implementation; government performance evaluation systems can be improved by incorporating climate adaptation effectiveness indicators (e.g., economic loss avoidance), to quantify policy outcomes[62].

6 Conclusions

This study systematically reviewed and comparatively analyzed the evolution of global climate adaptation policies and studies over the past two decades, focusing on their core concern domains. By constructing an alignment assessment framework, this study examined the interaction patterns between policies and studies and evaluated the degree of alignment across different domains. The results indicate that the alignment between the two is relatively strong; however, the alignment with respect to spatio-temporal scales remains generally insufficient. Significant disparities in alignment were observed across domains, and the alignment in adaptation target and action varied by field. Domains, such as cities and infrastructure, climate risk and disaster management, and water resource management, exhibited relatively high alignment, whereas ecosystems and biodiversity lagged behind. Based on these findings, this study reflects on the potential risks associated with high-alignment domains (including diminished forward-looking capacity and path dependence) and analyzes the underlying causes of weak alignment in medium- and low-alignment domains (including high barriers to interdisciplinary integration, limited methodological operability, constraints on data availability, and long-term imbalances in resource allocation). Then, this study proposes three strategies for shifting from outcome alignment to mechanism alignment: 1) optimizing policy–research bidirectional feedback mechanisms, 2) promoting interdisciplinary collaboration and exchange mechanisms, and 3) enhancing coordinated support through resource allocation and governance mechanisms. Together, these recommendations offer insights and guidance for the future development of climate adaptation policies and studies.

However, this study has several limitations. First, the analysis focused primarily on international and national-level climate adaptation policies, and the potential influence of variations in regional and community policies on these findings requires further examination. Second, the analysis concentrates on major and frequently discussed domains, whereas underrepresented areas, such as climate justice and cultural heritage, despite their importance in advancing climate adaptation theory, require deeper investigation. Finally, the literature sample was limited to Chinese- and English-language publications, thus future studies could extend to multilingual sources to enhance the applicability and theoretical depth of the findings.

ELECTRONIC SUPPLEMENTARY MATERIAL

Supplementary material is available in the online version of this article at https://doi.org/10.15302/J-LAF-2026-0015.

Competing interests | The authors declare that they have no competing interests.

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气候适应政策与研究的核心关切是否契合？——政策文件与文献的比较评述

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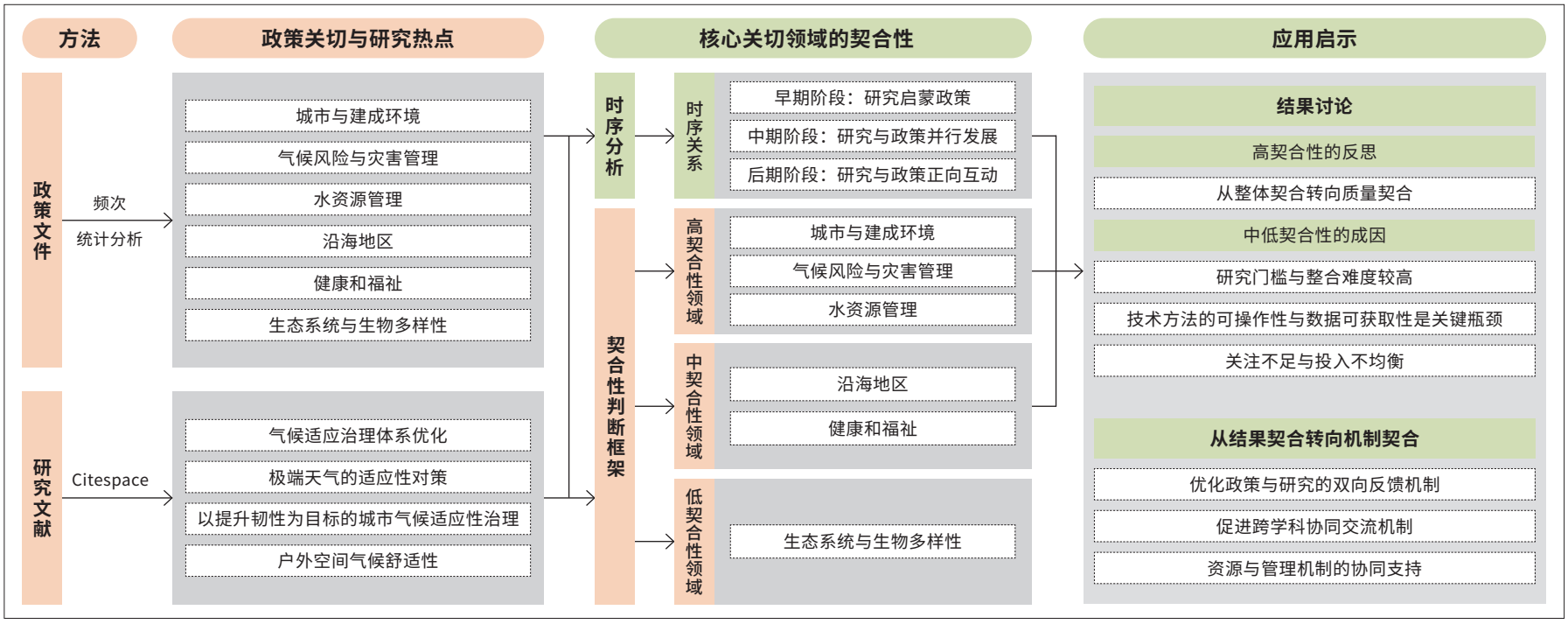
图文摘要



摘要

比较评述气候适应政策和研究成果的契合性，有助于认识并缩小二者差距，提升人居环境气候适应行动的成效。全面梳理了政策及研究的发展脉络，揭示二者互动的演进模式，从关注程度、适应对象、行动措施与适应尺度4个维度构建了契合性判断框架，评估了核心关切领域的契合性。结果表明，政策已进入全球协同的新阶段，研究重心则从理论过渡到应用。二者关系经历了研究先行、并行发展到双向互动的转变，但协同效率和深度仍需进一步提升。从核心关切领域来看，整体契合性较好，城市与建成环境、气候风险与灾害管理、水资源管理契合性最高，沿海地区与健康和福祉居中，生态系统与生物多样性偏低；对象和行动契合性良好，但尺度契合性不足，未来情景模拟与区域、社区尺度的研究仍显薄弱。未来需优化政策与研究的双向反馈机制、促进跨学科协同交流机制，以及资源与管理机制的协同支持。本文成果丰富了气候适应治理理论，也能为政策与研究的未来发展提供启示与指引。

关键词

气候适应；气候变化；文献综述；政策体系；契合性

文章亮点

- 基于气候适应政策与研究双重视角的比较述评
- 明确了气候适应政策与研究之间存在相互影响、正向互动的关系
- 构建了涵盖关切程度、对象、行动与尺度的契合性判断框架
- 核心关切领域的整体契合性较好但领域间差异显著
- 提出了优化双向反馈机制、跨学科协同交流、资源分配与管理的未来工作方向

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1 研究背景

气候变化的影响正以空前的速度和强度冲击全球，极端高温、洪涝、干旱等气候灾害愈发频繁[1]，人居环境遭受严重威胁。自1990年联合国政府间气候变化专门委员会（Intergovernmental Panel on Climate Change，IPCC）提出适应战略[2]以来，国际社会逐渐意识到开展适应气候变化的行动迫在眉睫。

近年来，全球在气候适应政策制定和理论研究上已取得显著进展。政策层面，从《坎昆协议》到《巴黎协定》，气候适应行动优先级提升并实现制度化。各国政府加速制定气候适应政策，关注城市基础设施、水资源管理、生态系统保护、农业安全和公共健康等多个领域。中国也出台了《国家气候适应战略2035》等多部气候适应相关政策文件，明确提出要强化人居环境适应气候变化的能力[3]。同时，城市与建成环境、气候风险与灾害管理[4]等领域也取得了丰硕研究成果，为政策制定与行动实践提供了坚实的理论与方法支撑。当前，相关综述多侧重于空间规划[5]、城市水管理[6]、全球政策工具总结[7]等方面，鲜有分析政策和研究二者在气候适应领域契合度的研究。

学术研究一定程度受政策引导，二者的最终目标均指向服务于社会的实际需要[8–9]。科学研究对政府决策有重要支撑作用，但研究内容并不是总能与最迫切的政策需求有效匹配，尤其在复杂的环境治理领域[10]。因此，理解气候适应政策与研究关切领域的潜在错位，对缩小二者差距、提升人居环境气候适应行动的成效具有重要意义。本文聚焦于“气候适应政策与研究的核心关切是否契合”这一核心问题，从政策与研究的双重视角出发，构建契合性判断框架，评估二者核心关切领域的匹配程度，并从中识别政策与研究的优化方向。本研究旨在：1）梳理全球气候适应政策与研究在不同阶段的演进脉络、核心关切领域；2）构建契合性判断框架，评估政策与研究在核心关切领域的契合性；3）提出学界与政府在未来气候适应工作中的策略与建议。与此同时，因中国人口众多且位于全球气候敏感区，极易受气候变化的不利影响，本文亦关注中文与英文气候适应研究、政策之间的异同和差距，以期为以中国为代表的全球南方国家的气候适应行动提供参考。

2 研究框架与方法

2.1 气候适应：定义与特征

IPCC的气候评估报告将“气候适应”（climate adaptation）定义为：“在人类系统中，针对实际或预期的气候及其影响进行调整，以减轻危害或利用有利机会；在自然系统中，针对实际气候及其影响进行调整”[11]，即强调主动调整以应对已存在或将要发生的气候变化或极端天气事件。后文基于气候适应概念及特征开展样本筛选与文本解析。

2.2 样本收集

政策样本筛选方面重点关注政策文件中的气候适应相关内容是否符合政策框架的完整定义，即是否包含明确的目标、原则、计划和工具等要素[12]。以1990年为起点，最终筛选出来自中国、英国、日本等国家，以及IPCC等国际组织的政策文件45份（表1），时间跨度为2007~2024年。研究以2007年的IPCC《第四次评估报告》[13]与《巴厘路线图》[14]、2010年的《坎昆协议》[15]及2015年的《巴黎协定》[16]等里程碑事件为节点，将政策进程划分为3个阶段。

文献样本收集方面，以Web of Science核心数据集与中国知网（北大核心、CSSCI和CSCD来源期刊）分别作为中英文文献检索源。以“气候适应”（climate adaptation）、“气候适应性”（climate adaptability / climate adaptiveness）、“气候适应型”（climate adaptive / climate-adaptive）为检索词，学科限定为区域研究（Area Studies）、区域城市规划（Regional and Urban Planning）、城市研究（Urban Studies）与环境科学（Environmental Sciences）。经预检索与主题相关性核查，与城市、区域、环境领域匹配度较高的有效样本主要始于2004年，因此，检索时间限定为2004年1月1日至2024年7月1日。进一步开展人工筛选，遴选出涵盖规划设计、工程技术、国土景观保护与生态修复、历史与遗产保护等领域的文献。值得一提的是，进行人工筛选时发现，2004年与2005年的

表1：纳入本研究的全球重点气候适应政策文件

国家／组织	年份	政策
第一阶段（2007—2009）：减缓与适应并重		
《联合国气候变化框架公约》缔约方大会	2007	《巴厘路线图》
欧盟	2007	《欧洲适应气候变化——欧盟行动选择》绿皮书
	2009	《迈向气候变化适应战略框架》白皮书
IPCC	2007	《第四次评估报告》
澳大利亚	2007	《国家气候变化适应框架》
中国	2007	《应对气候变化国家方案》
德国	2008	《德国适应气候变化战略》
印度	2008	《国家气候变化行动计划》
英国	2009	《苏格兰气候变化适应框架》
第二阶段（2010—2014）：适应框架系统化		
《联合国气候变化框架公约》缔约方大会	2010	《坎昆协议》
	2013	《华沙损失与损害国际机制》
欧盟	2013	《欧盟适应气候变化战略》
IPCC	2014	《第五次评估报告》
加拿大	2013	《加拿大适应平台》
中国	2013	《国家适应气候变化战略》
	2014	《国家应对气候变化规划（2014—2020）》
德国	2011	《德国气候变化适应战略适应行动计划》
英国	2013	《国家适应规划 I》
美国	2011	《联邦机构气候变化适应计划》
	2013	《总统气候行动计划》

国家／组织	年份	政策
第三阶段（2015 年至今）：适应行动全球化		
《联合国气候变化框架公约》缔约方大会	2015	《巴黎协定》
	2023	《阿联酋全球气候韧性框架》
欧盟	2021	《新欧盟适应气候变化战略》
国际景观设计师联盟	2021	《气候行动承诺》
IPCC	2018	《IPCC 2018 年全球升温 1.5℃特别报告》
澳大利亚	2015	《澳大利亚国家气候韧性和适应性战略》
	2018	《国家灾害风险减少框架》
	2021	《国家气候韧性和适应性战略》
	2022	AILA《气候正效设计》
巴西	2016	《国家气候变化适应计划》
加拿大	2023	《加拿大国家适应战略》
	2024	《加拿大政府适应行动计划》
中国	2022	《国家适应气候变化战略 2035》
德国	2015	《适应行动计划Ⅱ》（载于首次进展报告）
	2020	《适应行动计划Ⅲ》（载于第二次进展报告）
	2024	《2024 德国适应气候变化战略》
日本	2015	《气候变化影响适应国家计划》
	2018	《气候变化适应法》
	2021	《气候变化适应计划》
南非	2019	《国家气候变化适应战略》
英国	2018	《第二次国家适应规划》
	2023	《第三次国家适应规划》
美国	2023	《国家气候韧性框架》
	2025	ASLA《气候和生物多样性行动计划（2026-2030）》

中文研究中的“响应”与本文的“适应”内涵不同，故将其剔除。经去重处理和最终检查，共收集1 967篇文献，英文文献1 589篇，中文文献378篇。

在文献内容分析部分，首先基于CiteSpace.6.3.R3，对文献发文量和关键词频次进行统计，使用LLR算法进行关键词聚类和时间线分析，以此划分发展阶段并归纳核心关切领域。其次，人工精读每个聚类中前5%的高被引文献，并重点关注具有较大影响力的经典文献及最新研究成果。结果显示，英文文献聚类模块值Q值为0.768，平均轮廓值S值为0.891；中文文献聚类Q值为0.930，S值为0.978，表明聚类显著且合理。

2.3 契合性：定义、判断框架与审查指标

“契合性”（alignment）指两个相关要素或体系在目标与行动安排上相互支持、相互匹配的程度，即一方的使命、目标与计划在多大程度上支持并被另一方的使命、目标与计划所支持[17]。据此，本文将该概念引申为：研究文献在整体及关注程度、适应对象、行动措施与适应尺度上与政策核心关切领域的匹配程度。为确保契合性判断的客观性与科学性，参考伊丽莎白·康拉德等[18]提出的“主要问题—子问题—审查参数”的评估思路，构建了契合性判断框架（表2）。该框架由主维度、子维度和审查指标3部分组成，包含关注程度、适应对象、行动措施与适应尺度4个维度，根据政策内容设置具体子维度。契合性判定采用“子维度—主维度—综合契合性”的审视流程。为兼顾覆盖度与均衡性，本文以各子维度对应的研究数量及占比为审查指标，运用自然断点法将其划分为低、中、高3级，再计算子维度的平均等级作为主要维度的契合性判定依据，并最终汇总为整体契合性。

表 2：契合性判断框架

主维度	子维度	审查指标
关注程度	—	各领域研究数量与研究总数量的比例
适应对象	视政策内容而定，例如老人、儿童等弱势群体	与子维度相契合的研究数量和该领域研究总数量的比例
行动措施	视政策内容而定，例如基于自然的解决方案（Nature based Solutions，NbS）以及基于地方知识的管理策略	
适应尺度	研究对各个空间尺度的覆盖程度	全球／跨国、国家、区域、城市、地方／社区 5 个关键尺度的研究数量及比例
	研究对不同时间尺度的覆盖程度	未来时间尺度的研究数量和该领域研究总数量的比例

3 气候适应政策与研究：进程、核心关切领域

3.1 气候适应政策：进程、核心关切领域

3.1.1 进程

各政策阶段的发展特征整分析表明，总体而言，目前的气候适应政策呈现多领域覆盖、多层次协作、定期监测、动态调整、国际合作的特点。在核心关切领域上，综合政策文本中的高频领域与相关文献的分类标准[19]，识别出水资源管理、生态系统与生物多样性、沿海地区、农业、林业、健康与福祉、渔业、基础设施、城市与建成环境、气候风险与灾害管理、能源11个核心关切领域并存的格局。在体制建设上，强调通过法律手段和监管体系保障气候适应政策的实施[20]。在合作层次上，则涉及到全球、区域、城市、社区乃至个人层面的多层次合作。与发达国家的政策整体特征相比，中国等全球南方国家的适应政策体系在规划约束力和法律法规支持方面相对薄弱，支撑保障机制亦尚未形成制度化的落地路径。

3.1.2 核心关切领域

在11个核心关切领域中，基于与空间形态、自然生态和人文需求的关联性，本文选取了6个领域开展深入分析。农业、林业、渔业、基础设施和能源领域多集中于交通、通信和育种等工程技术领域，故暂未考虑。基于前述时间节点，分段整理各时期政策的适应领域，统计其出现频次。早期政策聚焦于水和生态系统，2015年后，对健康与福祉等领域的关注度大幅提升，政策关注重点正由以自然生态系统为主转向自然生态与人文福祉并重。

分析发现，各个领域的适应对象与行动措施具备一定共性特征（表3）。首先，生态导向趋势明显增强。越来越多的组织意识到适应不仅是短时应对，更是长期过程，以NbS为核心的无悔方案（no-regret measures）能够更有效地应对这种持续性需求[21]。其次，气候适应与气候风险评价逐步融入空间规划体系[22]，体现出向“主动预防”的转变[23]。德国将气候风险地图纳入国土规划，限制高风险地区的开发，并调整人口布局以避开脆弱区域[22]。此外，政策的人本化导向愈发显著，更加关注热浪等气候风险对人类健康的影响[24]，加拿大等国家进一步提出提升弱势群体适应能力的具体举措，并通过公众参与机制整合原住民与地方知识，提升适应政策的社会公平性与包容性[25]。

表 3：核心关切领域研究数量及契合性分析

核心关切领域	文献数量	关注程度	适应对象	行动措施	适应尺度	综合契合性
城市与建成环境	1 020	●●●	●●	●●	●	●●●
气候风险与灾害管理	557	●●	●●	●●●	●●	●●●
沿海地区	207	●	●	●●●	●●●	●●
生态系统与生物多样性	188	●	●●	●	●	●
水资源管理	182	●	●●●	●●●	●●●	●●●
健康与福祉	108	●	●●	●●●	●●	●●
去重总计	1 686	—	—	—	—	—
比例	85.7%	—	—	—	—	—

注

●●●表示高契合性，●●表示中契合性，●表示低契合性。

3.2 气候适应研究的进程与热点

3.2.1 研究进程

英文气候适应研究在2010年首次呈现出主题多元化的发展趋势（图1–1）；至2016年，研究主题和发文量显著增加。据此，将英文气候适应的研究进程划分为3个阶段。近20年来，中文气候适应研究的发展轨迹也可大致划分为3个阶段：自2010年起，研究内容逐步多样化（图1–2），2018年后研究主题进一步拓展，发文量显著增长（图2）。

3.2.2 研究热点

由CiteSpace的高频关键词和聚类词条分析结果（图3）可知，全球气候适应研究在核心内容上呈现较高一致性，普遍关注政策与治理体系优化，如“adaptive policies”“政策机制”聚类，以及空间规划设计策略，如“green infrastructure”“国土空间规划”聚类。当前研究热点可归纳为4个方面：气候适应治理体系优化、极端天气的适应性对策、以提升韧性为目标的城市气候适应性治理，以及户外空间气候舒适性研究。尽管近年来涌现出气候正义（如去气候绅士化）及文化遗产气候风险（如古建筑保护）等新兴议题，但其研究体量仍相对较小。

整体而言，气候适应研究在对接政策与治理机制、纳入生态措施、嵌入空间规划与设计、回应人本需求，以及日益关注多系统耦合适应等方面不断拓展与深化，推动了气候适应行动的积极发展。相较而言，英文文献内容已拓展至社会公平、公众健康、生态系统服务等领域，视角多元度、跨学科融合度更高。而中文文献在自然生态和人本需求等方面的适应性研究方面尚待加强，特别是基于当地自然和社会经济条件的本土化气候适应策略等课题亟待探索。

4 政策与研究核心关切领域的契合性分析

4.1 政策与研究核心关切领域的时序分析

对比分析气候适应政策与研究的发展进程，有助于识别关键时间节点、梳理主题异同及互动模式，进而揭示二者的动态关联。时序对比表明，政策与研究的发展进程呈现出转折同步、主题趋同、互动模式变化等特征。尽管政策与研究采用了不同的阶段划分标准，但均将2010年确定为重要转折点。同时，《巴黎协定》于2016年正式生效，这也与英文研究在2016年开始的持续增长相吻合。这种时序关联性证实了政策演进与学术研究存在一定内在联系。因此，2010年和2016年可被视为政策与研究发展轨迹的重要交汇点。

在早期阶段，研究具有政策先导性，通过厘清概念与探讨适应行动重要性，为政策制定提供理论基础。随着政策完善，其对研究的引导作用渐强，两者正向互动关系愈加明显，契合性日益增强。尤其是在城市适应性规划领域，政策将城市与基础设施列为重点，研究则深入土地利用优化等具体问题。然而，对比分析也揭示了两者协同与响应反馈的效率和深度仍有待提升。例如，“不良适应”与“气候正义”的讨论难以在不同的政治环境下有效转化为政策实践。自2016年以来，政策与研究基本实现正向互动与双向循环，契合性进一步增加。研究主动对接政策要求，将政策作为选题导向与影响目标，并通过评估政策质量、核验政策实施效果、识别政策障碍，促进政策持续优化；而政策也积极吸收科研成果，将前沿理论转化为实际操作工具。

4.2 契合性分析

4.2.1 整体概况

为评估6个核心关切领域的契合性，本文基于契合性判断框架，通过R语言提取摘要关键词完成文献归类，并统计各领域内多维度的审查指标（表3）。结果显示，全球85.7%的研究文献涉及一个或多个政策核心关切领域。总体而言，各领域的综合契合性存在一定差异，城市与建成环境、气候风险与灾害管理和水资源管理领域的契合性相对较高，沿海地区和健康与福祉的契合性次之，生态系统与生物多样性的契合性欠佳。具体而言，适应对象契合性整体较好，行动措施契合性也普遍较高。空间尺度上，各领域均以城市为主，社区和区域次之，全球与国家最少。时间尺度上，对未来情景的模拟较少，反映现有研究对未来气候变化不确定性的应对能力有限。

4.2.2 高契合性领域

（1）城市与建成环境

政策逐渐呈现生态导向，倡导构建互联的生态化基础设施，以无悔方案提升城市适应力。研究对此积极回应，取得了诸多成果。例如，揭示气候系统与城市系统的互动机制，探索城市空间结构、土地利用与气候过程的相互作用[26]；运用IPCC适应指标体系、压力—状态—响应模型[27]和全球气候适应指数[28]等框架，全面评估城市的综合适应能力；提出城市空间分区管理框架，改变土地利用结构、建设蓝绿基础设施[29]。整体上，该领域的适应对象契合性和行动措施契合性适中，但多集中于治理与制度层面，空间实践案例仍显薄弱。适应尺度契合性亦有欠缺，城市群、都市圈等区域尺度及未来气候风险模拟预警有待加强。

（2）气候风险与灾害管理

政策普遍强调建立从预警到应对的全流程方案，研究也建立了系统的气候风险适应流程，涵盖风险和脆弱性评估、适应措施选择及适应行动的3个监测评价阶段。其中，关注度最高的是水风险，尤其是暴雨洪涝和海平面上升，相关研究通过多时段、多情景模拟揭示了气候不确定性带来的潜在风险[30]。极端热浪亦是重要议题，研究提出建立“热预警”响应体系[31]、调整城市空间结构[32]等行动。在微观层面，关注户外热舒适性，建议采用和风向平行的带状绿地[33]、配置合适的植被类型及水体[34]、控制建筑的朝向布局[35]等措施。该领域的整体契合性与各维度契合性均较好，但复合灾害风险应对和适应措施评估监测有待进一步探索。

（3）水资源管理

政策强调兼顾自然与社会的水资源系统，保障水资源的安全、清洁与可持续供应。研究成果推动了如低影响开发[36]、绿色基础设施、可持续排水系统[37]等新技术的发展，促进了去中心化管理和利益相关者参与决策等制度转型[38–39]，回应了湄公河、黄河等重点流域在干旱、洪涝等风险下的治理需求[40–41]。该领域的综合契合性良好，未来可在供水系统方面进一步提升适应对象契合性，加强景观规划与给排水等学科的融合，采用NbS以保障水质与极端天气下的供水安全。

4.2.3 中契合性领域

（1）沿海地区

政策强调通过海岸防护工程、生态系统恢复等行动，应对海平面上升及其他灾害，保证沿海地区生态、社会和经济可持续发展。与水资源管理相比，该领域更注重沿海居民和社会系统的适应性。研究多聚焦于有管理的撤退规划[42]，常用方法包括动态适应路径[43]、回溯规划[44]、多准则分析[45]，以及未来气候模拟与公众参与等情境化[46]的分析方式。然而，在适应对象和行动措施契合性中，生态系统相关议题表现欠佳。未来应加强对沿海地区生态系统的探索，构建灰–蓝–绿耦合的防护体系。在空间尺度契合性上，主要集中于城市尺度，尤其是沿海发达城市，较少关注脆弱村庄和社区，有待补充。

（2）健康与福祉

政策强调提升医疗系统及脆弱地区、人群对气候变化健康影响的适应能力，如空气污染、病媒传播和心理健康。现有研究主要聚焦于热应激[47]，其他领域稍显滞后，尤其是病媒传播[48]、医疗机构布局等。值得注意的是，该领域的关注度契合性较弱，文献数量很少。行动措施契合性方面，需进一步探索科学数据在疾病监测与防控预警中的应用。适应尺度契合性方面，宜关注小尺度以惠及个体。

4.2.4 低契合性领域

本研究只识别出生态系统与生物多样性这一个低契合性领域。美国景观设计师协会明确指出“气候和生物多样性危机的解决办法紧密相关”[49]，但该领域的契合性却最低。相关政策普遍强调扩大生态系统规模及适应力[3,50]，并维护物种栖息地以保持生物多样性。研究成果集中于城市生态系统，侧重以雨水花园、屋顶绿化、城市公园等NbS提升适应力[51]。相较而言，自然生态系统相关研究偏少，尤其是生物多样性研究相对不足。已有研究从生态系统恢复、生态网络建设、自然保护区设立、焦点物种的适应性分析[52]、生境质量提升等视角切入，“气候连通性”等新概念也为生物多样性适应研究提供了工具[53]。然而，这些研究数量有限，难以形成系统性科学支撑与行动指引。适应尺度契合性方面，关于自然生态系统未来变化趋势的预测与模拟亦不足，难以有效支撑政策对可持续适应的需求。

5 启示

总体而言，契合性分析结果揭示出现有研究格局呈现出研究重心失衡、时空尺度薄弱等特征，难以满足政策对全域覆盖、长期规划和可持续行动的需求。本文分别针对高、中、低不同契合性领域进行讨论，以为未来的适应工作提供反思与启发。

5.1 高契合性领域

得益于相对充足的资金支持和较低的学科壁垒，城市与建成环境、气候风险与灾害管理及水资源管理领域的契合性较好，已形成成熟的技术方法和丰富的研究成果。然而，政策与研究的整体契合性并非唯一或绝对理想的目标[54]。一方面，政策或许会滞后于快速变化的气候现实，导致单纯响应现行政策的研究失去前瞻性和学术价值。另一方面，高契合可能源于不均衡的研究投入，并以忽视其他重要议题为代价。例如，城市与建成环境领域中，59.1%的文献聚焦于治理框架，而智慧技术的开发与应用仅占1.4%；且这些文献多为案例分析，在选题、方法甚至成果上呈现一定同质化，长远来看可能会导致路径依赖[55]。未来，应推动高

契合性领域从“整体契合”转向“质量契合”：在适度转移研究资源攻克关键难题的同时，开发实用的决策模型、指标和政策工具，加强成果转化并验证其在经济与工程实践中的可行性。

5.2 中、低契合性领域

由于多重因素的叠加影响，中、低契合性领域（沿海地区、健康与福祉和生态系统与生物多样性）存在整体契合性欠佳与子议题发展失衡的问题。首先，其具有的高度跨学科与多系统耦合特性显著提高了研究门槛与整合难度[56]。例如，健康与福祉需融合规划、心理学、医学等多个学科，而学科壁垒加剧了研究的滞后与脱节。其次，技术方法的可操作性与数据可获取性是关键瓶颈。例如，方法简便的生态系统服务研究占比达48.4%，而对跨学科知识技术依赖更高的生物多样性研究仅占比17.0%。具体而言，沿海地区海平面模拟的模型构建难度限制了研究进展，健康领域常受制于伦理因素导致数据匮乏[57]，生物多样性则面临长期监测成本高而导致的数据稀缺问题[58]。最后，有限的研究资源往往优先流向即时可见的风险领域[59]，而中低契合性领域多涉及生态退化、健康潜在威胁等长期隐性风险，导致关注不足与投入不均衡。《联合国第四次适应基金报告》显示[60]，灾害风险领域获投资金最多，而森林部门最少，两者相差约30倍。不过，挑战亦蕴藏巨大潜力，跨界性可催生协同效益。例如，沿海防护可整合灰—蓝—绿基础设施兼顾生态社会适应；生态系统内可通过气候适应型生态网络建设，为物种存续及水、海防护奠定基础。

5.3 从结果契合转向机制契合

分析表明，政策与研究的契合性并非单纯的内容不匹配，而是受到内部与外部机制的共同影响。这意味着未来气候适应工作成效的关键在于从机制层面的根本性提升。强调动态互动与迭代优化的知识共同生产体系已被广泛验证有效[61-62]，可成为气候适应领域弥合政策—研究差距的核心策略。

1）优化政策与研究的双向反馈机制。建立政策制定者与研究者持续互动的深度对话平台，将双向反馈嵌入知识生产和政策应用全过程。设立常态化的政策解读会与研究发现会，在重要课题立项早期，邀请政策制定者共同明确需求与优先问题。同时，引入科学顾问等边界组织，充当“翻译器”，将复杂的研究发现提炼为易懂的政策结论，如将气候模型不确定性转化为多选方案，纳入政策，实现灵活指导[62]。政策制定过程亦然，通过试点项目跟踪与评估报告，及时将实施效果与挑战反馈给研究，持续校准研究方向，形成从知识到行动的良性循环。

2）促进跨学科协同交流机制。应对气候适应的系统性本质，须打破学科壁垒，建立跨学科协作与数据技术共享机制。可借鉴欧盟气候知识与创新共同体、美国海洋和大气局气候数据门户等经验，打造跨学科的开放数据平台和共享标准，促进科研机构间甚至与产业界的合作。同时应优先解决跨领域的共性问题或开发共用技术方法[54,63]，如整合机器学习和遥感等技术，规范跨领域研究范式，在多尺度推广NbS以实现协同效益、开发未来气候情景模拟工具等。

3）资源与管理机制的协同支持。首先，资金投入应纠正失衡，避免两极分化。优先支持现实紧迫、政策需求高但契合不足的领域（如生态系统与生物多样性），以及高价值却低关注的弱势领域（如气候正义）。同时，在管理机制上，可改革科研评价体系，增加对政策贡献和社会影响力的认可[62]，激励研究攻克重难点问题。政策层面则可建立法律规章、定期监测等硬性指标和适应性管理工具，并完善政府绩效考核体系，纳入气候适应效益指标（如避免的经济损失），量化评估政策成效[62]。

6 结论

本文系统回顾并对比分析了近20年间全球气候适应政策与研究的演进历程及核心关切领域，构建了契合性判断框架，揭示了政策与研究的互动模式和各研究及各个核心关切领域的契合状况。结果表明，整体上政策与研究的契合性较好，但尺度契合性普遍不足；各领域间的契合性差异显著，对象与行动契合性也因领域而异。其中，城市与基础设施、气候风险与灾害管理、水资源管理等领域契合性较高，而生态系统与生物多样性等领域则相对滞后。在此基础上，本文进一步反思了高契合性领域可能引发的前瞻性缺失与路径依赖风险，剖析了中低契合性领域受限于跨学科整合难度高、技术方法操作性不足、数据可获性低及长期资源失衡等成因，最终提出从“结果契合”转向“机制契合”的3项建议，包括优化政策与研究的双向反馈机制、促进跨学科协同交流机制，以及资源与管理机制的协同支持，为政策与研究的未来发展提供了启示与指引。

然而，本文仍存在一定局限：例如，本文仅涵盖国家层面的气候适应政策，地方政策的差异性对结论的影响尚待进一步检验；仅讨论热点领域，气候正义、文化遗产等弱势领域尚待深入挖掘，其对完善气候适应理论框架具有重要价值；此外，文献采样仅限中英文，未来可拓展至多语种，以提升研究的适用性与理论深度。

补充材料

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图 1. 中英文气候适应研究发展时间线
图 2. 中英文气候适应研究发展阶段
图 3. 气候适应文献的高频关键词、聚类及研究热点。