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Systematic Review

Conservation Practices for Climate-Driven Drought Adaptation Under Smallholder Farming Systems in Southern Mozambique: A Systematic Review

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Abstract

Climate-driven droughts pose major threats to rainfed farming worldwide. To address these impacts, smart agricultural approaches focusing on conservation practices (CPs) have been widely recommended by institutions such as the Food and Agriculture Organization of the United Nations (FAO), the World Food Programme (WFP), and the International Fund for Agricultural Development (IFAD), among others. This systematic review synthesizes evidence on CPs for climate-driven drought adaptation and the barriers to their adoption in southern Mozambique, where drought is predominant. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, a comprehensive search across four academic databases retrieved 595 records (2000–April 2025), of which 23 were peer-reviewed studies. Data was extracted and analyzed using Microsoft Excel 365 and NVivo 15. As a result, five major CPs were identified: (i) Minimum tillage; (ii) Mulching and residue retention; (iii) Maize–legume (cowpea, groundnuts, pigeon pea, and soybeans) intercropping and crop rotation; (iv) Drought-tolerant maize varieties; and (v) indigenous practices. The systematic review has shown that minimum tillage was associated with 89–90% increase in maize and legume yields; Mulching expands maize yields by 24–59%; intercropping increases maize and legume yields by more than 30%; drought tolerant maize varieties expand yields by 26–46%; and local practices support farming continuity and contribute to resilience, although quantitative yield effects were not reported, with adoption ranging from 75–100%. These findings suggest that minimum tillage and intercropping/crop rotation are the most effective CPs in enhancing yield and resilience. Despite their potential, the adoption is generally low (average around 40%, with some as low as 7–16% for minimum tillage). Reasons for limited uptake include economic, cultural, institutional, biophysical, and technological barriers. These findings highlight the need for integrated policy approaches that combine climate-smart agriculture with indigenous knowledge in southern Mozambique.

Keywords: systematic review; conservation practices; climate-smart agriculture; indigenous/traditional/local knowledge; drought adaptation; smallholder farmers; southern Mozambique

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1. Introduction

Climate change has emerged as a major global threat to food systems [1]. The global average temperature has increased by approximately 1.2 °C since pre-industrial times, with projections indicating that between 2030 and 2052 the temperature might increase 1.5 °C, causing more frequent climate extremes, such as floods, droughts, and cyclones [2–4]. The impacts of these climate events are particularly severe in Sub-Saharan Africa, where over 80% of the people rely on rainfed agriculture, but adaptive capacity is constrained by persistent socio-economic challenges [5]. Mozambique stands out as one of the most vulnerable countries to extreme climate events in the region [6]. Over the past two decades, it has been repeatedly affected by climate-related disasters [6,7]. Notably, Tropical Cyclones Idai (2019) and Freddy (2023) displaced more than two million people and caused damages exceeding USD 3.3 billion [8]. In the country's southern provinces (Maputo, Gaza, and Inhambane), prolonged droughts have become more recurrent, exacerbating food insecurity and threatening the sustainability of agricultural livelihoods [9].

Given the increasing climatic frequency and severity of dry periods, smallholder farmers in southern Mozambique are adopting diverse strategies to cope with and adapt to drought conditions [10–13]. Among these, conservation practices (CPs) include both climate-smart agriculture (CSA) practices and locally grounded indigenous knowledge (IK), which are gaining recognition for their potential to build long-term resilience [13–15]. CPs are defined in this study as farm-level strategies that promote the sustainable management of soil, water, and crop resources to enhance smallholder farmers' resilience and adaptive capacity to climate variability and climate-induced stresses. Studies in the region report the use of drought-tolerant crop varieties, minimum tillage, intercropping, mulching, improved soil and water management, and traditional forecasting methods as part of local adaptive strategies [13–16]. These approaches, while contextually relevant and often low-cost, are not always well-documented or systematically assessed in terms of their efficacy, coverage, or constraints [17].

Although empirical studies on drought adaptation among smallholder farmers are increasing, major knowledge gaps persist. First, there is a limited understanding of how conservation practices are implemented on the ground, and to what extent their adoption has contributed to tangible improvements in drought resilience and yield gain [14,17,18]. Second, the integration of indigenous and scientific knowledge systems, despite being widely advocated, is rarely operationalized in practice or evaluated in terms of complementarities and limitations [19,20]. Third, barriers to adoption, including access to land, credit, extension services, decision-making dynamics within households, and institutional support mechanisms, are often mentioned but not systematically analyzed or synthesized [11,12,14]. This review, therefore, seeks to consolidate fragmented insights into a holistic overview of conservation practices and their adoption barriers, with a focus on enhancing drought resilience in southern Mozambique.

To guide this analysis, the review adopts a conceptual framework that defines conservation practices (CPs) as both climate-smart agriculture (CSA) and indigenous knowledge systems [21]. Moreover, the analysis of the literature is guided by two frameworks: (i) Resilience Thinking Framework, which assesses how these practices strengthen farmers' capacity to absorb, adapt, and transform under recurrent droughts [22,23], and (ii) Sustainable Livelihoods Framework (SLF) to assess the barriers to their adoption [24]. The purpose of this systematic review is to synthesize the available evidence on conservation practices used by smallholder farmers in southern Mozambique to address climate-driven droughts. Specifically, it aims to: (i) describe the conservation practices employed in response to climate-driven droughts; (ii) assess the effectiveness of these practices in

enhancing resilience in rainfed agricultural systems; and (iii) identify the main barriers limiting their adoption.

Accordingly, the review is guided by two major research questions:

1. What conservation practices are used by smallholder farmers in response to climate change-induced and variability-induced droughts in southern Mozambique, and how effective are they?
2. What barriers to the adoption of conservation practices by smallholder farmers are identified in the literature, and what gaps remain in the existing evidence base?

Based on the existing evidence, the review is also framed by the following conceptual hypothesis: Conservation practices, including CSA techniques and indigenous knowledge systems, contribute to improved drought resilience among smallholder farmers in southern Mozambique.

2. Materials and Methods

This study followed the PRISMA 2020 guidelines [25]. The review protocol was structured around four stages: identification, screening, eligibility, and inclusion. The PRISMA 2020 Checklist used for reporting is provided in Supplementary File S3.

2.1. Search Strategy

The literature search was conducted in four databases: Web of Science, EBSCOhost, AGRIS, and Google Scholar. Boolean operators (AND/OR) were used to combine search terms, and the complete search strings are presented in Table 1. The same Boolean structure was applied across all databases, with minor syntax adjustments where required. Searches were limited to publications between January 2000 and April 2025 and included studies published in English and Portuguese.

Table 1. Search strings used for systematic review across four databases (Web of Science, Google Scholar, EBSCOhost, and AGRIS).

Database	Keywords Used
1. Web of Science. 2. EBSCOhost. 3. AGRIS. 4. Google Scholar.	(“conservation practices”) AND (“climate change” OR “Climate variability” OR “drought”) AND (“Southern Mozambique”). (“smallholder farmers” OR “subsistence farmers”) AND (“drought”) AND (“Southern Mozambique”). (“climate change adaptation”) AND (“drought”) AND (“Mozambique south” OR “Gaza” OR “Inhambane” OR “Maputo”). (“conservation agriculture”) AND (“climate adaptation”) AND (“Southern Mozambique”).

2.2. Screening Process

The selection of studies followed a structured four-stage screening process, as illustrated in Figure 1. The initial stage, “Identification”, identified a total of 595 records: 301 from EBSCOhost, 216 from Web of Science, 49 from AGRIS, and 29 from Google Scholar. Following identification, the second stage, “Screening”, started with the removal of duplicate records. A total of 255 duplicated entries were identified among the four databases and excluded, leaving 340 unique studies. The number of records retained after duplication check was as follows: EBSCOhost (n = 172), Web of Science (n = 123), AGRIS (n = 28), and Google Scholar (n = 17). In the next screening phase, studies were assessed based on their geographic and thematic relevance. This involved the review of titles and abstracts to determine whether the studies (i) had been conducted in southern Mozambique, and (ii) focused on conservation practices in response to drought. Studies that did not meet these conditions, such as those focused on other climate hazards (e.g., floods or cyclones),

conducted outside the study region were excluded. This step reduced the number of potentially eligible studies to 45, distributed as follows: EBSCOhost (n = 23), Web of Science (n = 16), AGRIS (n = 4), and Google Scholar (n = 2). The third stage, "Eligibility", focused on evaluating the academic quality and publication credibility of the remaining records. To maintain scientific rigour and ensure the reliability of evidence, only studies published in peer-reviewed journals with established academic standards were retained. After applying this filter, 23 studies remained eligible: 12 from EBSCOhost, 7 from Web of Science, 2 from AGRIS, and 2 from Google Scholar.

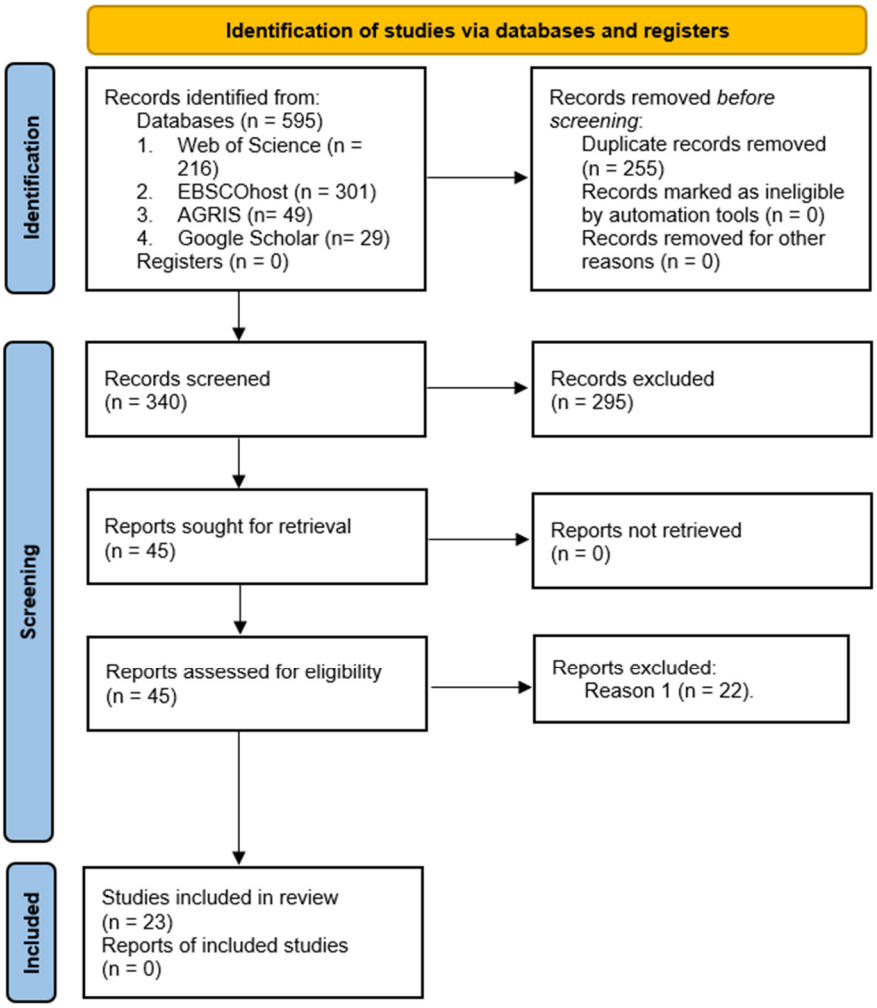

Figure 1. PRISMA 2020 flow diagram.

For the final stage, "Included", these 23 articles were then subjected to a full-text reading and critical appraisal process to confirm their alignment with the review's inclusion criteria. Each article was carefully examined to verify that it presented original empirical evidence, qualitative, quantitative, or mixed methods, on the use of conservation practices by smallholder farmers in the context of drought adaptation in southern Mozambique.

2.3. Inclusion and Exclusion Criteria

To ensure the scientific integrity and contextual relevance of this systematic review, a clear set of inclusion and exclusion criteria was established, as shown in Table 2. These criteria were applied throughout the screening process to filter studies based on PRISMA 2020. In terms of publication, only studies published between 2000 and April 2025 were considered. Eligible publications had to be peer-reviewed and written in either English or Portuguese. Studies falling outside this scope, including those not subject to academic

peer review or published in grey literature such as reports, proceedings, or non-indexed sources, were excluded. Regarding the type of data, the review prioritized studies that presented original empirical evidence, whether derived from qualitative, quantitative, or mixed-methods research designs.

Table 2. Criteria for inclusion and exclusion of literature selected for review.

Category	Inclusion Criteria	Exclusion Criteria
Publication type and period	Were peer-reviewed in English or Portuguese and published between 2000 and April 2025.	Were not peer-reviewed or were published in non-academic sources.
Type of data	Provided empirical data (qualitative, quantitative, or mixed methods).	Lacked empirical
Geographical location	Focused on smallholder farming systems (typically <2 ha) in Maputo, Gaza, or Inhambane.	Were conducted outside the provinces of Maputo, Gaza, or Inhambane.
Study context and focus	Addressed drought-induced adaptation strategies.	Focused on climate hazards other than drought (e.g., floods, cyclones, storms).
Conservation practices	Explicitly examined conservation practices, including but not limited to: Climate-Smart Agriculture practices and traditional farming strategies.	Addressed non-agricultural systems or non-smallholder production contexts.

The geographic scope was limited to studies conducted in southern Mozambique. This region was selected due to its high exposure to climate-driven drought and the predominance of smallholder agricultural systems that manage areas ranging from less than 1 hectare to 10 hectares [26]. Studies carried out in other parts of Mozambique or in different regions were not considered. In terms of thematic relevance, the central focus of the study had to be on adaptation strategies, but was not limited to soil and water conservation techniques, reduced or zero tillage, agroforestry, drought-resistant crop varieties, and traditional integrated farming systems. Studies that focused on non-agricultural domains, large-scale commercial farms, or contexts unrelated to smallholder agriculture were excluded from the analysis. Furthermore, research addressing other climatic threats, such as floods or cyclones, without reference to drought-specific responses, was not eligible for inclusion.

2.4. Data Extraction

A structured data extraction process was implemented using Microsoft Excel 365, Zotero 6.0, and SciSpace Web Software to ensure consistency across all included studies, as shown in Table 3. For each article, predefined data fields were used to systematically capture relevant information [25]. This included bibliographic details such as the article ID, authors, year of publication, title, journal or source, and full reference. Contextual information, such as the geographic location within southern Mozambique, study population, language, study design (qualitative, quantitative, or mixed methods), sample size, and data collection methods, was also recorded. The complete extraction dataset for all 23 included studies is available in Supplementary File S2. The extraction focused on whether the study described climate conditions, with specific attention to rainfall and temperature trends where applicable. It was also noted whether the article addressed crops, as well as the names of those crops. A key component of the extraction involved identifying and detailing conservation practices, including techniques such as minimum tillage, cover cropping or mulching, soil microbiology, crop diversification, intercropping, crop rotation, drought-tolerant varieties, agroforestry, and traditional practices. Any additional adaptation practices mentioned outside these categories were also considered.

Table 3. Structured data extraction framework for included articles.

Extraction Category	Description
Article ID	Unique identifier assigned to each article for tracking purposes.
Author(s)	Names of the authors who wrote the article.
Year	The article was published.
Title of the Article	Full title of the article.
Journal/Source	Journal name or source where the article was published.
Study Location within Mozambique	Geographic location of the study within Southern Mozambique
Climate Conditions Described (Yes/No)	Indicates if the article discusses climate conditions (e.g., rainfall, temperature).
Details on rainfall trends	Specific information on changes or variability in rainfall
Details on temperature trends	Specific information on temperature patterns
Crop mentioned (Yes/No)	Indicates whether the article refers to a specific crop.
Name of the crop mentioned	Name(s) of the crop(s) discussed
Conservation Practices Reported (Ex: Minimum tillage, mulching, traditional practices, etc.)	General mention of conservation practices used.
Effectiveness Practices Measures Reported (Yes/No)	Whether the article reports outcomes of the practices.
Details on the Effectiveness of Each Practice	Specific evidence of impact (e.g., improved yield, soil quality, water retention).
Barriers to Adoption Reported (Yes/No)	Indicates if the article discusses any limitations to adoption.
Details on Barriers	Describes challenges (economic, institutional, social, etc.).
Target Population	Describes who the study focused on (e.g., smallholder farmers, women).
Study Design/Methodology	Type of research design used (qualitative, quantitative, or mixed methods).
Sample Size	Number of participants or farms included in the study.
Data Collection Method	Techniques used for data collection (e.g., survey, interview, focus groups).
Key Findings	Summary of major findings relevant to the research objectives.
Gaps Identified by Authors	Gaps in research or practice are acknowledged by the authors.
Study Limitations	Limitations noted in the study
Funding Source	Source(s) of funding for the research (if mentioned).
Bibliographic Reference	Full reference.

Furthermore, information was gathered on whether the effectiveness of the reported practices was discussed, along with any evidence of outcomes such as improved yields or soil quality. The presence and nature of barriers to adoption were noted, including economic, institutional, or social constraints. Each study's relevance to the research questions was assessed, and key findings, author-identified gaps, study limitations, and funding sources were recorded. All extracted data were organized into a spreadsheet titled "Extracted Data," serving as a foundational resource for subsequent synthesis.

Operationalization of the Conceptual Frameworks

To ensure conceptual consistency in data extraction, coding, and synthesis, this review operationalized the Resilience Thinking Framework (RTF) and the Sustainable Livelihoods Framework (SLF) as analytical guides as shown in Table 4. The RTF was used to classify how each conservation practice contributed to the three resilience capacities: (i) absorptive capacity, reflecting buffering against drought impacts; (ii) adaptive capacity, representing incremental adjustments that improve farming performance under climate variability; and (iii) transformative capacity, involving deeper structural shifts in livelihood systems. During data extraction (Table 3), variables such as yield responses, soil moisture changes, water-use efficiency, and stability under dry spells were mapped to one of these three resilience capacities.

Table 4. Mapping of data extraction variables to components of the Resilience Thinking Framework and Sustainable Livelihoods Framework.

Data Extraction Variable	RTF Component	SLF Component
Yield response under drought	Absorptive/Adaptive	Natural capital
Soil moisture retention, infiltration, and soil organic carbon (SOC)	Absorptive capacity	Natural capital
Mulching/Cover crops effect	Absorptive/Adaptive	Natural/Physical capital
Minimum tillage outcomes	Adaptive capacity	Human/Physical capital
Intercropping benefits (maize–beans, etc.)	Adaptive capacity	Human/Natural capital
Crop rotation impacts	Adaptive capacity	Natural/Human capital
Agroforestry outcomes	Adaptive/Transformative	Natural/Physical capital
Drought-tolerant crop varieties	Absorptive/Adaptive	Human/Financial capital
Traditional/local knowledge practices	Absorptive	Social/Human capital
Level of adoption of conservation practices	Adaptive/Transformative	Human/Physical
Climate information access and use	Adaptive capacity	Physical/Human capital
Water harvesting or small-scale irrigation	Absorptive/Adaptive	Physical/Financial
Barriers: knowledge gaps, low literacy, age, gender roles	–	Human/Social capital
Barriers: limited labour availability	–	Human capital
Barriers: soil degradation, inconsistent rainfall, drought severity	–	Natural capital
Barriers: lack of tools, poor infrastructure, limited inputs	–	Physical capital
Barriers: cost of seeds/inputs, lack of credit, low income	–	Financial capital
Barriers: weak extension services, markets, policies	–	Transforming structures and processes

The SLF was systematically applied to analyze barriers to adoption by mapping constraints extracted from the literature to the five livelihood capitals, human, social, natural, physical, and financial, as well as transforming structures and processes. Gender roles, education, age, labour availability, and cultural norms were coded under human or social capital; land tenure, rainfall patterns, and soil fertility under natural capital; tools, equipment, irrigation, and communication systems under physical capital; and credit, costs of inputs, and market access under financial capital. Institutional barriers were assigned to the "transforming structures and processes" category.

This dual analytical approach allowed connecting biophysical effectiveness with socio-economic feasibility, producing a holistic interpretation of drought adaptation pathways.

2.5. Quality Assessment and Data Analysis

The methodological quality of all included studies was assessed using the Mixed Methods Appraisal Tool (MMAT, 2018) [27], which provides a structured and systematic framework for evaluating qualitative, quantitative, and mixed-methods research designs. Quality assessment was conducted independently by two reviewers (the first author and academic supervisor), who evaluated each study against the MMAT screening criteria and the five design-specific criteria. The reviewers reported no conflicts of interest in relation to any of the studies included in this review. Independent dual assessment was intentionally adopted as a bias-reduction strategy, preventing single-reviewer subjectivity from influencing quality judgments. Any discrepancies between reviewers were resolved through structured consensus-based discussion. Although no formal inter-rater reliability coefficient (e.g., Cohen's kappa) was calculated, the combination of independent screening and consensus adjudication offered a transparent and robust approach for minimizing selection and appraisal bias in the context of a two-reviewer team. Detailed MMAT scores for all included studies are provided in Supplementary File S1.

Given the prevalence of mixed-methods studies in the dataset, the reviewers adopted an inferential approach consistent with MMAT recommendations: when integration between qualitative and quantitative components was evident from study design, data triangulation, or joint interpretation, the mixed-methods criteria were considered satisfied. No studies were excluded based on quality appraisal scores, as the purpose of the assessment was to strengthen transparency, credibility, and bias-aware interpretation of the evidence base rather than to filter the dataset. Data analysis combined quantitative and qualitative approaches, performed in Microsoft Excel 365 and NVivo 15. In Excel, frequencies and percentages were calculated to summarize study characteristics and adoption rates of conservation practices, with outputs organized in Tables and Figures. NVivo 15 supported thematic coding of full texts, allowing the identification and categorization of adaptation practices, barriers, and study limitations.

2.6. Methodological Limitations of the Review

This review has several methodological limitations that should be considered when interpreting its findings. First, the study was not prospectively registered in PROSPERO due to the short academic timeline, although all steps of the review process were transparently documented in accordance with PRISMA 2020 guidelines. Second, substantial variation in study design, measurement approaches, and reporting quality across the primary studies limited the feasibility of conducting a meta-analysis and contributed to considerable heterogeneity in reported outcomes. Quantitative results were often presented using non-standardized metrics, lacked variance estimates, and were derived from diverse crop types, rainfall conditions, and soil characteristics, preventing the extraction of comparable effect sizes or the application of subgroup or sensitivity analyses. As a result, a structured narrative synthesis was adopted, and all reported ranges (e.g., mulching 24–59%) should be interpreted within their contextual variability rather than as statistically comparable outcomes.

Third, the evidence base presents inherent temporal and geographic limitations. Nearly all included studies were short to medium term ($\leq$3–5 years), preventing an assessment of long-term soil dynamics or yield stability under recurrent drought conditions. Moreover, geographic representation was uneven: Gaza province accounted for a disproportionate share of the evidence, while Inhambane and parts of Maputo were underrepresented, limiting the ability to conduct stratified analyses across agroecological zones.

Fourth, several relevant thematic areas could not be evaluated quantitatively due to gaps in the primary literature. No studies provided yield comparisons associated with indigenous practices, and none assessed the accuracy of traditional climate-forecasting indicators relative to meteorological services. Similarly, institutional mechanisms—such as extension coordination models or land-tenure strengthening—were identified as barriers in the literature but were not empirically evaluated in the included studies, limiting the extent to which the review could assess their effectiveness.

3. Results

3.1. Summary of Selected Studies

Figure 2 summarizes the geographic and methodological distribution of the 23 studies included in this systematic review. As shown in Figure 2a, most of the studies were conducted in Gaza province (n = 10), followed by Maputo (n = 4), Inhambane (n = 4), multi-province studies covering Maputo, Gaza, and Inhambane (n = 3), and two (n = 2) studies focusing on Maputo and Gaza. The dominance of Gaza may reflect its high agricultural vulnerability, particularly in arid and semi-arid districts of Guijá, Mapai, Mabalane, Chicualacuala, Chigubo, Massingir, and Massangena, located in this province. These dis-

tricts' rainfall ranges from 400 mm to 615 mm per year, and [28,29] is highly irregular and intermittent. These conditions might have made Gaza a hotspot for interventions and academic research on climate resilience. In contrast, Inhambane, despite having an extended arid and semi-arid area in the northern region (Funhalouro, Mabote, and Pande districts), remains underrepresented in the literature, suggesting spatial research gaps in southern Mozambique that warrant further attention.

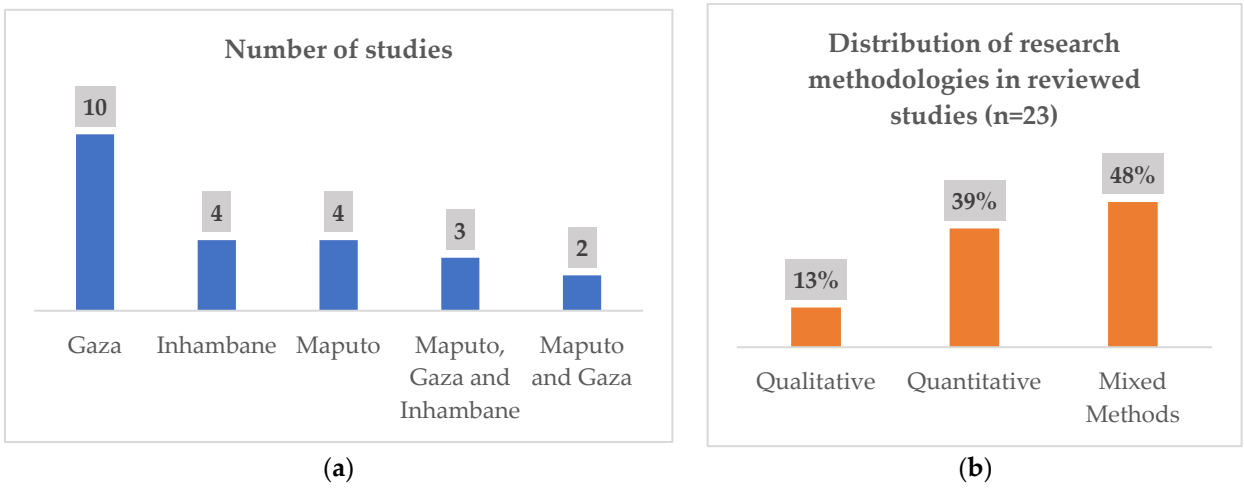

Figure 2. (**a**) Distribution of included studies by province in southern Mozambique. (**b**) Distribution of research methodologies in reviewed studies (n = 23).

In general, in these three provinces (Maputo, Gaza, and Inhambane), the precipitation often falls in a few intense events separated by long dry spells, leading to intermittent droughts and, in some years, premature cessation of the rainy season, resulting in seasonal droughts [30]. These droughts coincide with the critical flowering and grain-filling stages of staple crops grown by smallholder farmers, such as maize, cowpea, and groundnut, causing substantial yield losses [31]. Water deficits are further aggravated by annual evapotranspiration (1000–1300 mm) that exceeds rainfall in most districts, driven by rising mean temperatures (up to +1 °C above the 1950–2019 average), strong winds, and high solar radiation [31,32].

On the other hand, Figure 2b shows that mixed-methods approaches (quantitative and qualitative) are the most frequently used, accounting for 48% of the reviewed studies. These studies typically combined surveys, focus group discussions (FGDs), and interviews with key informants to explore both technical and socio-cultural dimensions of drought resilience. For example, ref. [13] employed 200 open-ended questionnaires, 25 FGDs, and 17 interviews to examine drought perceptions in Gaza, while [33] combined surveys and FGDs to understand information sharing in climate adaptation. Quantitative studies made up 39% of the total and were characterized by experimental trials (e.g., maize genotype and soil property assessments), structured household surveys (e.g., with 122 or 616 farmers), and statistical modelling. Qualitative studies were the least represented (13%) and were mostly literature-based or stakeholder-driven.

In terms of publication timeline, Figure 3 shows the year of publication of the 23 included articles. The distribution reveals a growing interest in research on climate resilience and sustainable agriculture in southern Mozambique in recent years. Most studies were published in 2024 (n = 4), and between 2019 and 2021, with three studies published each year. In contrast, earlier years, such as 2008 to 2015, show only sporadic publications, one article each year, suggesting that scholarly engagement with the topic was still emerging during that time. The number of studies declined slightly in 2022 and 2023, with only one

publication per year, most likely due to the COVID-19 pandemic, which led to movement restrictions between 2020 and 2023. However, interest appears to have resumed in 2025 (n = 2).

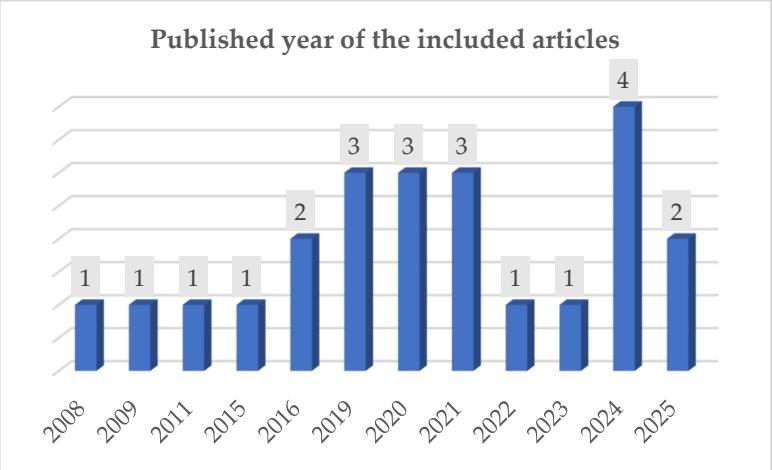

Figure 3. Published year of the included articles.

3.2. Description of Conservation Practices in Southern Mozambique and Their Effectiveness

Figure 4 illustrates the integration of CSA practices and Traditional/Indigenous Knowledge as key components of conservation practices in southern Mozambique used by smallholder farmers.

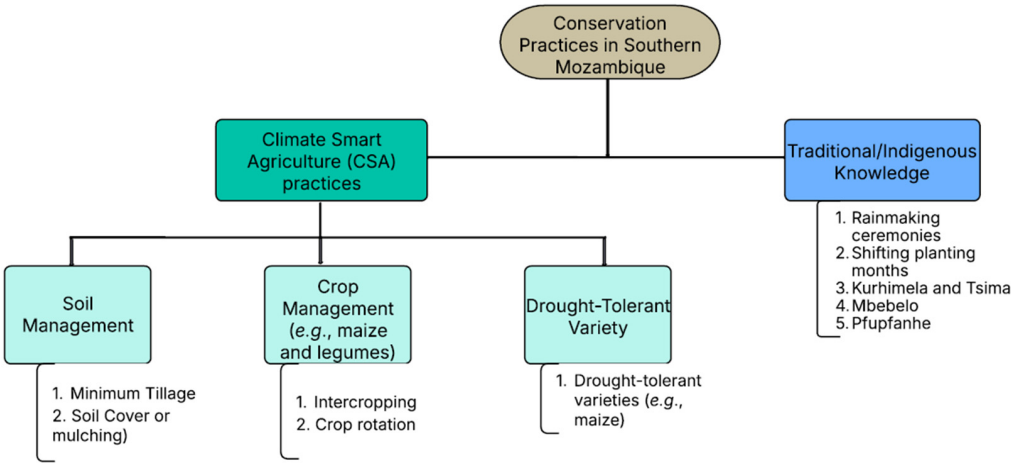

Figure 4. Conservation practices strategies adopted by smallholder farmers in Southern Mozambique.

These practices are implemented with the common goal of enhancing the resilience of smallholder farmers to recurrent climate-induced droughts.

3.2.1. Soil Management

Table 5 presents the Soil management practices (minimum tillage and soil cover) implemented in southern Mozambique. Experimental evidence in the region (Maputo, Gaza, and Inhambane provinces) indicates that minimum tillage (MT) reduces soil evaporation, increases infiltration, and enhances soil water storage through greater residue cover and organic matter accumulation [15]. These improvements are reflected in higher crop performance, with maize yields reported to be higher in 89% of cases and legume yields in 90% under MT relative to conventional tillage (CT) [15,34]. Localized trials further demonstrated that MT practices with tools such as basin planting and Jab planters increased maize yields by 13.7% and 11%, respectively, in comparison with CT systems [28,35]. Despite

these biophysical benefits, MT adoption in southern Mozambique is strikingly limited. The review showed adoption rates of only 16% in Inhambane and 7% in Gaza, with CT still dominating at 75–100% of farmers across key districts [28,35]. The persistence of CT reflects its customary use of the short-handled hoe in subsistence farming, the availability of animal traction, and its ability to quickly prepare land under rainfed conditions. However, this reliance increases vulnerability, as CT accelerates SOC loss, reduces infiltration, and lowers drought resilience, often resulting in yield decline [35,36].

The productivity impact of MT is also strongly site-specific. In semi-arid Malawi, MT basins increased maize yields by up to 95% under rainfall below 700 mm, outperforming jab planters and dibble sticks [37]. However, contrast emerges in wetter agro-ecologies, trials in Salima (Malawi) and Angonia (Mozambique) showed no yield advantages under MT due to waterlogging and nutrient leaching [37–39]. Similarly, in Gaza province, extreme drought years led to crop failure regardless of tillage type, illustrating that while MT can mitigate moderate climatic stress, it cannot eliminate vulnerability under severe rainfall deficits [35]. These findings underline that MT's efficacy under controlled trials does not always translate into effectiveness under heterogeneous smallholder conditions.

This study also revealed that soil cover practices, particularly mulching and residue retention, are more widely adopted in southern Mozambique than MT, and represent a cornerstone of CSA strategies in the region. Approximately 60% of smallholders reported maintaining crop residues on their fields, making this one of the most common soil management practices [28,35]. Evidence indicates that residue retention improves infiltration, reduces runoff, and enhances soil organic matter, resulting in maize yield gains ranging between 24% and 59% across different studies [37,39]. This wide range reflects substantial heterogeneity in rainfall regimes, soil texture, residue quantities, and trial protocols across sites. However, the primary studies did not report effect estimates with consistent stratification (e.g., by rainfall zone or soil type) or confidence intervals, which precluded a formal subgroup or sensitivity analysis to quantify the contribution of these factors to the observed variation. Comparatively, in Zimbabwe, adoption rates remain much lower, as residues are more commonly diverted for livestock feed [36]. This contrast highlights that while residue retention is widely practiced in Mozambique, competing demands for biomass elsewhere in southern Africa limit its adoption. However, despite relatively higher uptake, residue retention in Mozambique is rarely implemented at the recommended threshold of $\geq$30% cover. Competing uses of crop residues for livestock feed, fuel, and construction limit their availability for mulching [35]. Moreover, the review found that in many cases, residues are applied inconsistently, reducing their effectiveness in sustaining long-term soil fertility and yield stability. The minimum residue level required to achieve benefits remains contested, with some studies showing that sub-threshold coverage provides limited drought mitigation [37,39].

Long-term trials in Mozambique demonstrated that residue retention improves SOC, infiltration, and resilience after five or more years [28,36]. However, similar to evidence from Malawi and Zimbabwe, short-term results often show little or no yield advantage in the first years of adoption [37–39]. This temporal lag undermines farmer motivation in subsistence contexts where immediate food security needs are paramount. Nevertheless, survey data revealed that in Mozambique, CSA adoption that included mulching significantly improved household Food Consumption Scores (FCSs) by +5.486. In other words, households that adopted CA with mulching experienced, on average, an increase of 5.486 points in their Food Consumption Score compared to non-adopters ($p < 0.1$), unlike in Zimbabwe and Malawi, where incomplete adoption and small land areas prevented significant impacts [36]. This alignment suggests that when consistently applied and integrated with complementary practices, mulching contributes not only to yield gains but also to

improved food security, although the magnitude of benefits depends on both ecological conditions and socio-economic contexts.

Table 5. Soil management practices implemented in southern Mozambique.

Category	Conservation Practice—CSA	Type	Description	Effectiveness Among Adopters	Adoption of Smallholders' Farmers	Citation
Soil Management	Minimum Tillage vs. Conventional Tillage	Minimum Tillage (using implements or not)	Minimal soil disturbance to conserve moisture and structure.	Maize yields are higher by 89%. Legumes yield higher in 90%.	16% adopted in Inhambane province. 7% adopted in Gaza province.	[15,28,40–43]
		Conventional Tillage	Intensive soil ploughing before planting.	Soil degradation and SOC loss. Lower yields for both maize and legumes. Low drought resilience.	75–100% use conventional tillage in southern Mozambique.	
	Soil Cover (Crop Residue Retention/Mulching)	Cover Cropping/mulching	Using plants or crop residues to protect and enrich the soil	Maize grain yields by 24% to 59%. Maintains permanent soil cover with ≥30% crop residues.	60% adopted in southern Mozambique	

3.2.2. Crop Management

Table 6 presents the Crop management practices (intercropping and crop rotation) implemented in southern Mozambique. Evidence shows that maize–legume intercropping, involving crops such as cowpea, groundnuts, pigeon pea, and soybeans, is practiced by more than 60% of farmers in the region, with adoption rates ranging from 60% to 90% [15,16,41,42]. These figures were largely derived from household surveys and farmer interviews, confirming intercropping as a farmer-led adaptation strategy. This system consistently increases yields of both maize and legumes by over 30%, largely due to complementary resource use, improved nitrogen fixation, and enhanced soil cover [34]. From an adaptation perspective, intercropping buffers farmers against drought by reducing the risk of total crop failure. If one crop performs poorly under dry conditions, the companion legume often sustains household production and food supply [44,45]. In addition, survey-based evidence indicates that adopters of maize–legume systems reported significantly higher Food Consumption Scores ($p < 0.05$), reflecting both improved productivity and resilience to climatic shocks [37,45].

Crop rotation strategies, particularly alternating maize with legumes such as cowpea or groundnuts, are less widespread but still significant, with adoption levels between 40% and 74% among smallholder farmers in southern Mozambique [34]. Data from surveys and focus group discussions confirm that rotation improves pest and disease control, restores soil fertility, and stabilizes yields over time [45]. Trials in Mozambique and Zimbabwe further demonstrated yield increases of up to 38% for maize and cowpea rotations compared to monoculture systems ($p < 0.1$), highlighting their role in low-input environments [46]. Importantly, crop rotation enhances adaptive capacity to drought by improving soil organic matter, which increases water-holding capacity and reduces vulnerability during prolonged dry spells [47]. In Tanzania, maize–pigeon pea systems improved land use efficiency, with Land Equivalent Ratios (LER) consistently >1 [47], confirming productivity gains similar to those seen in Mozambique.

Table 6. Crop management (cereal and legume combinations).

Category	Type	Description	Effectiveness Among Adopters	Adoption of Smallholders' Farmers	Citation
Crop Management Cereal-legume combinations (e.g., maize with cowpea or peanut)	Maize–Legume Intercropping	Growing maize with legumes in the same field for soil health.	More than 60% of farmers practice intercropping between Maize and legume (Cowpea, Groundnuts, Pigeon Pea, and Soybeans). Increases the yield of both Maize and Legumes by more than 30%.	60% to 90% adoption in southern Mozambique	[15,41–43]
	Crop Rotation	Alternating different crops in the same field each season to restore the soil.	The highest yield in both Maize and Cowpea is 38%. Improve crop management practices (fewer pests, less disease, etc.).	40% to 74% of adoption in southern Mozambique.	

3.2.3. Drought-Tolerant Variety

Table 7 presents the drought-tolerant variety implemented in southern Mozambique. Drought-tolerant varieties demonstrated yield increases of 26–46%, equivalent to 695–1422 kg/ha of maize, compared with conventional varieties [10,13,33]. Adoption rates range from 40% to 77% in southern Mozambique [41,43,48,49]. However, national survey data reported only 11% of households planting improved maize to cope with drought in 2011 [50,51]. On the other hand, evidence from randomized controlled trials indicates that drought-tolerant maize offsets nearly all yield losses during moderate mid-season droughts, while conventional varieties suffer declines of up to 15% [52]. However, the protective effect was weaker under severe drought, where yields of improved varieties also fell significantly [39]. In addition, drought-tolerant maize with intercropping systems enhances both yield stability and dietary diversity, particularly when legumes such as cowpea, pigeon pea, and lablab are used [14,53]. These findings confirm that while drought-tolerant maize is critical for stabilizing food production, its effectiveness is maximized within broader risk management and soil fertility strategies [54]. Moreover, the findings indicate that drought-tolerant varieties exhibit greater effectiveness in mitigating drought impacts when cultivated in intercropping systems, as opposed to being grown as sole crops.

Table 7. Drought-tolerant variety.

Category	Conservation Practice	Type	Description	Effectiveness Among Adopters	Adoption of Smallholders' Farmers	Citation
Drought-tolerant Variety		Drought-tolerant maize.	Crop bred to survive with limited water.	26–46% higher yields of maize (695–1422 kg/ha more).	40% to 77% of adoption in southern Mozambique.	[10,13,33,41, 43,48,49]

3.2.4. Traditional

Table 8 presents the traditional practices implemented in southern Mozambique. The table shows that traditional practices remain highly adopted among smallholder farmers in southern Mozambique, with adoption rates ranging between 75% and 100% [13,20,48]. This widespread use reflects the continued reliance on Indigenous Knowledge (IK) as a central pillar of farming systems, particularly in contexts of recurrent droughts and climatic

variability [55]. In Gaza province, for example, farmers still attribute droughts to supernatural forces (51% to God and 12.5% to ancestors), shaping their reliance on ceremonies and prayers as first responses to climatic shocks [48]. These beliefs directly influence the timing and order of adaptation strategies, with 63.5% of households prioritizing collective spiritual actions before individual agronomic measures [13].

Practices such as rainmaking ceremonies (*Mbelelo*), shifting planting months, and exchange systems like *Kurhimela* and *Tsima* illustrate how communities embed spiritual, social, and ecological knowledge into their agricultural calendars [20]. Surveys and focus group discussions conducted in Chibuto and Guijá districts confirm that 31% of farmers still participate in traditional rain ceremonies, while 69% join collective church prayers as part of drought response strategies [48]. Similar findings are reported in South Africa and Zimbabwe, where rituals such as *Mutoro* and *Mbelelo* serve both to ask for rain and to strengthen communal resilience [55,56].

Traditional knowledge also provides practical benefits beyond ceremonies. Rituals to chase away pests (*Pfupfanhe*), indigenous food preservation systems, and the use of naturally resilient resources such as wood ash and creeper crops contribute directly to improving maize and legume yields [56]. However, none of the reviewed studies reported quantitative yield measurements (kg/ha) for these traditional practices, and the evidence remains qualitative in nature. Evidence from household surveys and FGDs in Gaza Province shows that farmers employ environmental indicators such as moon phases (92% of FGDs), cloud formations (88%), and wind direction (72%) to predict rainfall and adjust planting dates accordingly [20]. These methods, though increasingly challenged by climate variability, remain the most accessible and trusted forecasting tools for rural households. However, none of the included studies quantitatively compared the accuracy of these traditional forecasting methods with formal meteorological services. Therefore, their relative reliability remains an open evidence gap. Comparable strategies have been documented in Zambia and South Africa, where seed preservation, crop rotation, and indigenous pest management play key roles in sustaining production under drought [57,58].

Table 8. Traditional practices or Indigenous Knowledge (IK).

Conservation Practice	Type	Description	Effectiveness Among Adopters	Adoption of Smallholders' Farmers	Citation
Traditional	Traditional practices	Indigenous methods were passed down to manage farming naturally. Includes rainmaking rituals, pest-control rituals, burial ceremonies, shifting planting months, exchange systems (Khurimela, Tsima), and reliance on local natural resources. Also, the use of environmental indicators such as moon phases, cloud formations, and wind direction.	31% of farmers in Chibuto and Guijá districts still join rainmaking rituals; 69% participate in collective drought prayers; 92% use moon phases, 88% cloud formations, and 72% wind direction (Gaza Province). These practices improve maize/legume yields and strengthen resilience.	75% to 100% adoption in Southern Mozambique	[13,15,16,20, 29,34,41,48, 59,60]

To support a clearer and more integrated interpretation of the evidence, Table 9 provides a consolidated summary of the main conservation practices identified in this review. For each practice, the table synthesizes: (i) its classification as a CSA or indigenous

practice, (ii) reported adoption ranges, (iii) observed yield or production effects, (iv) the principal barriers to uptake, and (v) geographic coverage within southern Mozambique.

Table 9. Summary matrix of conservation practices, adoption rates, yield effects, barriers, and geographic coverage in southern Mozambique.

Practice	Type (CSA/Indigenous)	Adoption Range (%)	Yield/Production Effects	Main Barriers	Geographic Coverage
Minimum tillage	CSA	7–16% (CT widely dominant)	Higher maize yields in 89% of observations; 11–14% gains with basin/jab-planter	Labour intensity; lack of implements; cultural preference for ploughing	Gaza, Maputo, Inhambane (semi-arid areas)
Crop residue retention/mulching		~60% maintain residues; <30% adequate cover	Yield gains: 24–59%; improved moisture and SOC over ≥5 years	Competing uses (feed, fuel); low biomass; short-term gains limited	Maputo, Gaza, Inhambane
Maize–legume intercropping		60–90%	Yield increases >30% for both maize and legumes; improved food security indicators	Labour; input costs; weak extension; gendered access	Widespread across southern Mozambique
Crop rotation (maize–legume)		40–74%	Maize yield gains up to 38%; pest/disease reduction	Land scarcity; fragmented plots; limited knowledge	Maputo, Gaza, and some evidence from Zimbabwe
Drought-tolerant varieties		40–77% (national baseline ≈ 11%)	26–46% higher yields (695–1422 kg/ha) under moderate drought	Seed cost; variable performance; access constraints	Maputo, Gaza, Inhambane
Indigenous knowledge practices (forecasting, rituals, collective systems)	Indigenous	75–100% use at least one practice; 92% moon phases; 88% cloud patterns	Reported to sustain yields and resilience; no kg/ha estimates available	Generational erosion; institutional neglect; limited validation	Gaza (notably Chibuto, Guijá), parts of Maputo and Inhambane

3.3. Barriers and Challenges to Implementation in Southern Mozambique

Although conservation practices show clear benefits in mitigating drought impacts, their adoption in southern Mozambique remains uneven. Multiple social/cultural, economic, institutional, technological, and biophysical barriers continue to constrain wider implementation. Figure 5 provides an overview of these barriers.

Additionally, a synthesis of all barriers reported across the included studies indicates that constraints do not operate with equal weight or frequency. Economic barriers emerge as the most recurrent and decisive constraints, as they directly limit farmers' ability to adopt or sustain conservation practices. Institutional weaknesses represent the second most influential category, shaping farmers' access to knowledge and support. Technological constraints constitute a third tier by affecting the practical feasibility of implementation. Biophysical factors tend to be site-specific and less amenable to policy intervention. The social and cultural dynamic is the last; its effects generally act through behavioral rather than technical pathways. Table 10 summarizes this hierarchy of barriers and their relative prominence across the evidence base. The following sections explore each barrier category in detail.

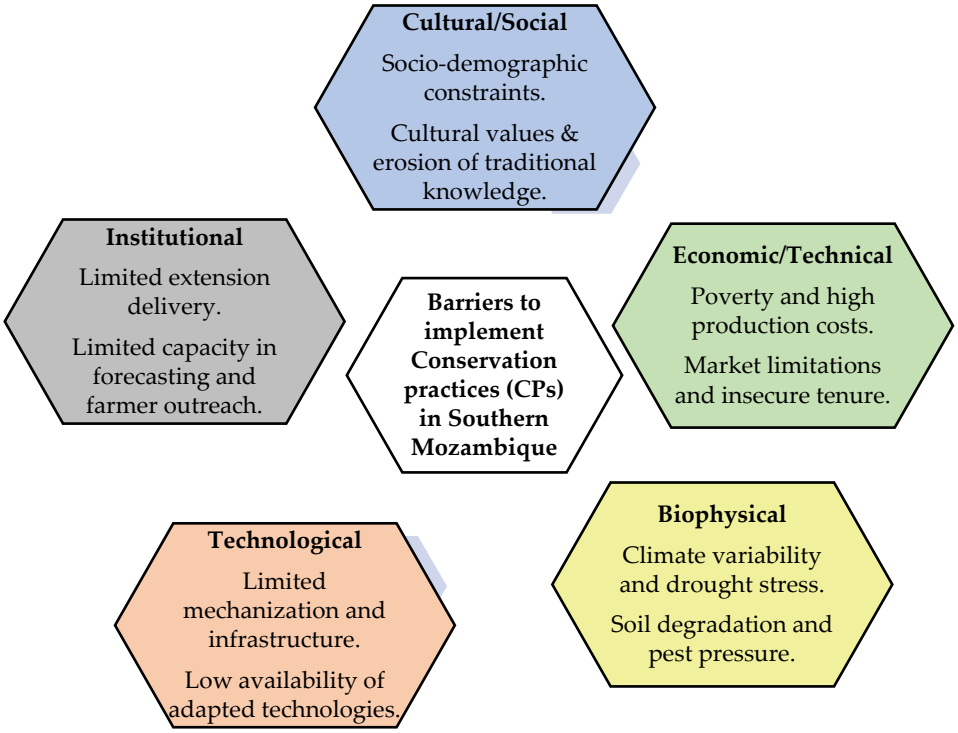

Figure 5. Key barriers and challenges to implement conservation practices (CPs) in southern Mozambique.

Table 10. Hierarchy of barriers and their relative prominence across the evidence base.

Rank	Barrier	Frequency in Evidence	Impact on Adoption	Tractability	Citation
1	Economic	Very high	Very high	Low	[10,13,15,20,33,35,43,48,49,59,60]
2	Institutional	High	High	Medium	
3	Technological	High	High	Medium	
4	Biophysical	Medium	Very high	Low	
5	Social/Cultural	Medium/High	Medium	High	

3.3.1. Economic Constraints

Table 11 summarizes the economic constraints that influence the adoption of CSA in southern Mozambique. High levels of poverty remain a critical limitation, as nearly 68.7% of the population lives on less than USD 1.90 per day, which reduces farmers' capacity to invest in improved technologies [13]. This situation mirrors findings across Africa, where limited access to credit and insurance is consistently identified as a major constraint to CSA adoption [61]. In Mozambique, surveys show that 52% of farmers fail to adopt CSA practices due to a lack of financial capacity to make on-farm investments [26]. These results align with evidence from South Africa, where access to credit significantly raises the likelihood of adoption, with one study reporting that a 1% increase in credit access can increase CSA uptake by 63% [62].

The cost and availability of inputs and equipment also constitute major barriers. Farmers face high prices for seeding equipment such as jab planters [60], while improved seeds, fertilizers, and pesticides remain scarce or unaffordable [59]. Studies from across Sub-Saharan Africa confirm that the high cost and limited accessibility of inputs reduce resilience and increase vulnerability to climate shocks [63]. Technical equipment such as irrigation kits, animal or tractor, powered implements, and Information and Communication Technologies (ICTs) for climate services also remain prohibitively expensive, limiting widespread use [64]. These challenges are compounded by poor infrastructure and limited

market access. In Mozambique, only 20% of roads are paved, constraining both input delivery and surplus marketing [26]. This is consistent with findings from South Africa, where poor infrastructure and fragmented value chains undermine the profitability of CSA interventions [65].

Table 11. Economic constraints to adopt CSA.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Economic	Climate Smart Agriculture (CSA) practices	High levels of poverty (68.7% of the population live below USD 1.90 per day). Limited Access to Agricultural Inputs (e.g., hybrid varieties, fertilizers, etc.). High prices of seeding equipment (e.g., jab planters). Lack of markets for surpluses. Insecure land tenure disincentivizes long-term investments in soil quality. Lack of adequate crop residues for soil cover limits CSA uptake.	[13,33,59,60]

In Mozambique, insecure land tenure exacerbates economic barriers, as farmers are unwilling to invest labour and resources into plots where ownership and use rights remain uncertain [33]. This corresponds to regional evidence that ambiguous tenure discourages long-term investments in CSA, particularly in soil fertility and agroforestry practices, which require extended time horizons to be profitable [64]. On the other hand, in Mozambique, the lack of crop residues to ensure soil cover further limits the technical feasibility, constraining the practical implementation of CSA practices [13].

These economic constraints also highlight the potential role of targeted financial mechanisms in enabling CSA adoption. Although the primary studies reviewed did not evaluate input subsidy schemes, cooperative purchasing models, or tenure-security interventions, broader regional evidence suggests that such mechanisms can reduce liquidity constraints, lower upfront costs of improved seeds and equipment, and increase farmers' willingness to invest in longer-term practices. In contexts of widespread poverty—where 68.7% of Mozambicans live below USD 1.90/day—targeted, well-designed subsidies or group-based procurement systems may be particularly relevant for overcoming short-term affordability barriers. Likewise, strengthening tenure security can incentivize soil-fertility investments that require multi-year planning horizons. However, because none of the reviewed studies empirically assessed these mechanisms, their potential role is discussed here as a policy implication rather than an evidence-derived conclusion.

The economic and institutional barriers identified in this review suggest the need for targeted policy instruments to strengthen the adoption of conservation practices [13,33].

Given that high input costs and liquidity constraints were consistently reported across the included studies, well-designed, time-bound input subsidies, cooperative purchasing schemes, or community-level revolving funds could improve farmers' ability to access the seeds, fertilizers, and equipment required for CSA practices [59]. Moreover, studies like [13,33] pointed to the role of insecure land tenure in discouraging long-term soil and water conservation investments. Strengthening land-rights documentation and expanding tenure security programmes may therefore enhance farmers' willingness to adopt practices whose benefits accrue over multiple seasons.

3.3.2. Institutional

Table 12 summarizes the institutional weaknesses that influence the adoption of CSA in southern Mozambique. The limited capacity of the Mozambican National Meteorological

Institute (INAM) to monitor and disseminate climate information mirrors findings across Africa, where poor institutional frameworks and weak policy support reduce the reliability of climate services for agricultural planning [33,64]. Similarly, government responses that prioritize short-term relief rather than long-term adaptation reflect the institutional inefficiencies observed in South Africa, where fragmented support systems and reactive policy approaches hinder effective CSA implementation [62]. These weaknesses are further reinforced by rigid bureaucratic systems that slow research and adaptation processes, consistent with broader reviews that identify weak institutional arrangements and incoherent policy frameworks as central barriers to CSA adoption [35].

Table 12. Institutional barriers to adopting CSA.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Institutional	Climate Smart Agriculture (CSA) practices	The Mozambican National Meteorological Institute (INAM) is limited in its capacity to adequately monitor, forecast, and communicate weather and climate data. Government responses are often reactive, uncoordinated, and untimely, focusing on relief rather than long-term adaptation. Bureaucratic management systems with rigid logical frameworks hinder evolutionary research processes. Lack of visits by extension agents is a problem for farmers due to logistical issues (e.g., lack of fuel).	[13,33,35]

Another institutional constraint concerns the delivery of extension services. In Mozambique, logistical issues, such as a lack of transport and fuel, prevent extension officers from regularly reaching farmers, reducing opportunities for knowledge transfer and follow-up [13]. Comparable evidence from South Africa shows that while farmers acknowledge the usefulness of extension, the quality of climate-related advice remains poor, with fewer than 2% of smallholders receiving support annually between 2014 and 2017 [62]. Moreover, the lack of coordination among institutions and overlapping mandates generates confusion for farmers when accessing services, echoing findings from regional reviews that emphasize the absence of clear institutional frameworks and the need for integrated governance structures [64]. These institutional deficiencies are not only technical but systemic, highlighting that CSA adoption depends on building coherent, well-coordinated, and adequately resourced institutional environments.

Table 13 summarizes the institutional weaknesses that influence the adoption of traditional practices in southern Mozambique. For traditional and indigenous practices, the table shows that institutional barriers arise mainly from limited scientific research and documentation. This gap prevents the incorporation of local knowledge into formal agricultural policies and advisory programmes [13]. Similar patterns are noted across Sub-Saharan Africa, where CSA interventions often neglect indigenous knowledge, assuming farmers are homogeneous and disregarding diverse cultural practices [65,66]. Such exclusion reduces the legitimacy of external interventions and widens the gap between formal institutions and community-based systems, weakening adoption rates and community ownership of adaptation measures.

Table 13. Institutional barriers to adopting traditional/Indigenous practices.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Institutional	Traditional/Indigenous practices	Limited scientific studies on traditional/indigenous practices	[13]

The erosion of indigenous knowledge systems is also intensified by institutional neglect. Younger generations in Mozambique increasingly rely on modern meteorological services that rarely integrate traditional forecasting, which diminishes confidence in indigenous practices [13]. Across Africa, this dynamic is reinforced by top-down CSA programmes that fail to recognize local knowledge as coequal with scientific expertise, creating resistance and limiting uptake [64,66]. Bridging this divide requires institutional reforms that integrate participatory approaches, systematically document indigenous practices, and embed them into extension and research frameworks. Such efforts would ensure that CSA and traditional strategies complement rather than compete, enhancing resilience at the community level.

3.3.3. Technological Barriers

Table 14 summarizes the technological barriers that influence the adoption of CSA and traditional practices in southern Mozambique. Farmers without appropriate implements cannot execute conservation operations such as minimum tillage, residue retention, and precision planting at the right time [10,49]. Regionally, similar patterns are reported across Sub-Saharan Africa, where the absence of CSA-specific equipment and thin input–machinery supply chains are repeatedly flagged as core technological bottlenecks that depress farm-level adoption [67]. On the other hand, communication barriers compound these issues; low-quality radio/TV/mobile signals and sparse electrification restrict access to seasonal forecasts, early warnings, and agronomic guidance, widening the technological divide between better-connected and remote households [43,49]. Taken together, the Mozambican findings align with regional evidence that technological barriers are less about farmer reluctance and more about missing or ill-adapted tools, weak power/connectivity, and limited research–extension bandwidth to localize technologies at scale [15,33].

Table 14. Technological barriers to adopting CSA.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Technological	Climate Smart Agriculture (CSA) practices	Lack of mechanization. Lack of electricity. Low-quality radio, TV, and mobile signals are structural factors limiting access to these resources.	[10,15,33,43,49]

This systematic review of 23 studies did not identify any technological barriers associated with the adoption of traditional or indigenous practices.

3.3.4. Biophysical Barriers

Table 15 summarizes the biophysical barriers that constrain the adoption of CSA practices in southern Mozambique. These include extreme droughts, high evapotranspiration surpassing rainfall, declining soil fertility, and pest outbreaks that undermine the effectiveness of drought-tolerant varieties, mulching, and other conservation practices [43,59,60]. Comparable, in Ethiopia and Kenya, rainfall variability and recurrent droughts are consistently cited as major drivers of low CSA adoption, while poor soil quality is linked to limited yield gains from conservation practices [61]. A broader review confirms that farm size, distance to plots, access to water, and local topography are decisive biophysical constraints that condition adoption outcomes, as farmers closer to resources or markets are more likely to implement CSA successfully [68,69]. Moreover, agroecological diversity across the region complicates the universal application of CSA technologies, requiring site-specific interventions rather than one-size-fits-all approaches [70].

Table 15. Biophysical barriers to adopting CSA.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Biophysical	Climate Smart Agriculture (CSA) practices	Extreme droughts reduce the performance of drought-tolerant maize varieties High evapotranspiration exceeding rainfall undermines soil moisture retention Soil degradation and declining fertility limit the effectiveness of conservation practices Pest and disease outbreaks aggravated by climatic stress discourage adoption	[10,43,59,60]

Table 16 summarizes the biophysical barriers that constrain the adoption of traditional practices in southern Mozambique. Traditional forecasting systems based on local environmental indicators, such as clouds, winds, or stars, have lost reliability under increasing climatic variability, weakening farmers' confidence in indigenous practices [13].

Table 16. Biophysical barriers.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Biophysical	Traditional/Indigenous practices	Traditional rainfall prediction is losing reliability due to increasing climate variability Environmental indicators (clouds, wind, stars) are no longer consistent predictors of rainfall	[13]

These findings show that biophysical barriers act as transversal constraints, not only cutting across CSA and indigenous practices but also reinforcing economic, institutional, social, and technological barriers. As such, overcoming these barriers requires system-level responses that complement household-level strategies and strengthen the enabling environment for CSA adoption.

3.3.5. Socio-Cultural Barriers

Table 17 summarizes the socio-cultural barriers that influence the adoption of CSA in southern Mozambique. Adoption of CSA technologies in southern Mozambique is highly conditioned by gender and age. Male-headed households benefit from greater access to resources and extension services, while women face socio-cultural restrictions that limit their participation in training and decision-making [48]. In Malawi and Zambia, similar trends were observed, with female-headed households more likely to abandon CSA due to financial constraints and lack of inputs, while widows frequently cited lack of access to information as a primary barrier [71]. Age also plays a role, as older farmers in Mozambique tend to resist new practices, preferring familiar routines [20]. These findings align with evidence from Bushbuckridge, South Africa, where regression models confirmed education as a significant positive predictor of CSA adoption ($\beta = 1.554$, $p = 0.014$), while larger household sizes had a strong negative effect ($\beta = -1.307$, $p = 0.007$) [72]. Across the reviewed studies, uptake patterns were consistently less favourable for female-headed households and older farmers, even though effect sizes and model specifications were not reported in a sufficiently harmonized way to permit a formal comparative meta-analysis by gender or age cohort.

Table 17. Social/cultural barriers to adopting CSA.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Social/Cultural	Climate Smart Agriculture (CSA) practices	Gender Male-headed households have a higher probability of adopting improved technologies due to their social and cultural position and preferential access to information compared to female-headed households. Age Older farmers are less flexible to new ideas and have shorter planning horizons. Others Farming time experience, household size, and farmers' associations also influence adoption. Cultural beliefs directly influence responses to drought, sometimes leading to practices that are not necessarily adaptive or effective in the long term. Farmers' preference for the staple food crop maize leads to monocropping practices. Farmers' preference for landraces over improved varieties is due to local adaptation and low input requirements.	[13,20,33,48,60]

Cultural norms and local perceptions add another layer of complexity. In Mozambique, cultural beliefs surrounding drought responses sometimes encourage maladaptive practices, such as rituals or communal ceremonies, which may reinforce social cohesion but fail to deliver long-term resilience [13,33,60]. More broadly, CSA initiatives across Africa often struggle because they disregard farmers' local knowledge [66]. This mismatch between external interventions and community realities creates resistance, reducing adoption rates. The evidence thus suggests that CSA cannot be successfully scaled unless participatory approaches and context-specific designs are prioritized [73]. Traditional and indigenous practices present both resilience strategies and barriers to CSA adoption. In southern Mozambique, farmers' preference for landraces over improved varieties illustrates this dynamic; landraces are locally adapted and require fewer external inputs, but their use limits the uptake of new CSA technologies [20].

Table 18 summarizes the socio-cultural barriers that influence the adoption of Traditional/Indigenous practices in southern Mozambique. The declining number of elders has eroded the transmission of weather-prediction skills, leaving younger generations with limited familiarity with these methods [20]. This erosion coincides with the increasing dominance of modern meteorological forecasts, which often fail to integrate or validate traditional knowledge, leading to distrust and cultural disconnection [66]. The reviewed studies indicate that the intergenerational decline of Indigenous Knowledge may limit its potential interaction with formal CSA initiatives. However, none of the included studies evaluated the institutional or practical feasibility of such integration.

Moreover, spiritual beliefs that attribute climate events to supernatural forces reduce farmers' perception of their adaptive capacity, discouraging investment in proactive adaptation strategies [13]. These findings align with broader African evidence, where the neglect of local knowledge and cultural systems in CSA design is identified as a major obstacle to adoption [66].

In general, across the included studies, gender and age emerged as important determinants of adoption behaviour. Male-headed households consistently exhibited higher uptake of CSA practices, largely due to greater access to land, inputs, credit, and extension

services. Female-headed households more frequently faced constraints related to labour burdens, limited access to agronomic information, and socio-cultural restrictions on participation in training. Age differences were also notable: older farmers demonstrated lower willingness to adopt CSA technologies but maintained stronger reliance on indigenous knowledge systems, whereas younger farmers were more inclined to adopt modern practices yet had weaker familiarity with traditional forecasting and resource-management methods. Although reported across multiple studies, these disparities were measured using heterogeneous indicators, preventing quantitative comparison. Nonetheless, the synthesis underscores that gender- and age-responsive approaches are essential for equitable and effective adoption of conservation practices.

Table 18. Social/cultural barriers to adopting traditional/Indigenous practices.

Barrier Type	Conservation Practice	Barrier Detail	Citation
Social/Cultural	Traditional/Indigenous practices	The reduced number of elders in the community is causing a decline in traditional practices. Younger generations have reduced knowledge of traditional prediction methods compared to elders. Lack of documentation of traditional practices. Beliefs that supernatural forces control the weather reduce farmers' perception of their own adaptive capacity	[13]

4. Limitations of the Literature

Based on the systematic review of 23 studies, there is a degree of geographic imbalance, while Gaza province is well represented, Inhambane and Maputo provinces remain understudied. This limits external validity across heterogeneous agroecological zones. This imbalance also prevented a robust stratified analysis by province, and the findings should therefore be interpreted as indicative for southern Mozambique as a whole rather than fully representative of each specific agroecological zone. For this reason, province-level comparisons could not be conducted, and the conclusions should not be interpreted as agroecologically uniform. The overrepresentation of Gaza (43% of all included studies) likely shapes the overall results, while evidence from Inhambane and parts of Maputo remains limited and insufficient for region-specific inferences.

And on the other hand, most of the available evidence derives from short-term trials, which cannot capture a long-term system response, yield trajectories, or soil fertility dynamics under recurrent droughts. For most practices, study durations were $\leq$3–5 years, and the review did not identify any trials exceeding five years; as such, our conclusions primarily reflect short- to medium-term responses rather than long-term system dynamics. Because study durations were inconsistently reported and no study followed farmers beyond five years, the evidence base does not allow a systematic classification of short-term ($\leq$2 years) versus long-term ($\geq$5 years) outcomes. Therefore, all reported effectiveness measures should be interpreted as short- to medium-term effects, which may differ substantially from long-term system trajectories.

5. Knowledge Gaps and Future Research Directions

Future research should adopt a prioritized and hypothesis-driven agenda to address the main gaps identified in this review. First, experimental studies should test the hypothesis that integrated CSA packages (e.g., mulching combined with drought-tolerant varieties) generate more stable yields under drought conditions than single-practice adoption. This could be assessed through randomized controlled trials implemented across multiple agroe-

cological zones, with sample sizes of approximately 200–400 households per zone over at least three agricultural seasons.

Second, mixed-methods research should examine whether co-designed participatory trials that integrate indigenous knowledge with scientific climate information improve adoption rates and decision-making accuracy. Participatory action research combining household surveys, focus groups, and on-farm trials would be suitable, supported by panel data to track adoption trajectories over time.

Third, future studies should test the hypothesis that institutional coordination among meteorological services, extension systems, and research institutions enhances the usability of climate information and accelerates CSA uptake. This could be evaluated using quasi-experimental designs comparing districts with and without coordinated advisory models (e.g., decentralized extension hubs or digital climate advisory services), over a 2–4 year implementation period.

Finally, research should prioritize the evaluation of policy and financing interventions, such as targeted input subsidies, credit schemes, and land-tenure security measures, using experimental or quasi-experimental approaches to assess their effectiveness in relaxing liquidity constraints, particularly among the poorest smallholder households.

6. Conclusions

This systematic review highlights that smallholder farmers in southern Mozambique rely on a diverse set of conservation practices, encompassing both Climate-Smart Agriculture (CSA) techniques and Indigenous Knowledge (IK), to adapt to climate change-induced and variability-induced droughts. These practices, such as minimum tillage, mulching, intercropping, crop diversification, drought-tolerant varieties, and traditional forecasting methods, contribute to improved soil and water management, enhanced yields, and strengthen resilience in rainfed farming systems. However, adoption remains uneven across provinces and practices. While some approaches, particularly those rooted in indigenous traditions, demonstrate relatively high uptake, many CSA techniques face low adoption due to persistent barriers. Socio-economic constraints (limited access to credit, inputs, and markets), institutional weaknesses (insufficient extension services and policy support), cultural dynamics (gender roles, decision-making), and technological and biophysical gaps collectively limit the broader scaling of these practices. The review also reveals significant knowledge gaps. Empirical evidence on the long-term effectiveness of conservation practices remains scarce, with most studies being short-term and spatially concentrated. Integration of CSA and IK, though widely advocated, has rarely been systematically documented or evaluated. In conclusion, building climate-resilient smallholder farming systems in southern Mozambique requires more than the promotion of individual practices. It calls for: (i) integrated strategies that combine CSA techniques with indigenous knowledge; (ii) policy interventions that strengthen extension services, credit access, and institutional coordination; and (iii) targeted research that uses longitudinal, participatory, and comparative approaches to assess practice effectiveness and farmer adoption dynamics. Addressing these gaps will not only enhance the adaptive capacity of smallholder farmers but also contribute to sustainable livelihoods and food security under a changing climate.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su18052525/s1, Supplementary File S1: MMAT quality appraisal for all included studies; Supplementary File S2: Data extraction file containing all information extracted from the 23 studies and Supplementary File S3: PRISMA 2020 Checklist. References [74–78] are cited in the supplementary materials.

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Abbreviations

The following abbreviations are used in this manuscript:

CPs	Conservation Practices
CSA	Climate-Smart Agriculture
SLF	Livelihoods Framework
MT	Minimum Tillage
CT	Conventional Tillage
IK	Indigenous Knowledge
FGD	Focus Group Discussion
FAO	Food and Agriculture Organization of the United Nations
WFP	World Food Programme
IFAD	International Fund for Agricultural Development

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