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Climate Change and Regional Development in South Africa: Exploring Emerging Research Trends

Mudanças Climáticas e Desenvolvimento Regional na África do Sul: Explorando Tendências Emergentes de Pesquisa

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Abstract

Regional development in South Africa is currently undergoing significant transformation as climate change increasingly impacts local economies and governance structures. Notably, the country has not yet fully implemented any climate change legislation, with the Climate Change Act only receiving presidential assent on March 17, 2025. As a result, climate change does not prominently feature in South Africa's research and policy agendas. Adaptation and mitigation efforts frequently arise from pressures unrelated to climate change, leading to fragmented and inconsistent approaches. In an effort to contribute to the current lack of research on climate change and regional development within South Africa, this study conducts a systematic review that examines the 20 most recent Scopus-indexed articles that explore the intersection of regional development and climate change in South Africa. In rapidly evolving fields like climate change, up-to-date research provides essential insights into the latest advancements and shifts in the area of study, making it crucial for a comprehensive review. This study ultimately enhances our understanding of the relationship between regional development and climate change in South Africa by identifying key themes, addressing critical gaps, and outlining effective pathways for the future.

Keywords: regional development; climate change; South Africa; systematic review; climate adaptation.

JEL: Q54; R1; R11

Resumo

O desenvolvimento regional na África do Sul está atualmente a passar por uma transformação significativa, à medida que as mudanças climáticas impactam cada vez mais as economias locais e as estruturas de governança. Notavelmente, o país ainda não implementou plenamente qualquer legislação sobre mudanças climáticas, tendo o Climate Change Act recebido apenas a sanção presidencial em 17 de março de 2025. Como resultado, as mudanças climáticas não ocupam um papel de destaque nas agendas de pesquisa e de políticas públicas na África do Sul. Esforços de adaptação e mitigação frequentemente surgem de pressões não relacionadas às mudanças climáticas, conduzindo a abordagens fragmentadas e inconsistentes. Com o objetivo de contribuir para a atual escassez de pesquisas sobre mudanças climáticas e desenvolvimento regional no contexto sul-africano, este estudo realiza uma revisão sistemática que examina os 20 artigos mais recentes indexados na Scopus que exploram a interseção entre desenvolvimento regional e mudanças climáticas na África do Sul. Em áreas de rápida evolução, como a das mudanças climáticas, pesquisas atualizadas fornecem insights essenciais sobre os avanços mais recentes e mudanças no campo de estudo, tornando-se fundamentais para uma revisão abrangente. Este estudo aprimora a compreensão da relação entre desenvolvimento regional e mudanças climáticas na África do Sul ao identificar temas-chave, abordar lacunas críticas e delinear caminhos eficazes para o futuro.

Palavras-chave: desenvolvimento regional; mudanças climáticas; África do Sul; revisão sistemática; adaptação climática.

JEL: Q54; R1; R11

1. INTRODUCTION

Climate change has become one of the defining global challenges of the 21st century, reshaping the conditions under which economies grow, society's function, and governance systems operate. Climate change significantly impacts regional development across various dimensions, including economic, environmental, and social aspects (Cai, 2025). The effects are diverse and vary by region, influenced by factors such as temperature changes, urban development, green vegetation, energy consumption, and environmental regulation (Karahasan & Pinar, 2023). In response, how regional development policies are shaped has been changing. For instance, climate considerations are no longer peripheral but are understood as integral to economic planning, infrastructure investment, and social policy (Faradiba & Zet, 2020). The climate–development nexus, which links environmental change to spatially uneven processes of growth, governance, and livelihoods, has thus become a central concern across global research and policy, as pointed out by Liu et al. (2018).

Major international agreements reflect this interplay, as for example the Paris Agreement explicitly connects emissions reductions and climate adaptation to sustainable development and poverty eradication goals (UNFCCC, 2015), while the Sustainable Development Goals (SDG's) embed climate action within broader priorities such as water security, food systems, energy transitions, and resilient cities (Onbargi, 2024). As a result, research has increasingly highlighted climate change as a cross-cutting development challenge that increases inequalities, threatens established livelihood systems, and exposes limitations in planning frameworks designed for more stable climatic conditions (Tanner & Horn-Phathanothai, 2014; Trisos et al., 2022). These challenges are particularly acute in Africa, where the continent contributes the least to global greenhouse gas emissions yet face some of the most severe projected impacts (Ghio et al., 2023). Studies such as that of Bedeke (2023) show that climate-related mortality from floods, droughts, and storms is already disproportionately high in highly vulnerable African regions, and that key development sectors across the continent have experienced measurable climate-related losses and damages (Trisos et al., 2022). Limited financial resources, inadequate access to infrastructure like roads and public health services, poor availability of weather forecast information, and a shortage of advanced technologies are increasing the vulnerability of African countries to climate change (Mall et al., 2017; Bedeke, 2023). All of these factors reduce the continent's capacity to adapt to climate-related risks.

The effects of climate change in South Africa are a prime example of Africa's challenges in adapting and managing environmental changes. As one of Africa's most industrialized economies, and among its highest emitters its coal-dependent energy system drives elevated per capita emissions, even as large segments of the population remain highly vulnerable to climate risks (Mathu, 2014; Khobai & Sithole, 2022). Furthermore, according to Engelbrecht et al. (2022), the country is recognised as a climate hotspot, with projections indicating significant future warming and a general drying trend, particularly in western and central regions. These physical risks intersect with entrenched development challenges, including service delivery failures and fragmented governance, creating a complex landscape of exposure and vulnerability (Ziervogel et al., 2014; Anekwe et al., 2025). Despite this, climate adaption practices have not always been systematically integrated into South Africa's development policy. Responses have often emerged in reaction to crises such as energy shortages, water scarcity, or food system stresses, rather than from coherent climate strategy (Adom et al., 2023). The Climate Change Act (No. 22 of 2024), enacted in March 2025, marks the country's first comprehensive legislative framework on climate change. Although it introduces statutory carbon budgets, national and sub-national adaptation planning requirements, and formalises the Presidential Climate Commission as a central coordinating body (Republic of South Africa, 2024), implementation of this Act will depend heavily on a robust and context-specific evidence base, and government and partner follow-through.

Although research on climate change and regional development in South Africa has expanded over the past decade, systematic reviews of recent research remain limited (Arndt et al., 2021; Dzawanda et al., 2024). Given accelerating climatic shifts and the introduction of new statutory requirements in South Africa, synthesising the latest research could be insightful in providing insights into the latest trends and developments relating to climate change and regional development in South Africa. Therefore, this study provides a systematic review of the 20 most recent Scopus-indexed articles examining climate change and its role in regional development within South Africa. Systematic reviews help identify gaps in existing literature, demonstrating where further research is needed and emphasizing the current research trends associated with specific themes (Jia et al., 2024). In line with this approach, this study offers an overview of climate change and its connection to regional development in South Africa, while also providing direction for future research and ensuring that scholarly efforts concentrate on the most critical issues in this field. In doing so, the study contributes to providing more information that could be useful in creating effective, locally informed climate-resilient development agendas, and pave the way for future studies.

The rest of this is structured as follows; Section 2 presents the Literature Review, that gives an overview of some of the most pressing issues facing Africa and its various regions in terms of climate change, delving into the South African Scenario. Section three describes the Methodology employed in this study, including the PRISMA framework used. Section 4 presents the results from the review, including a discussion elaboration on what the results mean. Section 5 concludes the article, pointing out limitations, future research agendas and implications for policy.

2. LITERATURE REVIEW

The interplay between climate change and regional development represents a significant challenge of the 21st century, particularly in Africa, where high levels of socio-economic vulnerability, resource scarcity, and climate variability intersect with persistent developmental issues (Olutola, 2019). As mentioned, although Africa contributes minimally to global greenhouse gas emissions, it experiences disproportionate impacts from climate-related events, such as droughts, floods, food insecurity, and public health crises (Cai, 2025). This reality underscores the urgent necessity for integrating climate adaptation into regional development policies, though this is quite complex. Studies such as Iliyasu and Mamman (2025), highlight how Africa's limited capacity to adapt is largely due to poverty, ineffective governance, and inadequate infrastructure, which worsens the adverse effects of climate change. Additionally, climate change threatens the continent's biodiversity, exposing essential ecosystem services important for human survival, such as food production and access to clean water. The loss of biodiversity could lead to irreversible changes in ecosystems, putting food security and livelihoods at even greater risk. Agriculture, a

fundamental part of many African economies, is particularly vulnerable to fluctuations in climate. Decreased rainfall, shorter growing seasons, and heightened chances of crop failure all pose significant threats to food security. Scholars such as Omotoso et al. (2023), note that Africa's limited capacity to adapt is largely due to poverty, ineffective governance, and inadequate infrastructure, which exacerbate the adverse effects of climate change. Additionally, climate change poses a significant threat to the continent's biodiversity, jeopardising essential ecosystem services that are vital for human survival, such as food production and access to clean water (Sintayehu, 2018). Fajinmi et all. (2025), emphasise that the loss of biodiversity could lead to irreversible changes in ecosystems, putting food security and livelihoods at even greater risk. Agriculture, a fundamental component of many African economies, is particularly vulnerable to fluctuations in climate (Agyarko et al., 2025). These decreased rainfall, shorter growing seasons, and heightened chances of crop failure all pose significant added threats to food security.

What's more, the effects of climate change are not uniform across African subregions. For instance, Northern Africa is grappling with significant temperature rises and increased aridity, while East Africa faces a rise in heat waves (Khomsi et al., 2023). In addition, Central Africa is witnessing moderate temperature increases (Asante et al., 2025), West Africa is experiencing heightened drought conditions and shifts in monsoon patterns, and Southern Africa is warming at a rate that outpaces the global average, particularly affecting its semi-arid regions (Alemaw & Simatele, 2020). Such regional variations call for customized adaptation strategies. Additionally, extreme weather events, including droughts, floods, and heatwaves, drastically undermine progress toward the SDGs in Sub-Saharan Africa (Codjoe & Atiglo, 2020). These events adversely influence food security, health outcomes, educational opportunities, and urban sustainability, while also intensifying poverty and driving migration (Rother et al., 2022). Therefore, promoting livelihood resilience and enhancing disaster preparedness are essential in mitigating these impacts (Tidiane Ndour et al. 2025).

Socioeconomic vulnerabilities, such as widespread poverty, reliance on rain-fed agriculture, and governance difficulties, exacerbate the adverse effects of climate change in Southern Africa (Mutanga et al., 2024). As a key economic player in Sub Saharan Africa, South Africa faces distinct challenges arising from its dependence on resource-intensive sectors and its leadership role in continental climate policy (Olutola, 2019). These challenges hinder the incorporation of climate adaptation strategies into regional development policies, highlighting the need for localized, region-specific approaches (Dzawanda et al., 2024). Moreover, effective integration of climate policies relies heavily on political commitment and institutional reforms, where without these, governance remains fragmented and implementation ineffective. Some studies such as Gadu (2024) and Sibiya et al. (2023) add that political commitment is significant barrier in the country, where policy documents on climate commitments often exceed actual implementation. Moreover, adopting cross-sectoral strategies, like the water-energy-food (WEF) nexus, becomes vital in addressing multi-dimensional vulnerabilities and enhancing overall resilience (Gbetibouo et al., 2010; Bedeke, 2023). Thus, as climate change intensifies existing spatial inequalities in water, energy, and food security, creates significant hurdles for regional development and planning.

South Africa is increasingly facing extreme climate-related events due to climate change, which pose significant risks to regional development (Dube et al., 2022). These events encompass droughts, floods, heatwaves, wildfires, and storms, each contributing to various socio-economic and environmental challenges (Engelbrecht et al., 2025). In the past five years, some of the most notable occurrences have been severe droughts, particularly in the Western Cape, which have led to water shortages affecting both agriculture and urban water supplies (Muyambo et al., 2023). Additionally, severe floods in KwaZulu-Natal in April 2022 resulted in 544 fatalities, displaced 42,000 individuals, and directly impacted 140,000 people (He & Ding, 2023). The economic repercussions of this disaster have been considerable, with estimated costs exceeding US$3.6 billion (Engelbrecht et al., 2025).

These events interact with a developmental setting defined by various structural characteristics. Firstly, South Africa is confronted with deteriorating infrastructure, leading to a metropolitan-secondary city-rural continuum where climate adaptive capacity is unevenly distributed (Muyambo et al., 2023). Secondly, the local government framework in the country allocates significant development and service delivery responsibilities to municipalities that often lack the financial, technical, and human resources necessary to carry them out, even under stable climatic conditions,

much less in the face of intensified climate stress (Gadu et al., 2025). Thirdly, the energy sector in South Africa is heavily reliant on coal, with Eskom's coal fleet accounting for about 85% of the nation's electricity generation as of 2023, creating both a considerable emissions challenge and a necessity for a just transition (Hancock, 2024; Yıldıran et al., 2025). Lastly, the country's water systems are significantly stressed due to the interplay of climate change, increasing population, agricultural needs, and diminishing infrastructure, especially in semi-arid provinces like Limpopo, the Northern Cape, and the Free State (Adeola et al., 2022; Leonard, 2023).

Although there is an expanding amount of evidence about the effects of climate change on Africa and South Africa in particular, a significant gap still exists in academic studies that connect regional development with climate change. Most current research tends to view climate change and development as separate issues. However, an increasing number of researchers are acknowledging the importance of adopting integrated approaches to addressing climate change and its role in economies (Kim, 2018; Dany & Lebel, 2020). A systematic review of climate change mitigation strategies across Sub Saharan African nations such as Botswana, Malawi, Mozambique, South Africa, Zambia, and Zimbabwe, revealed that while research related to climate has grown, it is still mainly focused on mitigation and sector-specific studies, with little integration of regional development strategies and planning frameworks (Zhou et al., 2024). This is consistent with the broader trend noted by Callaghan et al. (2021), who indicated that low- and middle-income nations, despite facing the most significant climate challenges, continue to be under-represented in the global climate impact literature.

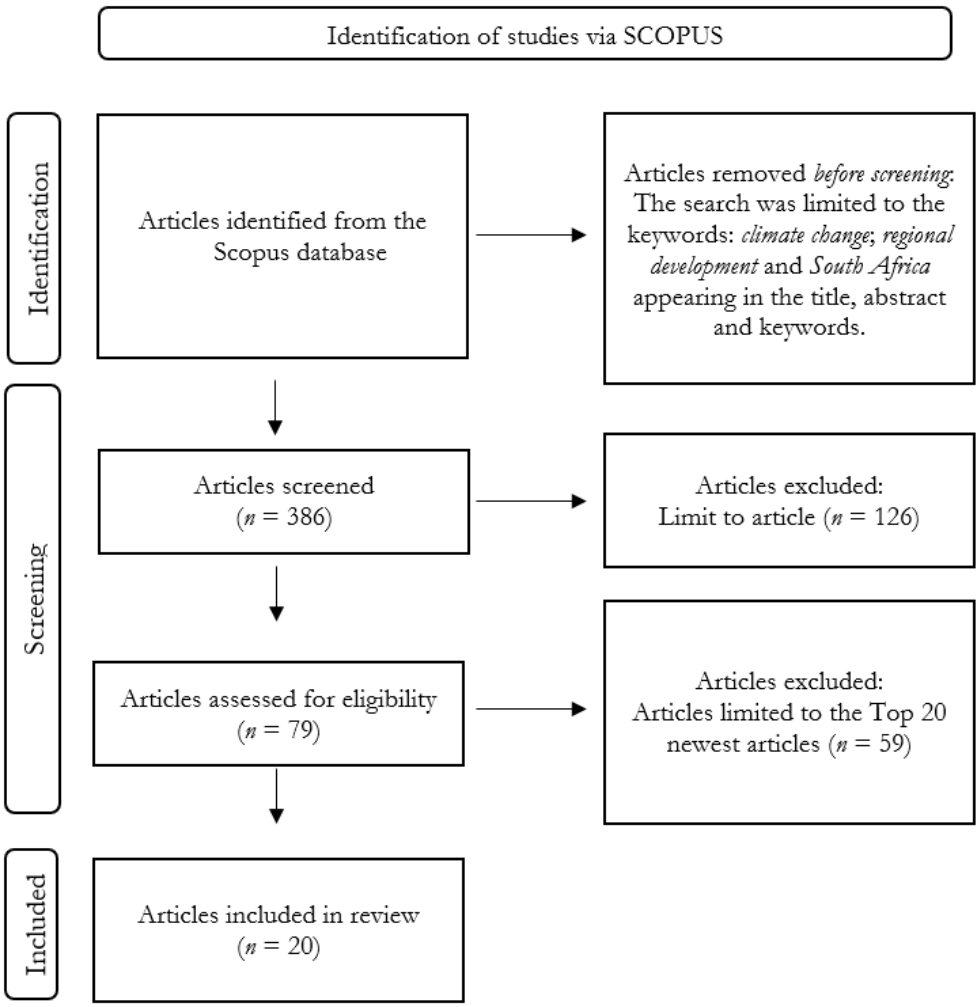
This fragmentation is especially evident in South Africa, where climate change has traditionally been regarded as a marginal concern in regional planning tools such as Integrated Development Plans and Spatial Development Frameworks, often being included only as an environmental note rather than as a fundamental aspect of development (Santhia et al., 2018; Gadu, 2024). The newly passed Climate Change Act (No. 22 of 2024) introduces a legal requirement for provincial and municipal governments to create climate response plans, highlighting both the urgency of the situation and the extent to which integrated climate-development governance has been lacking in South Africa's planning frameworks (Republic of South Africa, 2024). Additionally, the CSIR State of Climate Report (2022) and SANBI's National Biodiversity Assessment (2019) offer essential evidence regarding the impacts of climate change and gaps in adaptation at both municipal and ecosystem levels, supporting the aforementioned findings. Similarly, other researchers like Roberts (2019), Eriksen et al. (2021), and IPCC (2023) have contributed regionally focused insights on resilience, governance, and vulnerability, highlighting the necessity for climate adaptation in South Africa to be integrated into everyday governance and social frameworks rather than seen as a side issue related to the environment. Due to the rapid changes brought on by climate change, it could be argued that research from even five years ago might not accurately depict current scenarios, emerging risks, and the evolving priorities of both researchers and practitioners. This highlights the importance of conducting a systematic review of the latest scholarly work. By analysing the 20 most recent Scopus-indexed articles that explore the link between regional development and climate change in South Africa, this study aims to explore the latest research on climate change and regional development, that could show which thematic areas are gaining ongoing research interest, and which aspects of the climate-development link still lack exploration. In a scenario where South Africa's Climate Change Act has only recently taken effect, and its implementation framework is still being developed, understanding the current stance in research is important in contributing to deeper insights into the role of climate change in regional development within the country.

3. METHODOLOGY

This article provides a comprehensive overview of the most recent research published related to climate change and regional development in South Africa. As Caldwell and Bennett (2020) surmise, systematic reviews are particularly valuable for pinpointing areas that have been underexplored and for highlighting emerging research themes, thus informing future research areas. Furthermore, they offer a comprehensive and non-biased summary of all relevant studies on a given topic, which is crucial for evidence-based practice (Milner, 2015).

The systematic review used here, followed the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Page et al. (2023), explains that PRISMA is an evidence-based framework designed to assist researchers in enhancing the quality of their systematic review and meta-analysis reports. As noted by scholars like Hutton et al. (2015) and Page et al. (2023), PRISMA provides a structured approach that improves the completeness and clarity of reporting, thereby enabling researchers to better interpret findings and grasp the limitations of the evidence presented. The PRISMA framework used is presented in Figure 1.

Figure 1: PRISMA framework used for research selection



Source: Page et al. (2023)

The original search query, conducted on 7 March 2026, utilized for the Scopus database was ("climate change") AND ("regional development") AND ("South Africa"). The initial search identified 386 documents, as illustrated in Figure 1. All these documents were in English, making it unnecessary to restrict the search to that language. Subsequently, documents that were not journal articles were excluded from the search criteria. Ultimately, for the aims of this study, the focus was narrowed down to the 20 most recent articles available on the Scopus database. In rapidly evolving fields such as climate change, the newest published research can provide important insights into the latest developments or changes within the subject field. By focusing on the most up-to-date studies, the review ensures the incorporation of current research findings, which are typically more relevant.

4. RESULTS & DISCUSSION

Before examining the 20 latest published articles, the 79 articles were included in a pre-analysis to gain insight into the growth of research on the topic over the last two decades, as well as the leading authors institutions publishing on the theme.

Figure 2: Total articles published as of 2001

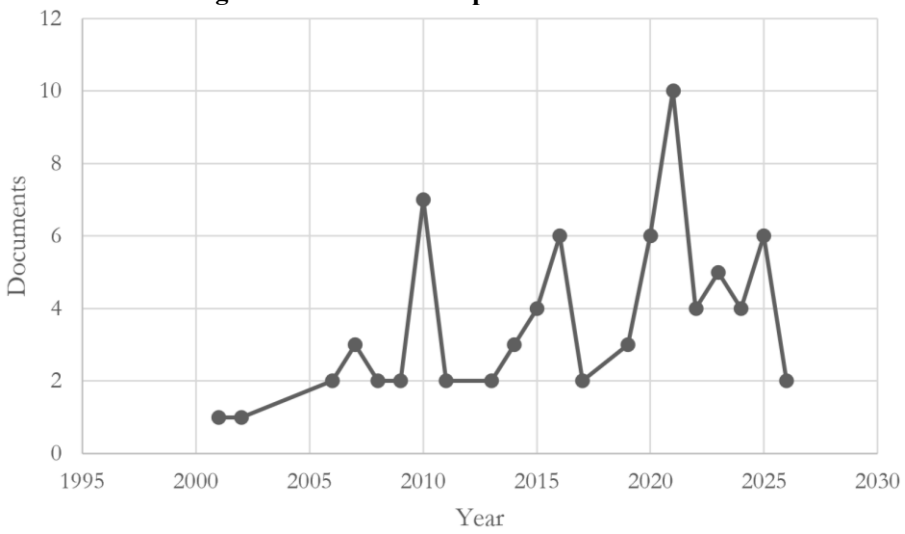


Figure 2 shows the overall number of articles related to climate change and regional development in South Africa from 2001 to the present (2026). Although a general increase can be observed, the trend is prominently irregular, reflecting considerable year-to-year fluctuations rather than consistent growth. This inconsistent pattern indicates that the interplay of climate change and regional development in South Africa has not yet formed an established, self-sustaining research field with a committed scholarly community. Instead, publications seem to be influenced by external occurrences, such as significant climate-related disasters, policy developments, or international funding opportunities, rather than being driven by ongoing disciplinary growth. This observation aligns with the larger conclusion drawn by Callaghan et al. (2021), who opined that climate change research in low- and middle-income countries tends to be episodic and reactive. The recent rise in publications starting around 2020 may be due to the effect of South Africa's increasing involvement with global climate commitments, including the Paris Agreement and, more recently, the establishment of the Climate Change Act (No. 22 of 2024), although this could only be confirmed in future studies.

Figure 3: Top 15 institutions publishing on the research topic

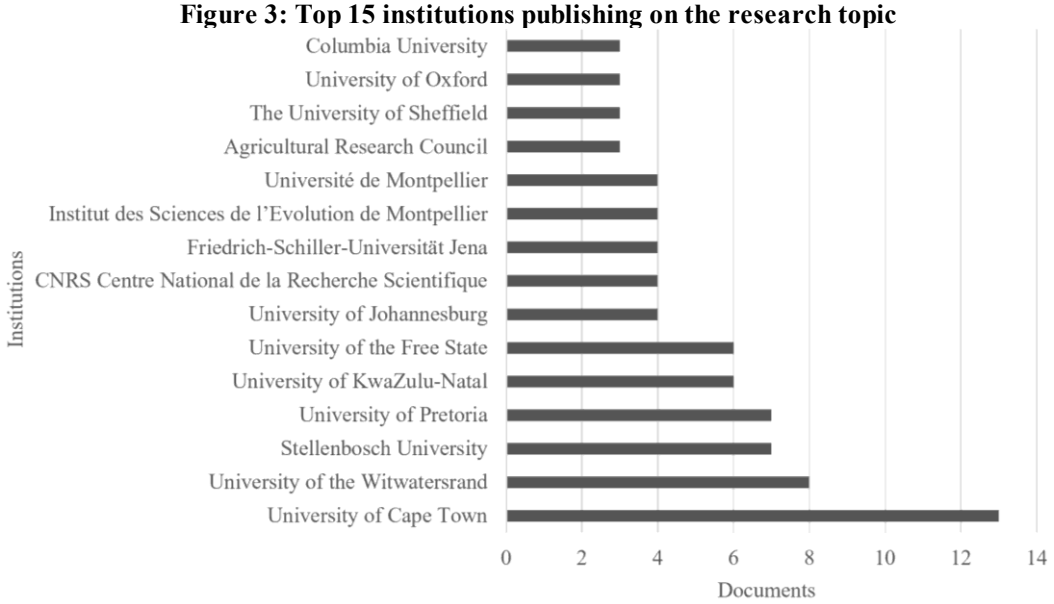


Figure 3 illustrates the leading 15 institutions involved in climate change and regional development research within South Africa. The University of Cape Town tops the list with 13 publications, followed by the University of the Witwatersrand with 8, and both Stellenbosch University and the University of Pretoria with 7 publications each. This distribution highlights several key points. Firstly, there is a significant concentration of research output among historically well-funded metropolitan institutions, all situated in prominent urban areas. This geographic and institutional concentration prompts critical questions about which knowledge and which vulnerabilities are prioritised in South African climate research, especially as the communities most affected by climate change are primarily found in rural and peri-urban regions, often in provinces that lack more robust research infrastructure. Secondly, the involvement of international institutions such as the University of Oxford, the University of Sheffield, and French research organisations like CNRS, suggests that this research area is partly supported by global collaborations and funding. While these partnerships enhance diversity and comparative insight, they also carry the risk of research agendas being shaped by external rather than locally defined priorities (Callaghan et al., 2021).

Figure 4: Top 10 authors publishing on climate change and regional development in South Africa

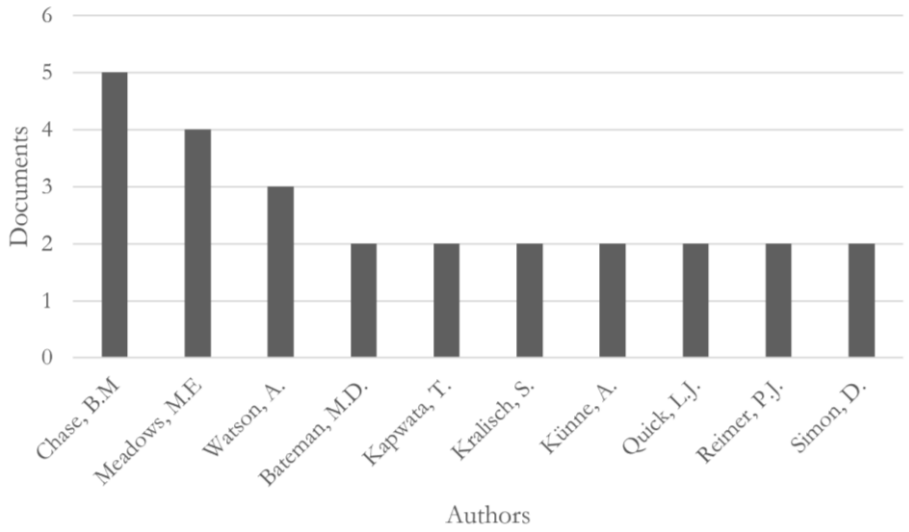


Figure 4 illustrates the leading 10 authors contributing to research on climate change and regional development in South Africa. The most active author, Chase, B.M., has published 5 works, followed by Meadows, M.E. with 4, and Watson, A. with 3, while the other seven authors each have 2 publications. These numbers are relatively low in absolute terms and indicate that there is no cohesive or established group of scholars concentrating specifically on this joint research area. The lack of a critical mass of specialized researchers could have a few consequences. It hinders the accumulation of contextual knowledge, limits the creation of South Africa-specific analytical frameworks, and diminishes the field's ability to generate comparative, and policy-focused research necessary for climate-resilient development planning. The low individual publication figures also imply that many inputs to this field come from researchers whose main focus is in other areas such as hydrology, energy policy, or public health, who engage with the climate-regional development relationship only incidentally. Building a core group of scholars explicitly working at this intersection should be viewed as a priority for research capacity, especially given the implementation demands established by the new Climate Change Act (No. 22 of 2024).

Table 1 presents the findings following the PRISMA framework. Table 1 illustrates the 20 latest articles published in Scopus relating to climate change and regional development in South Africa. Furthermore, it also shows the main emerging theme emanating from the study.

Table 1: 20 most recent Scopus-indexed studies on regional development & climate change in South Africa

Authors	Year	Title	Key Finding	Emerging Theme
Ndlela T. et al.	2026	Climate change and variability in Eswatini, 1981–2020	40-year record shows declining annual rainfall and significant warming across Eswatini; strong geographic variability signals urgent need for adaptive water management and early warning systems.	Climate risk, extreme events & water security
Radebe S.; Clark M.D.	2026	Near-surface groundwater prospectivity model for the Main Karoo Basin	Machine learning models (AUC 0.87) identify high-potential groundwater zones in the Karoo Basin; hotspots can serve as critical drought-resilience resources for water-stressed communities.	Climate risk, extreme events & water security
Chauke H.; Pongrácz R.	2025	Monthly scale validation of CMIP6/CORDEX climate models over South Africa	CMIP6 and CORDEX models show reduced biases over South Africa compared to CMIP5, but careful model selection remains essential for reliable regional climate projections.	Climate governance, vulnerability & decision support
De Bruyn C. et al.	2025	Climate vulnerability assessment of South African capital cities	Multidimensional PCA reveals heterogeneous urban vulnerability: Bloemfontein, Cape Town, and Johannesburg face highest combined exposure and sensitivity, while Mbombela and Pietermaritzburg retain greater adaptive capacity.	Climate governance, vulnerability & decision support
Engelbrecht F.A. et al.	2025	Extreme event attribution of the 2022 Durban floods using km-scale simulations	Climate change made the April 2022 KwaZulu-Natal floods at least 40% more intense; km-scale attribution methodology is scalable across the Global South, with direct implications for disaster risk finance.	Climate risk, extreme events & water security
Mandavya G. et al.	2025	Shifting weather regimes driving regional drought in South Africa	A post-2010 shift toward a persistently drier weather regime explains the 2015–2017 'Day Zero' drought in the Western Cape; weather-regime-based generators offer improved tools for long-term water planning.	Climate risk, extreme events & water security
Witter S. et al.	2025	Political economy of reforming global health initiatives	Funder-driven incentive structures in global health initiatives discourage collaboration and impede reform, including in the face of mounting climate-health threats; political-economy-aware governance reform is essential.	Climate, health & human wellbeing
Yıldıran N. et al.	2025	Feasibility of a 75 MW solar PV plant in South Africa	Solar PV investment shows strong financial and environmental returns, but community willingness to invest remains low; education and enabling policy are critical barriers to community-level energy transition.	Energy transitions & carbon management
Hancock K.J.	2024	Electric regionalism and the African power pools	Post-colonial path dependence and the influence of development banks and mining capital have locked African energy systems into centralised, fossil-fuel-dependent structures that resist decarbonisation; decentralised alternatives are better aligned with climate goals.	Energy transitions & carbon management
Kapwata T. et al.	2024	Heat thresholds for South Africa towards a heat-health warning system	Analysis of 8.48 million deaths identifies maximum temperature as the dominant predictor of mortality; district-specific heat thresholds provide the empirical foundation for a national heat-health warning system.	Climate, health & human wellbeing
Magazzino C. et al.	2024	Innovation, sustainability and cereal production in BRICS countries	Technological innovation and improved land management raise cereal yields, while agricultural emissions depress output; integrated policy packages combining productivity gains with emissions reduction are essential.	Agricultural resilience & food security
Sigauke C.; Ravele T.	2024	Compound drought-heat extremes in the Limpopo Lowveld	Copula-based models estimate joint drought-heat probabilities across elevation bands in Limpopo, providing a robust quantitative basis for compound-event disaster risk planning.	Climate risk, extreme events & water security
Makungo R.; Nkuna T.R.	2023	Climate adaptation strategies for smallholder farmers, Luvuvhu Catchment	Stakeholder MCDA identifies optimising irrigation, erosion control, and high-yield varieties as priority adaptation strategies; rankings are robust to stakeholder weight variations, indicating genuine local consensus.	Agricultural resilience & food security
Monteiro P.M.S.; Midgley G.F.	2023	Carbon dioxide removal science–policy partnership for southern Africa	Southern Africa will require CDR at 0.1–0.5 $GtCO_2$/yr; significant governance, technology, and skills gaps necessitate an urgent science–policy partnership to build the required institutional infrastructure.	Energy transitions & carbon management
Muyambo F. et al.	2023	Climate-induced weather events and urban water management in the Free State	Rising water stress in QwaQwa driven by climate events demands climate-resilient infrastructure, nature-based solutions, and accountable governance as integrated responses to urban water insecurity.	Climate risk, extreme events & water security
Obasa A.E. et al.	2023	Collective responsibility during the Hammanskraal cholera outbreak	The Hammanskraal outbreak links cholera risk directly to inadequate WASH infrastructure and displacement; climate change is identified as a compounding driver requiring collective, multifaceted governance responses.	Climate, health & human wellbeing
Zheng S. et al.	2023	Embodied carbon in BRICS forest industry trade	Paper products dominate embodied carbon in South Africa's forest trade; BRICS emissions are export-oriented, highlighting the need for coordinated supply-chain decarbonisation across trading partners.	Energy transitions & carbon management

Adeola A.M. et al.	2022	Observed trends and projections in the Olifants River Catchment	A 44-year record documents warming and persistent drought in the Olifants Basin; future projections under RCP4.5 and RCP8.5 indicate significant temperature increases and sustained water deficits with major implications for catchment management.	Climate risk, extreme events & water security
Gxokwe S. et al.	2022	Ecohydrological change in semi-arid wetlands using cloud computing	Google Earth Engine and Landsat analysis reveals a 350% increase in bare surface cover in Northern Cape wetlands (2016–2020), driven by precipitation variability; validates cloud-AI monitoring as a scalable tool for wetland conservation.	Climate risk, extreme events & water security
Magos Brehm J. et al.	2022	Conservation of crop wild relative diversity in southern Africa	64% of priority crop wild relative taxa face negative climate impacts; 50% lack ex-situ conservation and 21% fall outside protected areas; a complementary network of 271 sites is proposed to safeguard the genetic foundations of regional food security.	Agricultural resilience & food security

From analysing the studies presented in Table 1, 5 main themes emerged. These themes are *Climate risk, extreme events and water security, Energy transitions and carbon management, Agricultural resilience and food security, Climate governance, vulnerability and decision support* and lastly *Climate, health & human wellbeing.* The first theme, *Climate Risk, Extreme Events & Water Security*, constituting the most studies, focuses on the relationship between extreme climate events and water security, highlighting the importance of water stress in South Africa's developmental issues. Engelbrecht et al. (2025) find that climate change increased the intensity of the KwaZulu-Natal floods in April 2022 by at least 40 per cent, based on convection-permitting kilometre-scale simulations. This study applies formal extreme event attribution science, a method associated with the World Weather Attribution initiative and based on the work of Stott et al. (2016). The implications for development show that investments in infrastructure, disaster risk financing, and municipal planning have traditionally been based on historical return periods, which attribution science shows to be fundamentally insufficient in a changing climate. This is similar to findings from Zscheischler et al. (2020), who established that the simultaneous occurrence of multiple climate hazards presents significantly greater risks to infrastructure and development systems than single-hazard models can account for. Sigauke and Ravele (2024) apply this framework to the Limpopo Lowveld, offering estimates of joint drought-heat probability that align with South African risk modelling with disaster risk research. Regarding long-term trends, both Adeola et al. (2022) and Ndlela et al. (2026) report on multi-decadal warming and diminishing rainfall in the Olifants catchment and Eswatini, respectively, consistent with the notion that Southern Africa is a global climate hotspot where warming is expected to exceed the global average (Trisos et al., 2022). Mandavya et al. (2025) adds to this by linking the 'Day Zero' drought in the Western Cape from 2015–2017 to a lasting change in the weather patterns influencing South African rainfall. Collectively, these results reinforce earlier research by Mukheibir and Ziervogel (2007) who argued that urban water governance in South African cities must undergo fundamental redesign for a non-stationary climate. Muyambo et al. (2023) and Gxokwe et al. (2022) expand this concern to urban water management in the Free State and wetland degradation in the Northern Cape, respectively, while Radebe and Clark (2026) propose a constructive solution by utilizing machine learning for groundwater prospectivity mapping that identifies drought-resilient resources in the Karoo Basin. Together, these studies illustrate a panorama of accelerating water insecurity that is simultaneously physical, institutional, and spatial, and current governance frameworks, as confirmed at the regional level by Frontiers in Water (2025) and the CIWA Programme (2023), are ill-equipped to manage without structural reforms.

The second theme, *Energy transitions and carbon management*, highlights the conflict between South Africa's capability for renewable energy implementation and the institutional and political barriers that hold it back. Yıldıran et al. (2025) reveal the financial and environmental feasibility of large-scale solar investments, showing substantial returns despite low community willingness to contribute financially, a disparity attributed to insufficient education and supportive policies. This observation aligns with the global energy justice research, as noted by Abe and Azubike (2024). These authors contend that addressing energy marginalization in Africa necessitates not only technical viability but also fair governance of the transition process, ensuring that communities are active participants rather than mere beneficiaries. Hancock's (2024), analysis of path dependence in African power pools offers a structural explanation for why technically feasible transitions stagnate; this includes donor influence and the ability of extractive capital to anchor energy systems in fossil-

fuel dependence, making decarbonization difficult. This line of reasoning is particularly relevant to South Africa, where Xaba (2025), illustrates how the objectives of the Just Energy Transition Partnership (JETP) are compromised by the conflicting interests of coal-sector stakeholders, delays in decommissioning schedules, and governance challenges within Eskom and the larger energy administration.

Monteiro and Midgley (2023) and Zheng et al. (2023), expand the energy-carbon perspective beyond just the electricity sector. Monteiro and Midgley (2023), assert that southern Africa will need carbon dioxide removal at an annual rate of 0.1–0.5 $GtCO_2$, positioning the region within a global mitigation discussion where CDR has shifted from a theoretical concept to an operational necessity (IPCC, 2023). Zheng et al. (2023) highlight that South Africa's forest-sector trade is primarily export-focused in terms of emissions, showcasing a facet of carbon accountability that is largely neglected by domestic policy. Together, these studies indicate that while South Africa's research on energy and carbon management is technically sophisticated, its policy and governance structures are not yet prepared to effectively implement this. This is similar to the Stockholm Environment Institute's (2024) evaluation that the execution of the just transition in South Africa still lags behind its planning.

The third theme, *Agricultural resilience and food security*, reveals considerable shortcomings in South Africa's adaptation framework. Makungo and Nkuna (2023), finds locally prioritized adaptation tactics for smallholder farmers in the Luvuvhu catchment, namely enhancing irrigation, erosion management, and high-yield varieties. The study also underscores the disconnect between identified strategies and their actual implementation, hampered by issues like land tenure insecurity and inadequate extension services. This disconnect is a recurring theme in the literature on smallholder adaptation in Africa. Trisos et al. (2022), asserts that smallholder farmers often resort to coping mechanisms instead of transformative adaptation, noting that enhancing institutional capacity and ensuring secure land tenure are essential prerequisites that South Africa's rural governance often fails to deliver. Magazzino et al. (2024), examining BRICS, find that technological advancements increase cereal yields while agricultural emissions suppress them. This reinforces the argument for low-emission intensification as both a strategy for productivity and mitigation. This aligns with findings that staple crop yields in Sub-Saharan Africa are expected to decrease by 10–20% by 2050 if current climate patterns persist (Stuch et al., 2021), positioning agricultural innovation as not just an economic prospect but a necessity for food security. Moreover, Magos Brehm et al. (2022) highlights critical conservation deficits for crop wild relatives throughout Southern Africa, where 64% of priority species are at risk from climate change impacts. This biodiversity-focused approach to agricultural resilience is based on the framework for the Sustainable Use and Conservation of Plant Genetic Resources for Food and Agriculture (Mba et al., 2024). Studies such as Irie et al. (2025) highlight that agricultural biodiversity is crucial for food security and the resilience of agricultural systems. It includes the diversity of crops, wild relatives, and the ecological functions they support (Pietrusińska-Radzio et al., 2025).

The fourth theme emerging is that of *Climate governance, vulnerability and decision support*. Here, Chauke and Pongrácz (2025) show improved skill over South Africa compared to earlier generations, while cautioning that careful model selection remains essential, an important finding for the quality of climate projections underpinning adaptation planning. De Bruyn et al. (2025) translate physical and socioeconomic data into a multidimensional vulnerability assessment of South Africa's capital cities, revealing heterogeneous risk profiles that challenge the assumption that metropolitan size and resource endowment confer climate resilience. Together, these studies contribute to the foundational requirement for climate-resilient development- credible, localised, and decision-relevant climate risk information (Favretto & Stringer, 2026). The existing literature on governance underscores a significant and entrenched gap between advancements in scientific methodologies and their practical application in planning processes. Gadu et al. (2024) and Adom et al. (2023) highlight that South Africa's municipal Integrated Development Plans rarely incorporate modern climate projections. Gadu et al. (2025) employ an institutional adaptive capacity framework to demonstrate that local governments, particularly in the Eastern Cape, face substantial deficits in mandates, financial resources, and collaborative mechanisms across departments, hindering the transformation of national climate policies into effective actions. This challenge cannot be solely attributed to a lack of funding; it reflects what Averchenkova et al. (2019) describe as a deficit in

structural clarity, where the roles and responsibilities among national, provincial, and local authorities are poorly defined, leaving adaptation duties ambiguous within an institutional context.

Sibiya et al. (2023) build on this by illustrating how bureaucratic resistance, characterised as the tendency of departmental lines to view climate change as a subordinate environmental concern rather than as a central governance issue, represents an additional barrier that persists even when financial resources are apparently accessible. Together, these studies suggest that the governance failures related to climate issues in South Africa can be analysed through three critical dimensions, namely vertical fragmentation among various government levels, horizontal disconnection between sectoral departments, and a framing problem where climate change is perceived as secondary to primary development planning (Averchenkova et al., 2019; Sibiya et al., 2023; Gadu et al., 2024). This tripartite institutional analysis should inform future research initiatives and the implementation strategies outlined in the Climate Change Act (No. 22 of 2024), rather than simply attributing challenges to a lack of political will. Similar multi-level analyses of governance failures in other developing-country contexts have been proposed by Dany and Lebel (2020) and Sorgho et al. (2023), thus emphasising the relevance and analytical strength of this approach for South Africa.

The last emerging theme*, Climate, health & human wellbeing*, explore different yet interconnected ways in which climate change poses a risk to human health in South Africa. Kapwata et al. (2024) offer extensive evidence for identifying heat-health thresholds, using 8.48 million mortality records to show that maximum temperature was associated with increased risk of mortality. This finding aligns with research by Gasparrini et al. (2017), who showed across 732 locations in 36 nations that ambient temperature significantly contributes to overall mortality, particularly impacting populations with limited capacity to adapt. In South Africa, where outdoor workers, inhabitants of informal settlements, and the elderly are especially vulnerable to heat exposure, the lack of a national heat-health warning system represents a notable and solvable governance issue.

Obasa et al. (2023), in their analysis of the cholera outbreak in Hammanskraal, connect the risk of disease to insufficient water, sanitation, and hygiene (WASH) infrastructure and population displacement, highlighting climate change as an exacerbating factor. This highlights a problem where often extreme event responses tend to focus on isolated projects rather than comprehensive climate risk management. Global research on climate and health increasingly depicts such outbreaks as results of the interaction among climatic stressors, failures in governance, and socioeconomic vulnerability, characterized by Watts et al. (2021) as the 'syndemic' relationship between climate and health. Additionally, Witter et al. (2025) illustrates how structures of global health initiatives driven by funders hinder collaboration and obstruct reform, a finding that holds direct significance for South Africa's health system influenced by donors. Again, these studies indicate that the primary challenge of climate and health in South Africa lies not in clinical knowledge but within institutional frameworks, which suggests the need for governance reform as the key intervention.

In essence, the literature reviewed in this analysis reveals a predominant biophysical focus, with individual studies acknowledging the governance and political-economy factors but failing to centre institutional analysis in their frameworks. This oversight is particularly noteworthy considering that the evidence suggests South Africa's lack of adaptation stems more from governance and financial issues than from a lack of knowledge (Gadu, 2024; Adom et al., 2023). Furthermore, research often tends to be fragmented across various sectors and disciplines, which can hinder the development of comprehensive adaptation strategies. Moreover, the vast array of methodologies used within the studies highlights the rapid advancements occurring in this field. Most importantly, the collective findings indicate that climate change is not merely an impending threat for South Africa; rather, it is an ongoing and quantifiable driver of developmental disruption, manifesting through flooded urban areas, diminishing wetlands, increased heat-related mortality, and the proliferation of waterborne diseases. The pivotal challenge moving forward is effectively integrating this evidence into the statutory frameworks, budgetary allocations, and governance mechanisms mandated by the Climate Change Act (No. 22 of 2024). Addressing this integration must become a priority in the post-Act research and policy environment.

5. CONCLUSION

Climate change presents a significant and escalating challenge to regional development in South Africa, a nation defined by extreme weather conditions, socioeconomic disparities, and weak and fragmented governance. Despite this vulnerable position, climate change has historically been underexplored in South Africa's research and planning frameworks, with adaptation and mitigation strategies often arising from sector-specific pressures rather than from comprehensive, evidence-based policy making. In light of this, this study conducted a systematic review of the 20 most recent Scopus-indexed articles that examine the intersection of regional development and climate change in South Africa, aiming to shed light on prevailing research trends, emerging thematic priorities, and possible areas that future research and policy initiatives need to address. The importance of this study is highlighted by the recent passage of the Climate Change Act (No. 22 of 2024), which introduces statutory requirements for provincial and local governments to formulate climate response plans.

The review identified five emerging themes, with the most prominent theme centred on climate risk, extreme weather events, and water security, reflecting a growing body of research that documents rapid physical changes in the country's hydrological and meteorological systems. Across other themes such as energy, agriculture, governance, and health, a consistent trend emerged, where current research is rapidly advancing, yet the application of that knowledge in integrated development planning, governance reforms, and statutory implementation remains critically inadequate. Notably, the study uncovers the lack of a formal warning mechanism for South Africa's heat-health system and highlights the significant climate-induced threats to regional food security, particularly regarding crop wild relatives, which have received little policy attention. The predominance of well-established universities in research output and the inconsistent annual publication rates underscore that this field of study remains fragmented and, in its infancy, rather than a mature and coordinated scientific endeavour.

This study is not without its limitations. Firstly, while the focus on the 20 most recent Scopus-indexed articles is methodologically sound for capturing the latest research in such a fast-evolving field, it inevitably excludes a wider array of literature. This does limit the inclusion criteria of the chosen articles. Consequently, the findings reflect current trends rather than offering a comprehensive historical overview. Secondly, the Scopus database, although the largest repository of peer-reviewed literature, does not encompass all relevant research, such as grey literature, government reports, and studies published in non-indexed regional journals, which may contain important insights, especially regarding governance and community-level adaptation, which fall outside this review's scope. Additionally, the search criteria were specifically limited to the overlap of climate change, regional development, and South Africa, indicating that research indexed under related but separate terms, such as adaptation, resilience, governance, or spatial planning, was not included. Although this limitation was an intentional decision, future reviews using broader keyword searches could offer a useful addition to the current results. These limitations highlight several key priorities for future research. The most pressing need is for studies that centre on governance and political economy in their analysis rather than treating institutional challenges as secondary. South Africa's lack of adaptation is less about a lack of knowledge and more about deficiencies in governance capacity, political will, and the integrated institutional design at municipal and provincial levels. Research should explore how the implementation requirements of the Climate Change Act can be effectively operationalised within the existing constraints of local government, including documented financial, technical, and human resource limitations. Moreover, the geographic concentration of research efforts must be addressed, as various regions face unique climate-related challenges that necessitate tailored interventions. Finally, the reviewed studies consistently overlook the importance of integrating indigenous and local knowledge into climate adaptation strategies, a gap that potentially undermines both the cultural relevance and practical success of these strategies, particularly in rural and smallholder farming settings. Future research could systematically incorporate these knowledge systems alongside formal scientific approaches.

The insights from this study present several important policy recommendations. Municipal and provincial governments should aim to integrate climate risk information, such as projections and urban vulnerability assessments, into their planning processes, moving beyond the current tendency to treat climate issues as mere environmental add-ons. In the energy sector, decarbonization policies

must address the institutional barriers that reinforce South Africa's reliance on fossil-fuel infrastructure. It is essential that the Just Energy Transition is conducted with active community engagement and fair benefit-sharing, rather than being approached as a purely technical endeavour. Additionally, preserving crop wild relatives and enhancing the adaptive capacity of smallholder farmers need to be prioritised in South Africa's agricultural and biodiversity strategies, recognising them as vital to long-term food security rather than as secondary environmental concerns. As South Africa embarks on the implementation of its Climate Change Act for the first time, it is crucial to develop a coordinated, locally informed, and governance-focused research agenda to effectively address the country's most pressing environmental challenges.

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