UC Irvine

UC Irvine Previously Published Works

Title

Drought adaptation mapping in the Southern African Development Community: A scoping review

Permalink

https://escholarship.org/uc/item/8n77f2g2

Journal

PLOS Climate, 5(8)

ISSN

2767-3200

Authors

Poole-Selters, Leah

Vance, Eleanor

Anand, Vaibhav

et al.

Publication Date

2026-08-07

DOI

10.1371/journal.pclm.0000876

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at https://creativecommons.org/licenses/by/4.0/

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

PLOS Climate

RESEARCH ARTICLE

Drought adaptation mapping in the Southern African Development Community: A scoping review

Leah Poole-Selters[1]*, Eleanor Vance[1], Vaibhav Anand[2], Banawe Plambou Anissa[3], Chris Hillbruner[6], Christopher Ihinegbu[4,5], Miriam Silverman Israel[6], Jubeena Judi Joe[7], Caroline Kawira[8], Megan Lukas-Sithole[9], Renate Meyer[10], Relebohile Agnes Mojaki[11], Ian G. Moore[1], Miriam Nielsen[12], Susan Njambi-Szlapka[13], Erin Coughlan de Perez[1,10]

1 Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, United States of America, **2** St. John's University, New York, New York, United States of America, **3** Center for Research in Applied Economics and Management of Organizations, Department of Economics, University of Lomé, Lomé, Togo, **4** Department of Urban Planning and Public Policy, University of California, Irvine, California, United States of America, **5** Department of Geography and Environmental Sustainability, University of Nigeria, Nsukka, Nigeria, **6** Independent researcher, Chevy Chase, Maryland, United States of America, **7** Indian Institute of Forest Management, Bhopal, India, **8** Department of food Science, nutrition and technology, University of Nairobi, Nairobi, Kenya, **9** Cape Peninsula University of Technology, Cape, South Africa, **10** Red Cross Red Crescent Climate Centre, The Hague, Netherlands, **11** Department of Agricultural Economics and Extension, National University of Lesotho, Lesotho, Lesotho, **12** Lamont-Doherty Earth Observatory, New York, New York, United States of America, **13** University of Edinburgh, Jameel Observatory for Food Security Early Action, Edinburgh, Scotland

* Leah.poole@tufts.edu

Check for updates

OPEN ACCESS

Citation: Poole-Selters L, Vance E, Anand V, Anissa BP, Hillbruner C, Ihinegbu C, et al. (2026) Drought adaptation mapping in the Southern African Development Community: A scoping review. PLOS Clim 5(8): e0000876. https://doi.org/10.1371/journal.pclm.0000876

Editor: Sejian Veerasamy, National Institute of Animal Nutrition and Physiology, INDIA

Received: March 3, 2026

Accepted: July 7, 2026

Published: August 7, 2026

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pclm.0000876

Copyright: © 2026 Poole-Selters et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium,

Abstract

Evidence on how people adapt to drought frequency and severity is expanding, yet remains fragmented and insufficiently informative for assessing progress, limits, equity, and key priorities. Previous global syntheses demonstrate that adaptation is occurring but provide limited insight into how, where, for whom, and with what risks. This scoping review addresses these gaps by mapping peer-reviewed evidence on drought adaptation in the 16 countries that make up the Southern African Development Community (SADC) region, one of the few regions globally that exhibits an observed downward trend in precipitation while encompassing many countries, making it a valuable case for examining diverse approaches to managing changing risk. We review 141 studies published since 2020, documenting the geographic, sectoral, and thematic distribution of reported drought coping and adaptation strategies. We discuss the spectrum of adaptation strategies utilized in SADC, identify common enablers and barriers, assess conditions associated with success, and examine risks of maladaptation. We also analyze which approaches are described as "transformative" and the traits they share. Results reveal that studies are concentrated in a small number of countries, primarily South Africa, Tanzania, and Zimbabwe, and of the seven broad sectors identified, only two feature prominently: 1) Agriculture, food, forestry, fibre, and fisheries and 2) Water. There are major gaps in documentation of

provided the original author and source are credited.

Data availability statement: Data is available at: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/KTYJ5I.

Funding: Research reported in this publication was supported by the National Institute Of Environmental Health Sciences of the National Institutes of Health under Award Number P20ES036118 (awarded to ECdP). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

ecosystem-based adaptation and private-sector responses. Adaptation actions are predominantly individual or community-level, while institutional and governance-focused strategies, though less common, are more frequently associated with transformative change. Governance and social capital consistently shape outcomes, while maladaptation risks often arise from short-term coping strategies that deepen inequality or erode long-term adaptive capacity. By synthesizing what is known and not yet documented along with what is labeled transformative, this review provides a regionally grounded evidence base to support assessments of adaptation progress, limits, and pathways that avoid leaving vulnerable populations behind.

Introduction

Droughts are increasing in frequency, duration, and severity across many regions of the world, driven by rising temperatures, altered precipitation patterns, and growing climate variability [1]. These changes pose increasing risks to key socio-ecological sectors particularly in the global south, where exposure to climate hazards is high and adaptive capacity is often constrained. Rain-fed agriculture remains a central livelihood base for many people globally, especially in low- and middle-income countries, making drought a critical climate hazard with far-reaching social and economic consequences [2].The Southern African Development Community (SADC) region is one such area, characterized by high dependence on climate-sensitive livelihoods, recurrent drought exposure, and persistent structural constraints related to poverty, infrastructure, and governance.

Effective and sustained adaptation to drought is therefore essential for reducing climate risk and advancing climate-resilient development. While drought response and adaptation have long been practiced by many communities and groups, with varying degrees of success, a growing body of evidence indicates that households, communities, and governments are changing their behaviors to account for increased drought risk. The Intergovernmental Panel on Climate Change (IPCC) has documented widespread implementation of adaptation across sectors, including agriculture, water, health, ecosystems, and human settlements, while emphasizing persistent limits and growing risks of maladaptation. These assessments highlight that adaptation is occurring, but often not at the scale or speed required to manage escalating drought risk [3].

The Global Adaptation Mapping Initiative (GAMI) provides the most comprehensive synthesis of adaptation responses to date, mapping thousands of documented adaptation actions across regions, sectors, and hazards, inclusive of drought, through 2019 [4]. GAMI demonstrates that adaptation is widespread, particularly in food and agriculture systems, while other relevant literature notes that documentation of adaptation is also increasing [5,6]. However, GAMI focuses on the presence and type of adaptation actions rather than their implementation, effectiveness, and enablers. As a result, important questions remain unanswered about how adaptation strategies work and how maladaptation unfolds over time, particularly in countries from the SADC region.

It is unclear which drought adaptation strategies are most commonly used and under which social and economic conditions these adaptations lead to reduced drought impacts. Additionally, while "transformative adaptation" is increasingly sought after, there is little clarity on which strategies are framed as transformative, how transformation is defined, or whether such claims are supported by empirical evidence. Finally while maladaptation is widely recognized as a risk, emerging maladaptive outcomes remain inconsistently documented [7].

Without clearer evidence, it is difficult to assess progress toward climate-resilient development or to inform future climate risk management. An incomplete understanding of barriers and maladaptation risks may lead to overconfidence in short-term coping strategies that fail to build long-term resilience. This review addresses these gaps by synthesizing the recent literature on drought adaptation across sectors. Building on previous global assessments while extending beyond them, we focus not only on what adaptations are reported, but also on the conditions that shape their adoption.

Specifically, within the SADC region, we aim to:

1. Map reported drought adaptation strategies across sectors, including agriculture, water, livelihoods, health, ecosystems, and human settlements;
2. Identify common barriers and enablers influencing adaptation adoption and effectiveness;
3. Examine reported maladaptations and underexplored risks; and
4. Explore how transformation is defined, operationalized, and evidenced in the drought adaptation literature.

By synthesizing this evidence, this review seeks to clarify where adaptation is implemented, where it is falling short, and where critical knowledge gaps remain.

Methods

To address the aims of this review, we conduct a systematic synthesis of the peer-reviewed literature on drought adaptation in the SADC region. The review examines reported adaptation strategies, as well as the conditions influencing their implementation, documented maladaptations, and claims of transformation. We applied the following inclusion and exclusion criteria to define the scope of the literature included:

The search strategy queried peer reviewed studies published between January 2020-June 2025. These dates were chosen because the Global Adaptation Mapping Initiative has already documented adaptation through 2019.

A three-step search strategy was utilized in this review. First an initial limited search of Web of Science was undertaken to identify key words relevant to our search, which were used to develop a full search strategy for Web of Science, CABI, Africa-Wide Information, Scopus, and Ovid Medline. The search strategy, including all identified keywords and index terms, was adapted for each database *(see* S2 Table *for search terms for each database*). The reference list of all included sources of evidence was screened for additional studies. Only studies published in English were included, though a search was conducted to understand the number of papers excluded by this strategy by removing the English language requirement from the search strategy and the output was minimal (<10). Studies published after 2019 were included as the Global Adaptation Mapping Initiative has previously reviewed evidence prior to 2020.

Following the search, all identified citations were collated and uploaded into Endnote and duplicates removed. Following a pilot test, which was used to ensure all reviewers were clear on the criteria for inclusion and exclusions, titles and abstracts were screened by two independent reviewers for assessment against the inclusion criteria for the review. Inter-rater reliability for the initial screening was 99%. All disagreements were included in the data extraction phase where a third reviewer made the final decision on inclusion. Sources that met the inclusion criteria (Table 1), were retrieved in full and the full article with citation details were distributed to reviewers for blinded data extraction, which was completed using a standardized excel spreadsheet. Any disagreements that arose between the reviewers at each stage of the screening

Table 1. Inclusion and exclusion criteria for the review.

Include	Exclude
1. The paper is drought related 2. The paper addresses human systems or human-assisted systems such as farming 3. Specific coping strategies or adaptations are mentioned to deal with drought 4. Published post-2019 5. The paper presents tangible responses (such as existing government initiatives, implemented strategies, etc) 6. White papers not listed in the exclusion criteria 7. Includes one or more countries in the SADC region, defined as: Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini/ Swaziland, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, Zimbabwe	1. The paper does not specifically mention drought or synonyms for drought 2. The paper addresses natural systems such as plants or animals 3. The research is solely a vulnerability assessment or impacts-focused 4. Published in or before 2019 5. The paper primarily involves planning, prioritizing, or proposing responses 6. Conference proceedings, media articles, book chapters, grey literature (anything not peer-reviewed) 7. Does not include a SADC member country

https://doi.org/10.1371/journal.pclm.0000876.t001

and extraction process were resolved through a third reviewer. The results of the search and the study inclusion process are reported in Fig 1.

Data was extracted from papers included in the scoping review by up to two independent reviewers using a data extraction tool, which gathered information on adaptation activities and sectoral relevance, barriers and enablers to adaptation, possibilities of maladaptation, and evidence of transformation, each of which is defined in S3 Table.

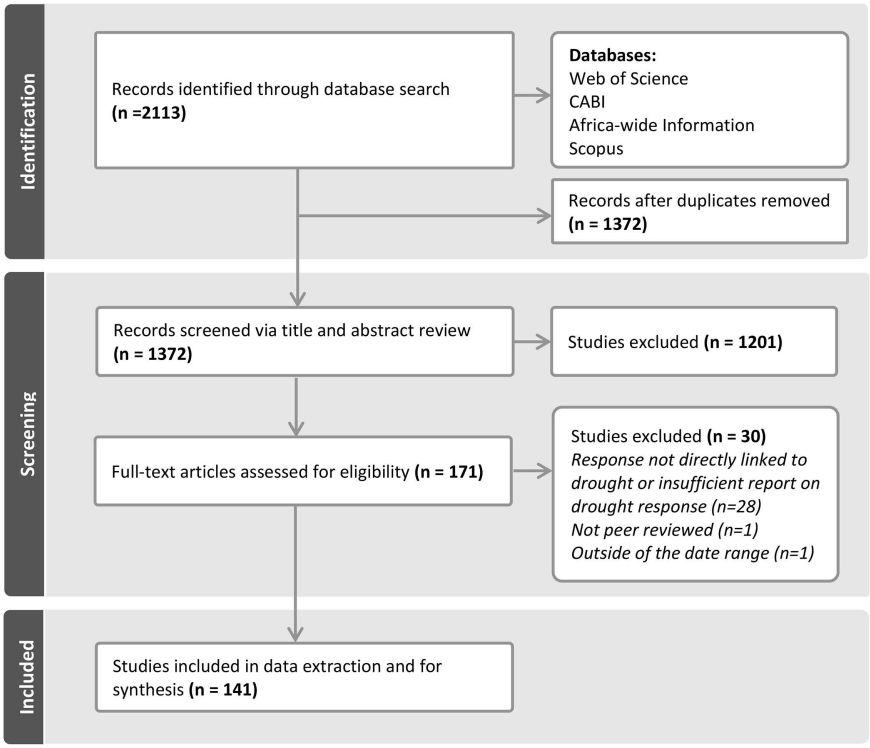


Fig 1. Prisma flow chart.

https://doi.org/10.1371/journal.pclm.0000876.g001

A pilot was conducted for data extraction and after 10% of articles had been reviewed, the authors met to discuss necessary clarifications. Revisions, including clarifying terms and deleting frequently unanswerable questions, were made to the tool at this time and the initial 10% of data was revised accordingly. Table 2 presents a breakdown of the tool's sectoral categories accompanied by a narrative summary.

Results and discussion

Adaptation summary

The thematic shading in Fig 2 corresponds to the relevant sustainable development goal. A reference guide is provided in S4 Table.

Evidence mapping and gaps

Geographic representation

Country of origin was determined by the study area and/or where interventions took place. When more than one SADC-region country was included in the study, that study was categorized as "multi-country." Multi-country *does not* include studies that assess one country within SADC and one more countries outside of SADC. As noted in Fig 3, evidence is concentrated in South Africa, Tanzania, Zimbabwe, and, to a lesser extent, Malawi. Some possible explanations for this are the exposure of drought, strong research capacity, and highly agriculture-dependent economies making adaptation a priority. These countries have also been the focus of many major donor-supported adaptation programs and English is widely spoken. The three countries not represented in the evidence, Comoros, Mauritius, and Seychelles, are all island states with less or more niche agricultural activity and a lower vulnerability to drought. There is a notable scarcity of multi-country studies; further research of this kind is warranted, as drought risk transcends national boundaries.

Sectoral representation

Sectoral relevance (Fig 4) was decided by each reviewer using the definitions provided in Table 2 and a "select all that apply" method. Most (n = 87, 62%) papers cover more than one sector and are included in the analysis for all sectors the paper represents. Evidence is lacking for ecosystem-related adaptation and, to a lesser extent, in

Table 2. Definitions of sectors included in results analysis.

Sector	Scope of Adaptation
Agriculture, food, forestry, fibre and fisheries	Adaptations related to food systems, agricultural production, agroforestry, fisheries, and livelihood strategies that affect food security
Water	Adaptations involving water resources, including hydrology, droughts, floods, sanitation, water scarcity, and water management or allocation
Poverty, livelihoods, mobility and fragility	Adaptations linked to poverty, livelihood resilience, equity, mobility or displacement, and responses in fragile or conflict-affected context
Human settlements, infrastructure, and industry systems	Adaptations in urban and rural settlements, infrastructure, and industrial systems to enhance climate-resilient development
Health and well-being	Adaptations addressing physical or mental health, disease risks, health systems, and the social factors affecting well-being under climate stress
Terrestrial and freshwater ecosystems	Adaptations involving terrestrial habitats and freshwater environments such as forests, grasslands, rivers, wetlands, and lakes
Ocean and coastal ecosystems	Adaptations focused on marine and coastal systems, including oceans, reefs, estuaries, and mangroves

https://doi.org/10.1371/journal.pclm.0000876.t002

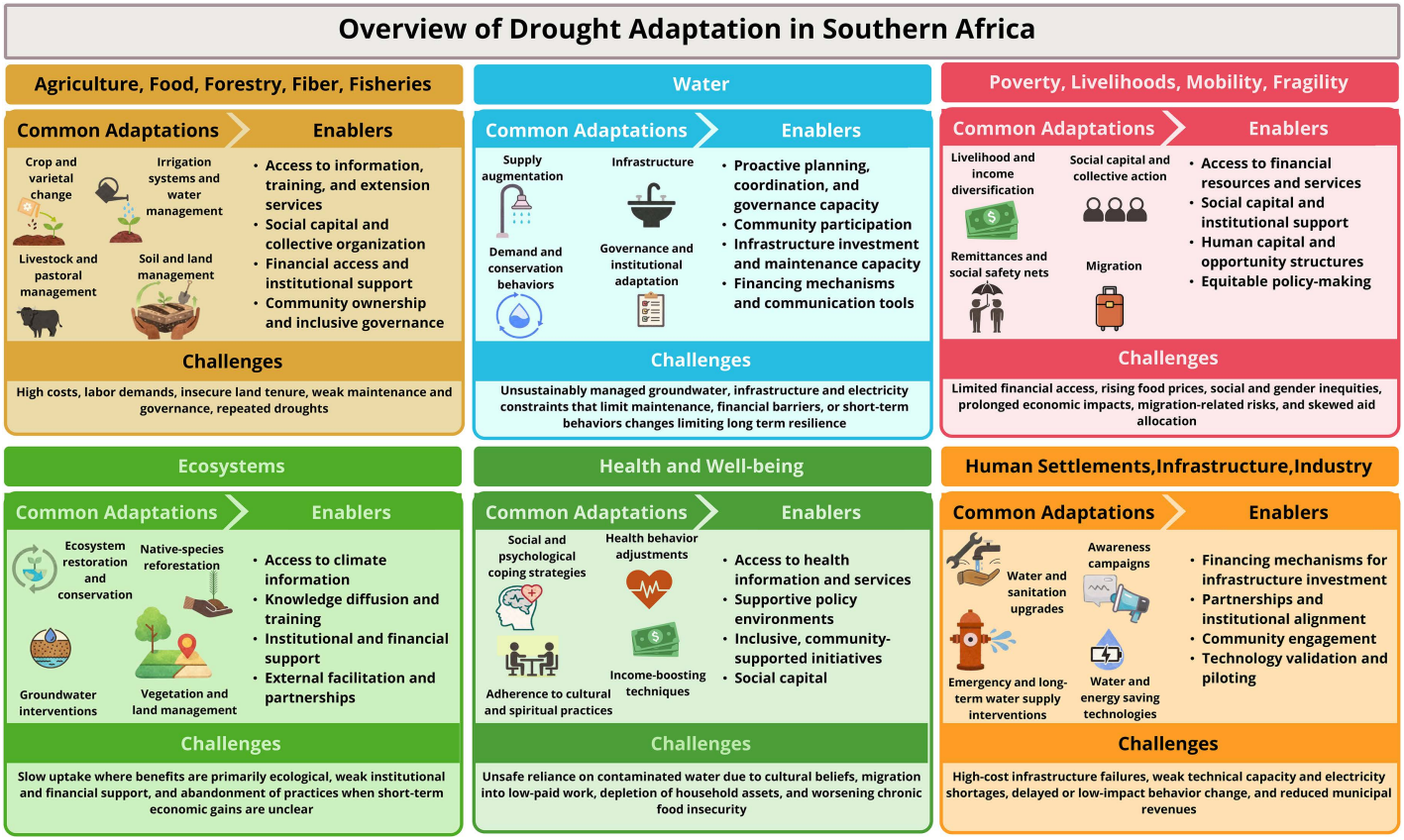


Fig 2. Overview of drought adaptation in Southern Africa. Note: Illustrations in Fig 2 are original artwork and do not contain proprietary clip art or third-party copyrighted images.

https://doi.org/10.1371/journal.pclm.0000876.g002

health and infrastructure. While there is significant amount of agriculture, food, forestry, fiber, finisheries and water evidence, much of this is concentrated in a few select countries. It is worth noting that some international groups and non-governmental organizations may be using reports to convey their work, which were excluded from this review.

In the pages that follow, we will detail the types of adaptation present in the literature, along with barriers and enablers to these adaptations and risks of maladaptation as presented by the existing literature. These details may not represent the full scope of adaptation that is happening in the SADC region, but rather what has been studied and published in academic writing.

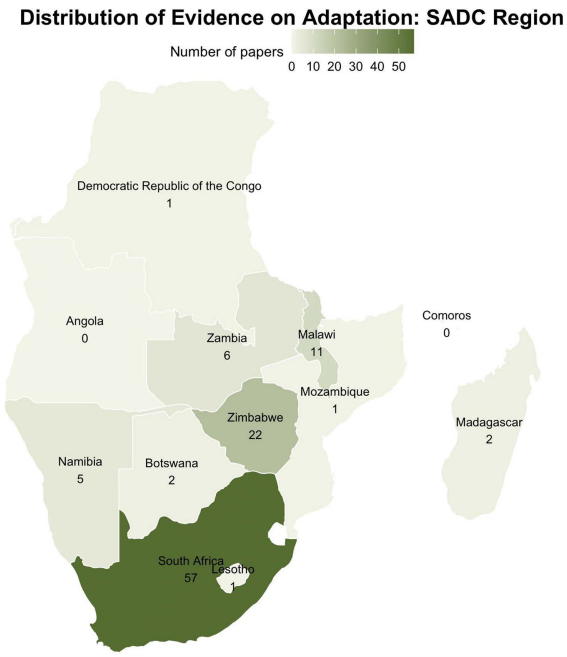
Agriculture, food, forestry, fiber, and fisheries

Reference numbers for papers discussing agriculture, food, forestry, fiber, or fisheries*	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 57, 59, 60, 61, 62, 63, 65, 66, 67, 68, 70, 71, 73, 74, 75, 76, 77, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 106, 107, 109, 110, 111, 112, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 128, 129, 131, 133, 134, 135, 139, 140

**Reference numbers correspond to the results table in S1 Table*

Country	# of papers
South Africa	57
Tanzania	27
Zimbabwe	22
Malawi	11
Zambia	6
Namibia	5
Multi-country	5
Madagascar	2
Botswana	2
Democratic Republic of Congo	1
Eswatini / Swaziland	1
Lesotho	1
Mozambique	1
Comoros	0
Mauritius	0
Seychelles	0
Total	141

Map of distribution of papers



5 studies that either addressed several countries within SADC or the SADC region as a whole which are not captured on this map.

Country boundaries are from Natural Earth (public domain: https://www.naturalearthdata.com/)

Fig 3. Where is the evidence.

https://doi.org/10.1371/journal.pclm.0000876.g003

What adaptations are being studied?

On the growing side, shifts in crop types, particularly the adoption of drought- and disease-resistant or early-maturing varieties, were among the most frequently reported strategies. These were often combined with crop diversification, planting crops with differing water or maturation requirements, intercropping, and crop rotation. Drought-tolerant varieties were consistently associated with higher yields relative to traditional varieties, though this was commonly only studied during drought years. Diversification of small grains allowed for some production under low-rainfall conditions when maize failed entirely. In several contexts, these strategies were also linked to improved food access and diet diversity.

Adjustments to planting practices, including shifting planting dates, staggered or sequential planting, and dry planting, were commonly reported. While these measures were often associated with improved short-term production outcomes,

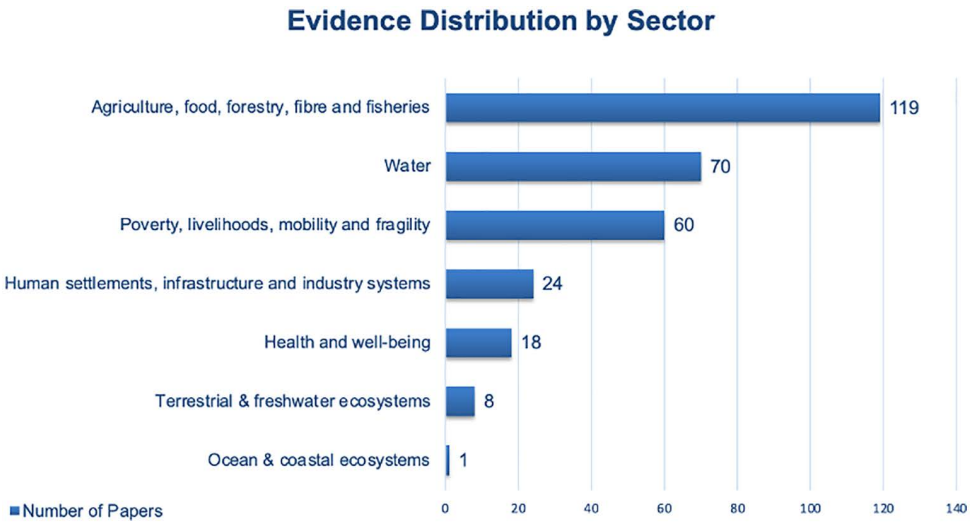


Fig 4. Evidence distribution by sector.

https://doi.org/10.1371/journal.pclm.0000876.g004

several studies emphasized temporal limits to drought recovery, noting that repeated shocks may constrain the longer-term effectiveness of planting adjustments alone [8–13]. Post-harvest adaptations, including improved food storage and seed banking, were described as contributing to more stable food availability across seasons and reduced vulnerability to post-harvest losses.

Soil and land management strategies frequently included no or low tillage, mulching, pit planting, and the use of organic waste and fertilizers, often framed as conservation agriculture or integrated soil fertility management. These practices were commonly associated with improved crop yields and soil quality indicators and in some cases contributed to improved food security and dietary diversity. However, several studies noted challenges to sustained adoption, emphasizing that continued use often declined after extension services or project support ended [13–19]. Agroforestry systems, including afforestation, woodlots, boundary trees, and fertilizer trees, were commonly perceived as positive with few drawbacks.

Agriculture-focused water management strategies included investments in irrigation infrastructure, water harvesting, and water storage. Irrigation was consistently associated with higher and more stable production, improved household food security, and increased income compared to rain-fed systems. At the same time, the sustainability of irrigation-based adaptations was frequently linked to maintenance requirements, institutional support, and farmers' technical capacity, with some studies noting that benefits diminish where systems are poorly maintained [15].

Livestock and pastoral adaptations included destocking, use of adaptable breeds, fodder production and preservation, livestock mobility, herd splitting, setting aside land for grazing, and alternative land use. Evidence suggests that fodder preservation, improved livestock housing, and improved access to drinking water reduced livestock mortality and disease incidence during drought. Nonetheless, recovery following severe drought was often incomplete, with herd sizes remaining depressed for multiple years in some contexts.

Many of the above strategies were discussed collectively under integrated frameworks such as climate-smart agriculture, ecosystem-based adaptation, integrated pest management, agroforestry, aquaculture, and integrated crop-livestock systems.

What barriers and enablers to success are described?

Barriers	Enablers
• Labor constraints and natural resource limits further complicated by the legacy of apartheid and social inequality • Farmers who do not own their own land are less motivated to and often cannot invest in long term solutions since they do not own the land and have limited access to related finance services • Difficulties balancing resource consumption versus accumulation • Limits to accessing information • Timing challenges such as syncing adaptation techniques with seasonal calendars in a changing climate • Age and health limit labor-intensive adaptations, especially in an aging farmer population • Recurring droughts compound impacts • Impressions that governments are mishandling funds can be demotivating • Cultural perceptions of crops can inhibit willingness to diversify • Inadequate gender representation leaves women behind • Lack of financial support along with high adoption costs • Education and asset gaps widening the socioeconomic divide	• Access to training, extension services, and group membership strongly influence sustained adoption, especially when these rights are extended to women • Rolling out project activities fully understood and owned by the community strengthens sustainability • Membership in farmer groups, farmer field schools, cooperatives, or savings and loan groups, provide a platform where farmers can share information • Access to credit improving long term investment capacity • Flexible social safety nets that can be combined with disaster risk management • Indigenous knowledge and strong local government engagement • Increased government contracts for farmers, including non-farm livelihood opportunities • Government promotion of improved and affordable seed varieties that can withstand drought stress • Early warning systems and digital weather platforms improving access to weather information • Piloting technologies in local communities to build trust and demonstrate value • Access to markets • Facilitate knowledge sharing across generations • Large household sizes have access to more labor • Breeder-farmer collaborations which combine farmer experiences with scientific experts to develop, select, and test new crop varieties • Social capital • Planning at all levels • Use of radio broadcasts for information sharing and social media for mobilizing individual action

What are the risks of maladaptation?

Drought-tolerant seeds must be purchased at the start of each season rather than saved, increasing farmers' expenses. Early-maturing cultivars can produce lower yields even in favorable conditions due to their shorter growth duration, again putting farmers at risk for less income. Some conservation practices are very labor-intensive, particularly if not mechanized, requiring additional time, effort, and costs. Agroforestry can also negatively affect yields by reducing farm space on small plots, although this effect is mitigated when combined with livestock. Irrigation, while improving water efficiency, can reduce long-term drought resilience if gains are used to expand irrigated areas, leading to increased water withdrawals and depletion. Quality storage structures are crucial for keeping out pests and maintaining dryness, and the lack of such structures limits households' ability to stock grains for extended periods, reducing income potential during droughts. Finally, selling livestock has longer term income-related consequences alongside immediate food security concerns.

Water

Reference numbers for papers discussing water*	2, 3, 4, 10, 11, 13, 19, 22, 25, 26, 29, 30, 31, 32, 36, 39, 40, 41, 42, 43, 45, 46, 47, 48, 50, 53, 54, 55, 56, 58, 59, 61, 62, 63, 64, 67, 68, 69, 70, 72, 73, 75, 76, 78, 81, 82, 83, 84, 88, 91, 93, 100, 103, 105, 108, 109, 110, 113, 122, 126, 127, 128, 132, 133, 135, 136, 137, 138, 139, 141

**Reference numbers correspond to the results table in S1 Table*

What adaptations are being studied?

Rainwater harvesting and storage emerged as a widely adopted household-level strategy, with evidence that women and school-educated households have higher adoption rates. Saving water in tanks and constructing water

canals on rooftops connected to storage containers are two documented examples. Infrastructure upgrades such as solar-powered boreholes are highlighted as relatively long-lasting interventions, while groundwater abstraction is increasingly used but accompanied by concerns about sustainability. Other water supply related responses include desalination, securing access to clean water through municipal taps, pumping drinking water, and diversifying water sources.

On the water demand side, studies document extensive use of water-saving behaviors and policies, including shorter showers, reduced laundry and cleaning, mandatory water use restrictions, water pressure management on taps, greywater reuse and recycling, and broader water reduction policies. Evidence suggests these measures can reduce water use and costs in the short-term but may not result in lasting change.

At the community scale, water infrastructure investments such as pit latrines, water metering systems, leak prevention and repair, and installing tanks and boreholes were commonly documented and some papers mentioned that these strategies helped prevent disease outbreak. Small-scale drip, or bucket irrigation is reported to have long-term benefits for water efficiency and production, but present some maintenance challenges. Developing and reviewing farm water budgets and decentralized water resource management have been used to improve planning and allocation. Additionally, sand dams show evidence of effectiveness, with significant increases in the number of months water can be collected after construction.

Governance and institutional strategies include re-negotiating roles and responsibilities between private and public actors in water provisioning, which has been shown to lower aggregated municipal water demand and provide opportunities for more equitable participation in policy design. Municipal coordination on water scarcity policy plans, community contributions to paying for water delivery, and enforcement through water committees reflect shifts toward shared responsibility, with evidence that communities develop a stronger sense of ownership and inclination to conserve water when they have a voice. More transformative potential is noted where community-based water tenure underpins governance arrangements, suggesting that equity can enhance the sustainability and effectiveness of water interventions in the long term [20].

What barriers and enablers to success are described?

Barriers	Enablers
• Communication issues • Perceived unfairness related to restrictions, policies, and tariffs • Propensity to revert back to old behaviors after awareness campaigns end • Financial barriers to inclusive participation and decision-making • Constraints on capacity, scale, and physical infrastructure • Evolving regulatory environments • Lack of community knowledge of ability to influence policy • Electricity shortages	• Proactive water planning and investment • Clear restrictions and targets • Repurposing existing policies [21] • Improved collaboration and coordination along with broader stakeholder inclusion • Improved infrastructure • Water committees [22] • Use of social media to mobilize individual action[15] • Tariffs and other financing mechanisms • Monitoring processes • Identifying community members as stakeholders

What are the risks of maladaptation?

Groundwater abstraction raises sustainability concerns, with several papers noting the need to monitor aquifer levels and implement recharge measures [23,24]. Water-saving behaviors, such as shorter showers, reduced laundry, mandatory restrictions, and greywater reuse, often decline once droughts or campaigns end, suggesting that these campaigns should be ongoing if they hope to improve water supply in the long term. Small-scale irrigation methods, like drip or bucket systems, face challenges due to maintenance needs and farmers' capacity to manage them independently, indicating that projects that require upkeep may not be sustainable solutions.

Poverty, livelihoods, mobility, and fragility

Reference numbers for papers discussing poverty, livelihoods, mobility, or fragility*	2, 4, 5, 9, 11, 14, 15, 16, 13, 18, 21, 22, 24, 25, 26, 28, 36, 38, 40, 41, 42, 43, 44, 46, 47, 49, 50, 52, 54, 58, 59, 61, 63, 65, 67, 75, 76, 80, 81, 82, 84, 85, 87, 89, 90, 91, 95, 97, 98, 100, 103, 106, 109, 112, 116, 129, 133, 135, 137, 139

**Reference numbers correspond to the results table in S1 Table*

What adaptations are being studied?

Diversifying income was the most commonly mentioned adaptation strategy used to address poverty and livelihoods. The means by which individuals diversified income ranged from sale of assets and belongings, off-farm employment, borrowing, selling livestock, using savings, and taking out loans, all of which demonstrated varying levels of success in improving outcomes or avoiding the worst impacts of the drought. Some studies even noted that these strategies were better suited for improving individual welfare during non-drought times. Dependence on remittance and social safety nets as well as leveraging social capital via collective labor, village savings and loan associations, livestock lending, borrowing food from neighbors or relatives, and communal granaries were also frequently mentioned strategies.

Migration was referenced in two forms: moving to urban areas for new work or to different rural areas with more rainfall for better grazing or farmland. Remittances were named as a motivating factor for the decision to migrate, where in many cases some family members would move and send cash or food assistance back to other family members who remained in their home village. In some cases, families were reunited once sufficient income was being made in the new place of residence [25].

What barriers and enablers to success are described?

Barriers	Enablers
• Socioeconomic factors, especially those linked to land ownership and availability of other financial resources • Financial impact of drought lasts beyond the return of rainfall, but not all resources do • Rising food prices • Lack of education or education opportunities • Lack of capital • Limited financial services	• Social capital • Expert consultations • Improving social safety nets • Policies promoting gender equality • Increased access to credit, loans, or skills • Higher wages • Knowledge of relevant determinants of poverty • Subsidies • Diversity of economic opportunities

What are the risks of maladaptation?

Limited aid, credit, and livelihood support can be directed toward households most likely to "succeed," which can strengthen individual resilience while diverting scarce resources away from the poorest, deepening overall poverty and inequality. Women are especially affected, as discriminatory inheritance and land-ownership laws restrict their ability to accumulate wealth, even when they take on economic responsibilities during drought [26]. Migration can lead to unintended harm: people and livestock are at increased risk for encountering conflict or death after moving into unfamiliar environments, families are separated, women are forced into traditionally male roles under stressful conditions, and competition over land and water increases conflict. Migrants often end up in poorly paid, unskilled work, meaning migration reduces immediate drought risk but can lock households into long-term economic insecurity.

Human settlements, infrastructure, and industry systems

Reference numbers for papers discussing human settlements, infrastructure, or industry systems*	3, 21, 25, 36, 39, 47, 49, 56, 63, 72, 78, 85, 88, 93, 98, 105, 113, 122, 128, 133, 135, 136, 137

**Reference numbers correspond to the results table in S1 Table*

https://doi.org/10.1371/journal.pclm.0000876.t009

What adaptations are being studied?

Strategies frequently described as human settlements, infrastructure, and industry systems include the use of pit latrines, drilling boreholes, and mandatory water use reductions. The use of heterogeneous infrastructure configurations, such as combining indoor flush toilets with backyard latrines on a single plot has been used to help residents address intermittent water supply, economic constraints, and safety concerns associated with having to navigate long distances in the dark to use shared toilets [27]. Regarding tourism, the hotel industry utilized several water-saving strategies including water-saving technological and infrastructure upgrades as well as awareness-raising strategies, encouraging guests and employees to make behavioral changes that conserve water. The upgrades allowed hotels to remain operational during periods of extreme water scarcity. Evidence of decline in water consumption levels related to awareness campaigns was mixed.

In Namibia, implementing emergency abstraction from the Windhoek Aquifer and pumping alternative drinking water sources from distances of up to 450km has been used to better serve rural communities. In urban areas, the #DontWashMeNAM campaign, where artists drew on dusty windshields to encourage water conservation is a unique strategy that led to an estimated 15–40% reduction in water used by car washes during the campaign [24]. However, despite their eventual success, the impact of the campaign had an "unacceptably long lead time" and the overall impact was much lower than targeted.

Several papers noted that infrastructure upgrades are long-lasting and continue to provide benefits even after the drought and help avoid future crises, emphasizing the need for long-term resilience policies and investment. Literature also discussed the importance of equitable investment in infrastructure.

What barriers and enablers to success are described?

Barriers	Enablers
• Funding for infrastructure improvements • Lack of assessments to inform investment needs • High upfront adoption costs • Weak institutional frameworks for technology validation • Electricity shortages	• Community involvement in organizing and planning awareness campaigns and other interventions/ treating local communities as relevant stakeholders • Clear goals or targets • Aligning programs with government development plans • Strategic partnerships between governments, private sector, and communities • Sources of financing such as grants, tariffs, and low/zero-interest loan options • Piloting technology in local communities to build trust and demonstrate value

https://doi.org/10.1371/journal.pclm.0000876.t010

What are the risks of maladaptation?

Short-term emergency responses can move too quickly and result in high-cost, low-efficacy results. For example, an expensive borehole was drilled to provide water to a hospital only to discover that the subterranean water was too high in magnesium and could not be used [28]. Additionally, lack of pre-existing technical expertise without training can make investment projects unsustainable. In the case of conservation campaigns, there were reports of reduced municipal revenue due to lower water consumption, impacting local economies more broadly. There were hotels and guest houses that replaced lawn grass with stones or artificial grass, which led to reduced groundwater infiltration [29].

Health and well-being

Reference numbers for papers focused on health and/or well-being*	3, 15, 21, 25, 26, 28, 32, 36, 40, 44, 46, 48, 100, 109, 113, 133, 139

**Reference numbers correspond to the results table in S1 Table*

https://doi.org/10.1371/journal.pclm.0000876.t011

What adaptations are being studied?

Strategies mentioned as health and wellness adaptation include peer or family support, migration, social capital, altering food consumption patterns such as skipping meals or eating less preferred foods, relying on less food, engaging in faith-based practices, exercise, and traditional cultural practices such as rain rituals. Health-promotion strategies were vaguely mentioned without clarification on what types of strategies were being promoted. Social capital was frequently discussed, with one paper noting that these relationships are important for gaining access to resources, information, and influence [30].

Regarding migration, people moved both to urban areas for new or to new rural areas with better farmland, but one study noted that the ability to send cash or food assistance back to their families was a significant motivating factor for the decision to migrate [31]. Authors also noted that while migration has been perceived as an often maladaptive short-term coping strategy, it can be a legitimate adaptation method due to its role in supporting various adaptive efforts. One indicator of positive outcomes for families who migrated was being able to send children back to school after previously being unenrolled [31]. Alternatively, one paper used the proxy variable of "thriving farmers" to indicate successful adaptation, which was defined as farmers who have not migrated due to drought and have sustained or improved their crop production and income. This study showed a positive and significant relationship between the adoption of on-farm adaptation strategies and "thriving" during drought, suggesting that those who adopted more strategies were more likely to report "thriving." [16].

What barriers and enablers to success are described?

Barriers	Enablers
• Peer-led initiatives, when unsupported or dismissed by the wider community, may not be sustainable • Cost of health services and health prevention measures, such as water treatment tablets	• Access to health information • Community belonging and collective discussion on resource distribution • Social capital • Policies that encourage urban migration • Roads to increase access to health prevention supplies and medical providers

https://doi.org/10.1371/journal.pclm.0000876.t012

What are the risks of maladaptation?

Literature identified increased health risks when using water from contaminated sources that is believed to be safe due to cultural rituals [32]. Despite some arguments that migration can have positive benefits, studies noted that migration may make people more vulnerable, as they are still paid very little, work in unskilled jobs, and lack the opportunity to learn new skills for higher-paid income. Literature also highlights how increased reliance on coping strategies, such as buying cheaper food, reducing meal sizes, or sending children elsewhere, could deplete household assets and adaptive capacity, potentially leading to deeper vulnerability and chronic food insecurity.

Terrestrial, freshwater, ocean, and coastal Ecosystems

Reference numbers for papers discussing terrestrial or freshwater ecosystems*	25, 32, 60, 73, 81, 126, 133, 139
Reference number for the paper discussing ocean or coastal ecosystems*	139

**Reference numbers correspond to the results table in S1 Table*

https://doi.org/10.1371/journal.pclm.0000876.t013

What adaptations are being studied?

Ecosystem-focused adaptations noted include restoration and conservation of agro-ecosystems, native-species reforestation, agroforestry practices that reshape forest structure, borehole rehabilitation to stabilize groundwater-dependent ecosystems, coastal rehabilitation, and targeted vegetation management. The literature notes some ecological risks that

are reduced or avoided by utilizing these strategies: biodiversity and carbon loss, forest degradation, soil erosion, habitat decline, invasive species spread, and watershed deterioration. Many of these adaptations provide co-benefits such as improved yields and more stable agro-ecosystems.

Progress and sustainability indicators within these adaptation efforts include evidence of changing attitudes towards conservation, increasing adoption rates of ecosystem-based practices, and some livelihood gains that help reinforce continued use. However, studies note that uptake can be slow, particularly where the benefits are ecological rather than immediately economic. This raises important questions: 1) Are strategies justified primarily as "doing it for the ecosystem" struggling to gain traction? 2) Can these strategies be reframed to increase uptake at the community level?

What barriers and enablers to success are described?

Barriers	Enablers
• Lack of institutional support, especially financially • Lack of inclusion in climate action plans to encourage political will • Access to climate information is identified as a crucial factor that makes farmers more likely to adopt ecosystem-based agriculture practices	• Membership in farmer field schools improves knowledge on how to use ecosystem-based agriculture practices • Access to credit • Diffusion of knowledge • Some training in conservation practices • Work done by third party organisations

https://doi.org/10.1371/journal.pclm.0000876.t014

What are the risks of maladaptation?

None explicitly mentioned for the ecosystems in the papers included in this review.

Which approaches are considered transformative?

Transformational adaptation was defined as long-term, irreversible changes in system function or structure. Across the eleven papers that reviewers agreed indicated transformational change, all programs address drought through collective, institutional, or community-based strategies that attempt to increase resilience, emphasizing technology, governance, and/or social networks. The cases collectively highlight that transformational shifts rarely emerge from technology alone, as power and resource redistribution repeatedly shape outcomes (Fig 5). Examples of restructured authority and participation in water management include polycentric arrangements, decentralization, and community-based water tenure.

Many programs share a reliance on collective action and multi-actor coordination. Cape Town's New Water Program, for example, depended on widespread individual cooperation and coordinated shifts across public and private sectors [23]. Similarly, Zambia's solar-powered borehole system required strong community water governance [20]. These examples reinforce that climate adaptation is best positioned to succeed when it mobilizes multiple stakeholders in complementary ways. Collaboration also emerges in cases emphasizing social networks and community participation, where social ties help mobilize resources and information across scales.

Another common thread is the central importance of governance. Polycentric governance in Cape Town, decentralized water management in Namibia, and community-based water tenure in South Africa and Zambia demonstrate that who controls water, and how decisions are made, can matter more than the physical availability of water itself [20,21,33,34]. Water source diversification, such as investments in desalination and solar-powered boreholes, becomes transformational primarily when paired with these governance shifts and equitable institutional arrangements.

Limitations

This review is only a snapshot of peer-reviewed literature on adaptation since 2020, excluding other forms of adaptation documentation. Many studies provided poor documentation of methods, including incomplete information on sampling procedures, timing of data collection, and definitions of key terms. Purposive sampling was frequently used, sometimes

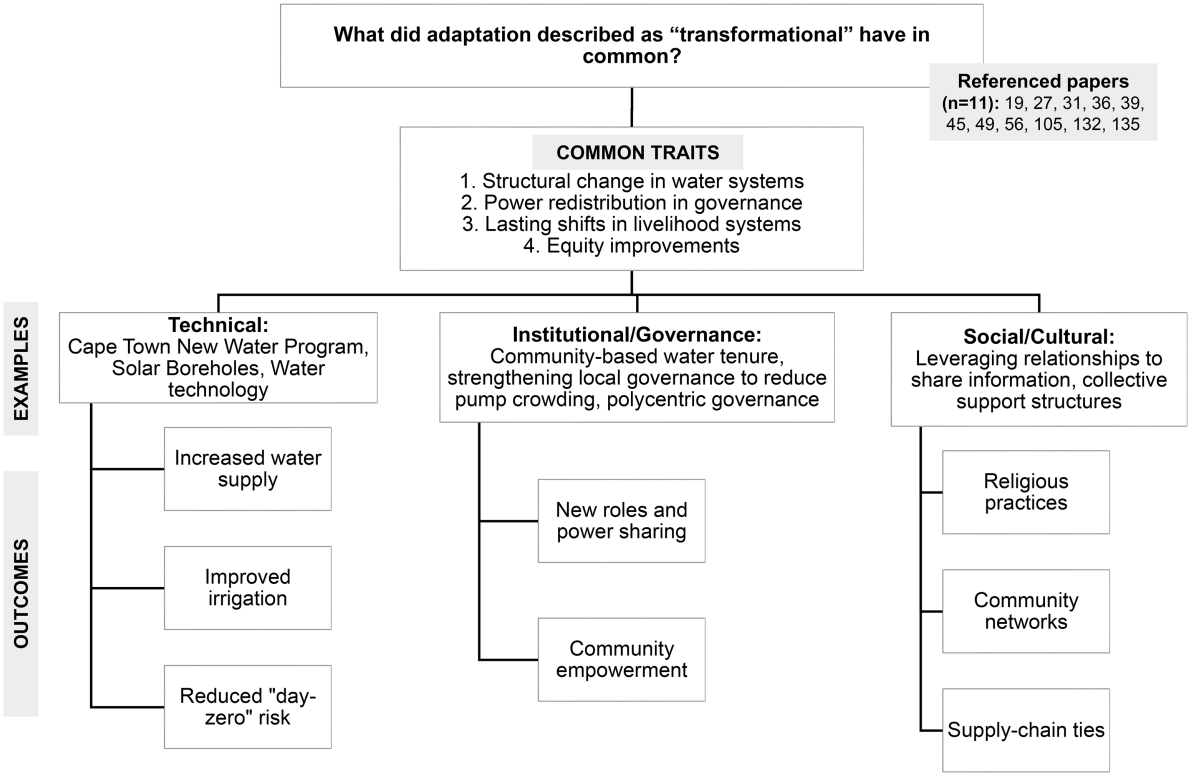


Fig 5. Traits of transformational adaptation.

https://doi.org/10.1371/journal.pclm.0000876.g005

targeting populations with extreme conditions such as farmers applying for emergency drought assistance (i.e., those with the least coping capacity). Several studies also lacked comparison groups when assessing the impact of promoted coping strategies. In some studies, data relied on long recall periods, raising concerns about accuracy of the information provided. Because of these limitations, we only report outcomes that are claimed or assumed and the findings of this review should be interpreted through that lens.

This review maps what is reported in the literature rather than was necessarily occurring on the ground and is therefore conditional on what is published, indexed, and captured by the search strategy. Where the review identifies apparent trends such as changes over time or differences across contexts, these reflect patterns in the published literature rather than direct estimates of real-world adaptation. Such patterns may also be shaped by publication, language, and indexing biases, as well as uneven geographic research capacity, which should be considered when interpreting the findings. Additionally, synthesis of findings was complicated by overlaps in categorizations and the subjective nature of several key classifications, including sectoral categories. The authors' perspectives, varying between local and international viewpoints, may also have influenced interpretations.

Conclusion

In the reviewed literature, adaptation success strongly hinged on recovery time between shocks, meaning droughts spanning multiple seasons can undermine the effectiveness of many strategies. Implementation of adaptation is often contingent on a households' ability to rebuild assets before the next drought, which could explain why short-term coping strategies repeatedly fail to improve long-term resilience, aligning with findings from other contexts and hazards [35,36].

This highlights temporal limits to adaptation, indicating that technical advancements alone such as improved forecasts may not be enough to improve wellbeing.

Ecosystem-focused strategies are often framed as environmental protection rather than livelihood protection. Adaptations framed as "for the ecosystem" may require explicit pairing with tangible, short-term, human-centered benefits to be worth promoting under resource constraints. Local priorities seem to be rooted in the reality of today rather than the possibilities of tomorrow, echoing findings that climatic shifts and their estimated impacts do not provide sufficient evidence to fully inform practical decision-making [37–39]. Similarly, health-focused adaptations are also often indirect or via awareness raising which is motivationally inadequate. Previous research has found health behavior change to be mostly dependent on self-efficacy, motivational and behavioral skills, and supportive social and environmental contexts rather than information alone [40–44].

Economic barriers dominate the literature. Some barriers are low-cost to address, but only if social and institutional contexts are considered. For example, information, awareness, and technology barriers often have relatively low-cost solutions, but these fail without trust and cultural alignment, a concern already noted by the IPCC AR6 [3]. The prevalence of governance-, social-, and awareness-related barriers in the reviewed literature point to the importance of genuine partnerships over tokenistic engagement. There are no substitutions for physical barriers such as inadequate infrastructure which are often constrained by finance. In cases where financial resources are finite but necessary for infrastructure development, failure to consider equity and community perspectives in resource allocation risks systematically overlooking vulnerable households.

The literature identifies some risk of maladaptation, but we found little evidence on whether these maladaptations are realized within communities and how those will impact future risk. Future evaluations should consider long term outcomes and prioritize follow up on unintended consequences.

Transformative adaptation was rarely defined or operationalized by the studies in this review. The few examples of adaptations viewed as transformative shared common traits such as power shifts and a focus on long-term outcomes. While this is a start to understanding how adaptation can lead to long-term resilience, more evidence is needed to build criteria for "transformational change." We are also left with several questions such as: *Does prioritizing transformation risk discouraging incremental but necessary action? How can incremental and transformative approaches coexist?* We suspect that true transformation may lie less in the novelty of practices and more in changes to recovery capacity, governance, and equity. For example, enabling recovery between shocks may be as transformative as introducing new technologies, given that short-term coping strategies frequently did not lead to improved resilience and recovery time between shocks was a common indicator of success. Regardless, transformation should be viewed as a trajectory, not a threshold.

Drought adaptation in SADC is widespread but uneven, often short-term, and constrained by structural factors; without attention to equity, governance, and recovery dynamics, adaptation risks stalling or becoming maladaptive. To address concerns around future adaptation, in addition to the questions already mentioned, we suggest that future research considers which strategies being implemented by local communities work well in combination and which are counter-productive or duplicative. Because drought doesn't stop at national boundaries, we recommend additional multi-country studies to help understand what aspects of adaptation are generalizable. Finally, adaptation evidence in the SADC region is heavily concentrated in food and agriculture, especially rain-fed crop production. Future research should explore other relevant sectors to maximize resilience.

Supporting information

S1 Table. Included paper references and relevance.
(DOCX)

S2 Table. Search strategy.
(DOCX)

S3 Table. Data extraction guidance.
(DOCX)

S4 Table. Shading template for overall graphic.
(DOCX)

S5 Table. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/
(DOCX)

Acknowledgments

This review builds on the Global Adaptation Mapping Initiative (GAMI), and we gratefully acknowledge the original GAMI authors who provided guidance on the development of the review protocol, especially Elphin Tom Joe. We thank Amy LaVertu and Mei Chung for their expert support and guidance with search strategies and methodology. We also thank William A. Masters, Selma Lendelvo, Carolyn Van Sant, and Anna Grossman for their helpful input. Research reported in this publication was supported by the National Institute Of Environmental Health Sciences of the National Institutes of Health under Award Number P20ES036118. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Author contributions

Conceptualization: Leah Selters, Erin Coughlan de Perez.

Data curation: Leah Selters, Eleanor Vance, Vaibhav Anand, Banawe Plambou Anissa, Chris Hillbruner, Christopher Ihinegbu, Miriam Silverman Israel, Jubeena Judi Joe, Caroline Kawira, Megan Lukas-Sithole, Renate Meyer, Relebohile Agnes Mojaki, Ian G. Moore, Miriam Nielsen, Susan Njambi-Szlapka.

Formal analysis: Leah Selters, Eleanor Vance, Renate Meyer, Erin Coughlan de Perez.

Funding acquisition: Erin Coughlan de Perez.

Methodology: Leah Selters, Megan Lukas-Sithole, Susan Njambi-Szlapka.

Project administration: Leah Selters.

Resources: Leah Selters, Erin Coughlan de Perez.

Supervision: Erin Coughlan de Perez.

Visualization: Leah Selters, Jubeena Judi Joe.

Writing – original draft: Leah Selters, Chris Hillbruner, Miriam Nielsen.

Writing – review & editing: Eleanor Vance, Vaibhav Anand, Banawe Plambou Anissa, Chris Hillbruner, Christopher Ihinegbu, Miriam Silverman Israel, Jubeena Judi Joe, Caroline Kawira, Megan Lukas-Sithole, Renate Meyer, Relebohile Agnes Mojaki, Ian G. Moore, Miriam Nielsen, Susan Njambi-Szlapka, Erin Coughlan de Perez.

References

1. Chapter 11: Weather and Climate Extreme Events in a Changing Climate. Accessed December 30, 2025. https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/
2. Rainfed Agriculture - an overview. ScienceDirect Topics. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/rainfed-agriculture 2026 February 9.

3. Pörtner HO, Roberts DC, Tignor MMB. Climate Change 2022: Impacts, Adaptation and Vulnerability. Pörtner HO, Roberts DC, Tignor MMB, editors. 2022.
4. Berrang-Ford L, Siders AR, Lesnikowski A, et al. A systematic global stocktake of evidence on human adaptation to climate change. Nature Climate Change. 2021;11(11):989–1000. https://doi.org/10.1038/s41558-021-01170-y
5. Callaghan MW, Minx JC, Forster PM. A topography of climate change research. Nat Clim Chang. 2020;10(2):118–23. https://doi.org/10.1038/s41558-019-0684-5
6. Nalau J, Verrall B. Mapping the evolution and current trends in climate change adaptation science. Climate Risk Management. 2021;32:100290. https://doi.org/10.1016/j.crm.2021.100290
7. Schipper ELF. Maladaptation: When Adaptation to Climate Change Goes Very Wrong. One Earth. 2020;3(4):409–14. https://doi.org/10.1016/j.oneear.2020.09.014
8. Grewer U, Kim D-H, Waha K. Too much, too soon? Early-maturing maize varieties as drought escape strategy in Malawi. Food Policy. 2024;129:102766. https://doi.org/10.1016/j.foodpol.2024.102766
9. Inman EN, Hobbs RJ, Tsvuura Z. No safety net in the face of climate change: The case of pastoralists in Kunene Region, Namibia. PLoS ONE. 2020;15(9 September).https://doi.org/10.1371/journal.pone.0238982
10. Mugari E, Masundire H, Bolaane M. Adapting to climate change in semi-arid rural areas: A case of the limpopo basin part of Botswana. Sustain. 2020;12(20):1–34. https://doi.org/10.3390/su12208292
11. Drysdale RE, Moshabela M, Bob U. A creeping phenomenon: the association between rainfall and household food insecurity in the district of iLembe, KwaZulu-Natal. Clim Dev. 2021;13(2):128–38. https://doi.org/10.1080/17565529.2020.1737795
12. Dumenu WK, Takam Tiamgne X. Social vulnerability of smallholder farmers to climate change in Zambia: the applicability of social vulnerability index. SN Appl Sci. 2020;2(3). https://doi.org/10.1007/s42452-020-2227-0
13. Muroyiwa B, Masinda N, Mushunje A. Smallholder farmers' adaptation strategies to mitigate the effect of drought on maize production in OR Tambo District municipality. Afr J Sci Technol Innov Dev. 2022;14(2):459–71. https://doi.org/10.1080/20421338.2020.1847385
14. Bosekeng LC, Mogotsi K, Bosekeng G. Farmers' perception of climate change and variability in the North-East District of Botswana. Livest Res Rural Dev. 2020;32(1).
15. Chidavaenzi FR, Mazenda A, Ndlovu N. Household survival and resilience to food insecurity through the drip irrigation scheme in dry rural areas. Jamba. 2021;13(1):985. https://doi.org/10.4102/jamba.v13i1.985 PMID: 33936560
16. Hagamu AE, Sesabo JK, Mkuna E. Growing hope in dry lands: A look at how Tanzania's smallholder farmers thrive despite drought. Tanzan J Agric Sci. 2024;23(1):178–200.
17. Mbombo-Dweba TP, Mayanja MM, Rakgwale TJ, Oguttu JW. Factors correlating with the ability to cope with drought conditions in the greater Letaba local municipality, South Africa, 2014-2016. Appl Ecol Environ Res. 2024;22(2):1029–50. https://doi.org/10.15666/aeer/2202_10291050
18. Said M, Temba A. The economic viability analysis on the Adopted Climate Change Adaptation Strategies among Maize Farmers in semi-arid of central Tanzania. EAJSTI. 2023;4. https://doi.org/10.37425/eajsti.v4i3.697
19. Selya NY, Dimoso P, Mgale YJ. Exploring the Adoption and Impact of Conservation Agriculture among Smallholder Farmers in Semi-Arid Areas: Evidence from Chamwino District, Tanzania. Res World Agric Econ. 2023;4(2):47–61. https://doi.org/10.36956/rwae.v4i2.801
20. van Koppen B, Mweemba CE, Amarnath G, Schreiner B. Community-based water tenure in equitable and transformative drought resilience. Curr Res Environ Sustain. 2024;8. https://doi.org/10.1016/j.crsust.2024.100266
21. Eakin H, Shearing C. Emergent polycentric governance in response to drought: Motivations, transaction costs, and feedback in corporate and city collaboration. Env Pol Gov. 2024;35(2):262–75. https://doi.org/10.1002/eet.2141
22. Mapuka FN, Nel W, Kalumba AM. Exploring household water conservation methods in rural South Africa: a case of the Mbhashe and Mnquma local municipalities. Sustain Water Resour Manag. 2024;10(4). https://doi.org/10.1007/s40899-024-01127-x
23. Blake D, Hartnady CJH, Hay ER, McGibbon DC, Towers LC, Riemann K, et al. Geoethical issues around water security for the City of Cape Town (South Africa) and groundwater resilience in uncertain circumstances: development of the Atlantis, Cape Flats and Table Mountain Group Aquifers. Sustain Water Resour Manag. 2023;9(5). https://doi.org/10.1007/s40899-023-00928-w
24. van Rensburg P, Tortajada C. An assessment of the 2015–2017 drought in Windhoek. Front Clim. 2021;3. https://doi.org/10.3389/fclim.2021.602962
25. Rosen JG, Mulenga D, Phiri L, Okpara N, Brander C, Chelwa N, et al. "Burnt by the scorching sun": climate-induced livelihood transformations, reproductive health, and fertility trajectories in drought-affected communities of Zambia. BMC Public Health. 2021;21(1):1501. https://doi.org/10.1186/s12889-021-11560-8 PMID: 34344335
26. Hazel A, Meeks G, Bharti N, Jakurama J, Matundu J, Jones JH. Opportunities and constraints in women's resource security amid climate change: A case study of arid-living Namibian agro-pastoralists. Am J Hum Biol. 2021;33(4):e23633. https://doi.org/10.1002/ajhb.23633 PMID: 34181282
27. Alda-Vidal C, Browne AL, Lawhon M, Iossifova D. Sanitation configurations in Lilongwe: Everyday experiences on and off the grid. Urban Studies. 2024;61(9):1773–88. https://doi.org/10.1177/00420980231217661

28. Quintana AV, Mayhew SH, Kovats S, Gilson L. Resilient health systems in action: How actor relationships and organizational adaptation shaped the health sector's response to the 2015–2018 Western Cape drought. Oxford Open Climate Change. 2025;5(1). https://doi.org/10.1093/oxfclm/kgaf014
29. Visser G, Cloete J. Guest houses, drought and water management strategies in the Cape Winelands, South Africa. Afr J Hosp Tour Leis. 2021;10(5):1549–61. https://doi.org/10.46222/ajhtl.19770720.178
30. Nyahunda L, Tirivangasi HM. Harnessing of social capital as a determinant for climate change adaptation in Mazungunye communal lands in Bikita, Zimbabwe. Sci April. 2021;8416410(41). https://doi.org/10.1155/2021/8416410
31. Chetto R, Mdemu M, Kihila J. Migration dynamics of smallholder farmers in semi-arid rural areas: harnessing coping and adaptation strategies for climate change effects in Tanzania. GeoJournal. 2025;90(2). https://doi.org/10.1007/s10708-025-11314-8
32. Hovden L, Paasche T, Nyanza EC, Bastien S. Water Scarcity and Water Quality: Identifying Potential Unintended Harms and Mitigation Strategies in the Implementation of the Biosand Filter in Rural Tanzania. Qual Health Res. 2020;30(11):1647–61. https://doi.org/10.1177/1049732320918860 PMID: 32449474
33. Hegga S, Kunamwene I, Ziervogel G. Local participation in decentralized water governance: insights from north-central Namibia. Reg Environ Change. 2020;20(3). https://doi.org/10.1007/s10113-020-01674-x
34. Joseph S, Antwi MA, Chagwiza C, Rubhara TT. Climate change adaptation strategies and production efficiency: The case of citrus farmers in the Limpopo province, South Africa. Jamba. 2021;13(1):1093. https://doi.org/10.4102/jamba.v13i1.1093 PMID: 34917286
35. Berdegué JA, Castillo MJ, Gómez I, Gordillo G, Navea J, Rojas I, et al. The importance of assets for coping with COVID-19 and other shocks. Global Food Security. 2024;40:100732. https://doi.org/10.1016/j.gfs.2023.100732
36. Ahsan MdN. Can Strategies to Cope with Hazard Shocks be Explained by At-Risk Households' Socioeconomic Asset Profile? Evidence from Tropical Cyclone-Prone Coastal Bangladesh. Int J Disaster Risk Sci. 2017;8(1):46–63. https://doi.org/10.1007/s13753-017-0119-8
37. Panda. Transformational adaptation of agricultural systems to climate change. WIREs Climate Change. 2018.
38. Weaver CP, Lempert RJ, Brown C, Hall JA, Revell D, Sarewitz D. Improving the contribution of climate model information to decision making: the value and demands of robust decision frameworks. WIREs Climate Change. 2012;4(1):39–60. https://doi.org/10.1002/wcc.202
39. Lemos MC, Rood RB. Climate projections and their impact on policy and practice. WIREs Climate Change. 2010;1(5):670–82. https://doi.org/10.1002/wcc.71
40. Hagger MS. Psychological Determinants of Health Behavior. Annu Rev Psychol. 2025;76(1):821–50. https://doi.org/10.1146/annurev-psych-020124-114222
41. Short SE, Mollborn S. Social Determinants and Health Behaviors: Conceptual Frames and Empirical Advances. Curr Opin Psychol. 2015;5:78–84. https://doi.org/10.1016/j.copsyc.2015.05.002 PMID: 26213711
42. Braveman P, Gottlieb L. The social determinants of health: it's time to consider the causes of the causes. Public Health Rep. 2014;129 Suppl 2(Suppl 2):19–31. https://doi.org/10.1177/00333549141291S206 PMID: 24385661
43. Sallis JF, Nader PR. Family Determinants of Health Behaviors. Health Behavior. Springer US. 1988. p. 107–24. https://doi.org/10.1007/978-1-4899-0833-9_6
44. Abid M, Ali A, Rahut DB, Raza M, Mehdi M. Ex-ante and ex-post coping strategies for climatic shocks and adaptation determinants in rural Malawi. Climate Risk Management. 2020;27:100200. https://doi.org/10.1016/j.crm.2019.100200