

A Systematic Review of the Impact of Climate Change Adaptation Strategies on Food Security in Africa

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ABSTRACT

Climate variability embedded in anthropogenic activities and natural factors adversely impacts the growing Seven hundred and seventy-seven million food insecure in Africa. In addition to climate change, food insecurity is exacerbated by population pressure, limited access to credit facilities, and dependence on rainfed agriculture. Efforts in Africa to synthesize reports on sustainable CCAS in ameliorating climate change and enhancing food security are limited. In view of the preceding, this systematic review, in line with the PRISMA 2020 checklist, was undertaken to keep farmers abreast with sustainable adaption strategies by reviewing 30 reports across 24 journals from the Mendeley and Scopus databases covering 13 years. Initiating the eligibility criteria of open access journal, the English language, reports on CCAS in Africa excluded 1,714 reports. Further reviews of the abstract and full text excluded 194 reports. The result revealed that CCAS (notably crop diversification, mixed cropping, rainfall prediction, planting drought-resistant crops, and sales of crops and livestock) impacts positively on food security in Africa. However, the preceding barriers militate the SDG goal of zero hunger and extreme poverty. To achieve a win-win scenario of sustainable environment and food security, farmers need support from African governments and multinational organizations on innovative CCAS strategies such as drip and sustainable irrigation, water recycling, rainwater harvesting, afforestation, extension services, and green farming. Limiting the scope of literature to open-access journals and time frame excluded important information on smart CCAS covered in other literature not considered in the study, increasing the bias in the study.

Keywords: Adaptation Strategies; Climate Change; Food Security; Sustainable Environment; Systematic Review.

1. Introduction

Sufficient literature exists on the impact of climate change adaptation strategies on food security in Africa [1-3, 11, 20]; however, the emphasis on system reviews in line with the 2020 PRISMA statement [8] to keep farmers in Africa abreast with global best practices in enhancing food security is limited. The efforts made by [1, 6, 24] to address this limitation are insufficient, as these studies were based on traditional and realist reviews with a scope below 2023. Importantly, systematic reviews “adhere closely to a set of scientific methods that explicitly aim to limit systematic error (bias), mainly by attempting to identify, appraise and synthesize all relevant studies (of whatever design) in order to answer a particular question (or set of questions) p.9 [9].”

In view of the foregoing, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 statement [8] was used to review 30 works of literature on the impact of climate change adaptation strategies on food security in Africa, spanning from 2010 to 2023. Also, while existing studies examined climate change adaptation strategies and food security nexus with inadequate emphasis on systematic reviews, global best practices on the blue economy, rainwater harvesting, smart, and sustainable water management in line with drip irrigation and desalination method to convert 40 million cubic wastewater and the treatment of an estimated 35% of Israel’s wastewater [36] are inadequately furnished [5, 9, 16, 20].

This necessitated the review to infer the impact of the existing climate change adaptation strategies on food security in Africa in order to advance policy recommendations on emerging and innovative global best practices in sustainable food production in the face of climate change.

Climate change adaptation strategy largely depends on awareness and perception of climate variability [4, 5, 15, 22]. Averting disaster requires that farmers are first and foremost aware of the prevailing phenomena and the cost of inadequate measures in mitigating the shocks, notably climate change. Climate change is “any change in climate over time which arises as a result of both human activity and natural variability” [7]. It is exacerbated by increased Greenhouse Gas Emissions (GHGs) induced by the burning of fossil fuels, population pressure, and anthropogenic activities in the forest frontiers [5, 6, 24, 27]. As a result, climate change in a ripple effect culminated in intermittent and erratic rainfall, flood, drought, changing pests and weeds with high tolerance to pesticides and weedicides, and a projected 50% decline in agricultural yields by 2020 in Africa [10, 34]. In addition to the decline in crop yields, smallholder farmers in Africa who depend on rain-fed agriculture with limited credit facilities and crude adaptive capacity are constrained by these barriers to ameliorate the increasing impact of climate change [4, 5, 14].

Climate change impacts adversely on the four components of food security: food availability, food accessibility, food utilization, and food systems stability, which in turn culminates adversely on human health, livelihood assets, food production and distribution channels, and changing purchasing power with market flows [1]. The impact is more prevalent in Africa than in advanced nations owing to farmers’ growing inability to mitigate climate shocks. In semi-arid economies, climate change-induced drought adversely impacts the food security of pastoral communities, resulting from poor milk and meat yields, morbidity of livestock, and poor revenue yields [12]. Similarly, climate fluctuations in the Horn of Africa (HoA) have a detrimental effect on the well-being and food stability of pastoral communities [12, 29], farming households [22, 25, 27], and an adverse impact on the Gross Domestic Product (GDP). Evidence in [17, 18) revealed that climate change-induced low crop yields among subsistent farmers in South Africa necessitated climate change awareness and the growing indigenous and innovative strategies to improve food security. Other studies [4, 28] also established an inverse relationship between climate variability and food security in Africa, which calls for effective adaptation strategies to intensify food security in Africa. More also, [28] avails that the increasing negative effect of climate variability on maize productivity in Mali calls for policy measures to enhance farmers' adaptive capacity, given that maize is targeted among the cereal crops in the Agricultural Development Policy (PDA) to address poverty and insecurity as agriculture constituted the main source of livelihood, contributing a 33% to the GDP of the country. Thus, it is most important to intensify climate change awareness and the adaptive capacity of farmers to ameliorate the increasing negative effect of climate variability on Africa's economies and food security.

The interaction between climate change awareness and adaptation significantly impacts food security [15, 17]. Climate Change Adaptation Strategy (CCAS) is the process of employing intelligent measures to both mitigate and adapt to the impacts of climate shocks. This not only helps protect the environment but also enhances food security. Food security which “exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” p. 281 [FAO cited in 3]. It is the production of food, trading of food, the nutritional value of food, and also how individuals and countries maintain access to food over time periods in the face of challenges [3]. Farmers’ growing awareness of climate variability and increasing indigenous and innovative strategies to ameliorate the impact on food security have engendered empirical inquiries establishing nexus and positive correlations in Africa [12-20]. In Niger, changing

farmers' adaptive capacities such as crop and income diversification and changing planting times to climate variability led to increased household income by 7721.526 FCFA and food security of households adopting climate change adaptation strategies by 7% to 9% than households devoid of climate change adaptation strategies. Similarly, [20] showed that about 72% of rice farmers in Ogun State, Nigeria, that adopted climate change adaptation strategies were food secure, while in contrast, 65.55% of rice farmers without adaptation strategies were food insecure. This is validated by empirical inquiries in Ethiopia of a significant positive effect of climate change adaptation strategies on the food security of enset farmers [11] and pastoral communities [29].

Despite the growing positive correlations between climate change adaptation strategies and food security, population pressure has posed a growing setback as an intensified global food production of 5% of the current rate is required to meet global food needs by 2050. In addition to the growing adverse impact of climate variability and population boom on food security, an estimated 80% of the poor in Sub-Saharan Africa (SSA) depend on agricultural activities characterized by inadequate access to credit facilities, low adaptive capacity to climate change, inadequate techniques/crude methods of water harvesting, and inadequate management of blue economy to enhance food security [1]. In furtherance to the preceding, a report in the Mogalakwena community of the Limpopo Province, South Africa, submitted that smallholder farmers are aware of the increasing climate variability and thus employed adaptive strategies such as improved seed, fertilizer application and changing planting dates to improve agricultural produce but are, however, constrained by inadequate access to credit facilities, market, irrigation, information about climate change, and extension services [17]. Against these backdrops, a small variation in climate change engenders further the seven hundred and seventy-seven million food insecure population in Africa [39], which calls for innovative adaptation techniques such as water harvesting, blue economy, and green farming to enhance food security in the face of the changing climate in Africa. The inability to engage in sustainable agricultural practices to meet the food needs of the seven hundred and seventy-seven million food-insecure Africans will undermine the Sustainable Development Goals (SDGs) of mitigating hunger and extreme poverty [28, 39]. In view of the growing relevance of CCAS in enhancing food security, the review employed the Population, Intervention, Control, and Outcome (PICO) approach to address the succeeding research question.

❖ 2. Research Questions and Objectives

PICO aids in advancing research questions embedded in a study's Population, Intervention, Control, and Outcome. The review, which, however, is qualitative as it attempts to describe existing CCAS in enhancing food security in Africa, excluded Meta-Analysis. As such, farmers constituted the population, adaptation strategy formed the intervention, and food security made up the outcome of the study. The review thus attempts to address the question: How have farmers' adaptation strategies in the face of climate change impacted food security in Africa? The remainder of the study is divided into methods, results, conclusions, recommendations, and other information.

❖ 3. Methods

Following the PRISMA 2020 checklist [8], a search term with inclusion and exclusion criteria was developed to retrieve relevant reports (30) from Mendeley and Scopus across 24 journals. Six hundred and twenty-three (623)

reports were retrieved from the search on the Mendeley database conducted on 17th September 2023 with the search term: climate change adaptation strategies food security Africa. Including the inclusion criteria such as open-access journal for easy retrieval, and scope spanning from 2010 to 2023 yielded 81 reports. Further screening on titles limited the report on Mendeley to 77. The search terms were inserted on Scopus on 23rd September 2023 to retrieve relevant literature for the review. However, the Boolean operator ‘AND’ was included by Scopus, which yielded 1315 reports. The search was limited to Africa, journals, and the English language to yield 147 works of literature on climate change adaptation strategies on food security in Africa from Scopus. Specifically, [40-41] with the most citations on Mendeley, 1,789 and 742 citations, respectively, were removed for falling outside the scope of the review.

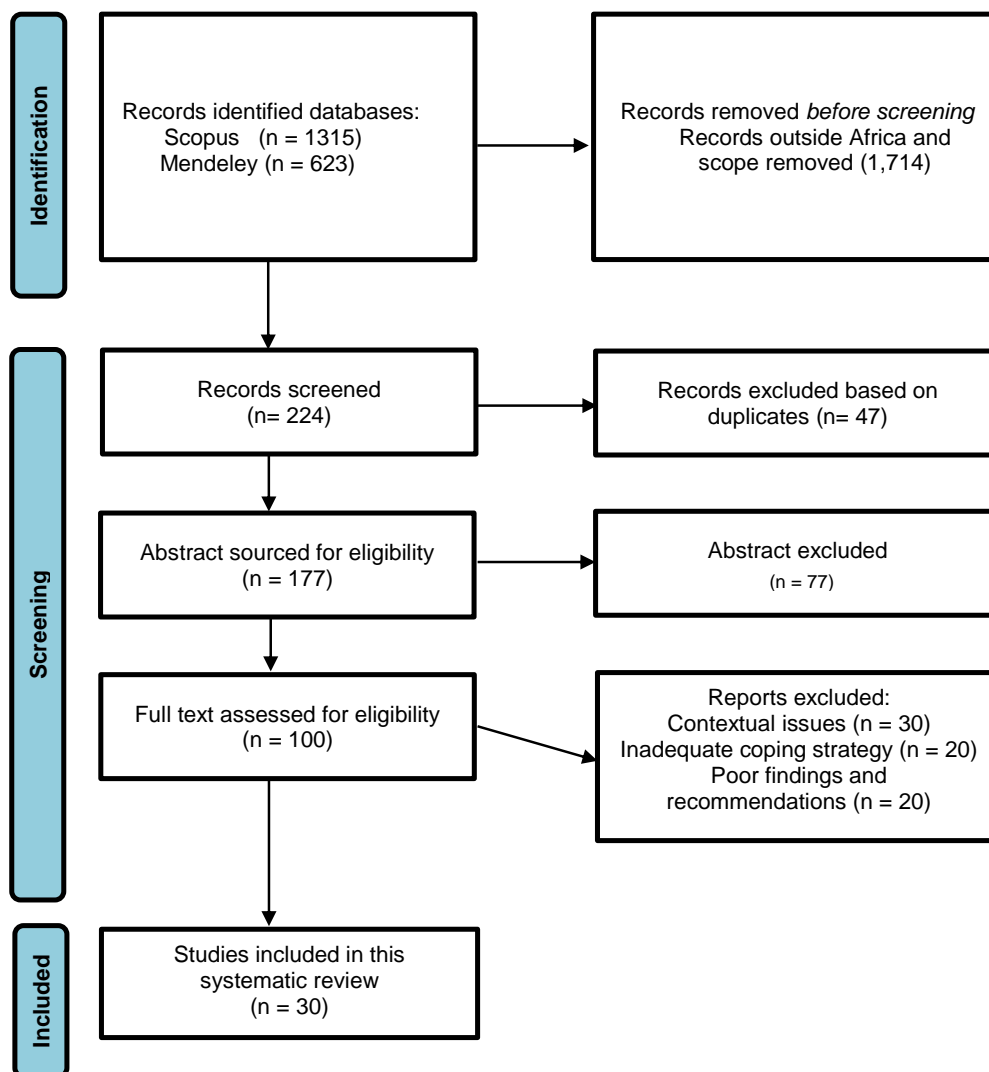


Figure 1. Flow chart of search strategy

To enhance efficiency in the screening process by both authors, the 224 reports from Scopus and Mendeley with title, abstract, keywords, the name of journals, author, and author’s affiliation were exported to Excel Spread Sheet to sort duplicates and relevant works for the review. A total of 47 duplicates were removed from the Excel spreadsheet, leaving 177 reports for further screening. A detailed review of the abstract excluded 77 reports. Further review of the full text emphasizing contexts such as climate change, adaptation strategies, food security,

methodology, findings, and recommendations excluded 70 reports, leaving 30 eligible reports for the review. The 30 eligible reports retrieved from Scopus and Mendeley databases were augmented with gray literature [7-9, 34-41] sourced manually to provide conceptual clarification and relevant statistical data for the review. Both authors used content analysis to examine the Climate Change Adaptation Strategies (CCAS) employed in the studies while conflicting issues were deliberated until a consensus was reached. The search strategy is represented in the flowchart in Figure 1.

The eligibility criteria involve inclusion and exclusion criteria, which rely on the PICO approach, unavailable full text, abstract-only papers, duplicates, and inaccessible papers [38]. Similarly, [9] avails that inclusion or exclusion criteria related to the population, outcome, methodology, methods, design, and context formed a study's characteristics. The inclusion criteria in the study encompass literature on climate change, adaptation strategies, food security, and Africa, open-access journal articles for easy retrieval of reports between 2010 and 2023, and publication in English. The study excluded literature with abstracts only, reports outside Africa, periodicals, and textbooks.

4. Results

Entering the search terms (climate change adaptation strategies food security Africa, with a Boolean operator 'AND' included on Scopus) yielded 1,938 results (623 from Mendeley and 1,315 from Scopus) for the review. Initiating a scope 2010-2023, Africa, the English language, and journals yielded 234 reports exported to an Excel spreadsheet for further screening. A total of 47 duplicates were removed, and a review of the abstracts excluded 70 reports. A detailed assessment of the full text, emphasizing context, methods, adaptation strategies, findings, and recommendations, excluded 100 reports, leaving 30 eligible literature for the review.

From the result, 33.3% (16.7% each) of the research was conducted in South Africa and Ethiopia, 30% (10% each) was carried out in Zimbabwe, Kenya, and Nigeria, 26.7% (6.7% each) was conducted in SSA, Ghana, Africa, and Uganda, while the remaining 10% (3.3% each) was conducted in Botswana, Niger, and Mali. The reports cut across 24 journals, with Sustainability accounting for 10%, 26.7% (6.7% each) accrues to Heliyon, Climate Change, Cogent Food and Agriculture, and Climate Risk Management, and the significant 63.3% (3.3% each) accrues to the remaining 19 journals in the study. While [18] had the most citations (88), 26.7% of the reports had zero citations, 30% had 1-5 citations, 3% had 6-10 citations, and 23.3 had more than 20 citations. A significant 46.7% of the reports had two related keywords, 26.7% had three related keywords, and the remaining 16.7% had no related keywords. While a significant 96.7% of the reports revealed different climate change adaptation strategies used by farmers in Africa to enhance food security, [19] established no adaptation strategies in their reports.

The result of the review showed further that climate change adaptation research in Africa is still in the development stage and dominated by a few countries and regions, as Ethiopia and South Africa accounted for 33.3% of the research in the study. This is in consonance with a review by [24], which showed that Climate Smart Agriculture research in Africa is dominated by Kenya, South Africa, and Mali, with 20, 12, and 11 publications, respectively, and are skewed towards adaption strategies in the production of ze-maize rather than an inclusive framework in enhancing the wellbeing and food security of smallholder farmers and the populace. This is validated in [28], which

examined climate change adaptation strategies, productivity, and food security in Southern Mali by showing a positive correlation between the production of short-duration maize and the use of organic fertilizers as CCAS with maize productivity and food security in Southern Mali. Similarly [30] showed that CCAS such as low tillage, crop rotation, income diversification, and improved land management, among others, are used by maize farmers in Ngaka Modiri Molema, Southern Province, South Africa, to improve maize productivity and food security of smallholder farmers in the province. Invalidating the assertion on ze-maize productivity, our review of adaptation strategies employed by farmers to enhance food security in Africa cut across crop varieties, notably cocoyam in Zimbabwe [23], potato and enset production in Ethiopia [11, 27], rice farmers in Nigeria [20], and Carmel management among the Borana pastoralist in Southern Ethiopia [29].

Sufficient climate change adaptation research in enhancing food security in Africa is skewed towards small-scale rainfed agriculture [4, 13, 14, 26] with mixed cropping/crop diversification, changing planting dates, and cultivation of climate-resistant crops as the leading CCAS employed by smallholder farmers to enhance food security. Specifically, [3, 14, 18] revealed mixed cropping as the most applicable CCAS in enhancing food security. In addition, among smallholder farmers in Tillaberi, Dosso, Maradi, and Zinder, Niger, crop diversification, income diversification, and changing planting date were the most adopted CCAS to the neglect of innovative and environmentally friendly strategies such as agroforestry, irrigation and water conservation, and improved agronomic practices [10]. While significant portions of the reports [3-6, 10, 12, 14, 16, 22-24, 33] mentioned sustainable and environmentally friendly methods such as tree planting, RWH, and soil moisture enhancement as CCAS employed by farmers in Africa to enhance food security, they were minimally employed by smallholder farmers in Africa to enhance food security. As evident in [3], tree planting to conserve soil moisture accounted for an insignificant 2% of the CCAS, while crop diversification, mixed cropping, and climate change-resistant crop varieties accounted for 98.6%, 100%, and 98.6%, respectively, as strategies used by farmers to enhance food security in Aloga, Volta Region of Ghana. However, this drawback of overdependence on crude and unsustainable CCAS was addressed in [6], which showed efficient use of water in agricultural activities, treatment of waste and saline water to reduce over-dependence on freshwater, crop diversification, and sustainable irrigation to minimize water withdrawal as smart-climate change strategies. Although the review provided some valuable strategies, it fell short in demonstrating their actual implementation and effectiveness in Africa for boosting agricultural productivity amidst climate variability.

Most studies [13-15, 22] in the review over-emphasized the determinants and barriers to smallholder farmers' climate change adaptation strategies in enhancing food security by using logistic regression to infer the relationships [5, 10, 12-16, 19-20, 22, 25, 28]. While logistic regression is important in examining the relationship between explanatory variables and a dichotomous outcome variable, it violates the normality assumption. However, factor analysis, a more efficient method of reducing complexity that also upholds the assumption of normality to correct inaccurate estimates of factor structure [35], was ignored in CCAS research in Africa. Specifically, [28] used multinomial logistic regression to determine the factors influencing climate change adaptation strategies of maize farmers in Southern Mali as represented by the study's first objective rather than employing factor analysis to reduce complexity in the report.

5. Discussions

The ever-growing population and the impact of human activities on the environment pose a significant challenge to Africa. Not only does this challenge impact the 777 million people who suffer from food insecurity, but it also poses a threat to biodiversity and the overall health of the environment [39]. To mitigate the increasing negative impact of climate change, it is crucial to enhance farmers' understanding and awareness of the need to intensify adaptation strategies. This is particularly important in Africa, which is highly vulnerable to climate variability and where the enhancement of food security is of utmost importance. Thus, climate change adaptation strategies are crucial for enhancing food security. However, CCAS is a necessary but insufficient approach to enhance food security and a sustainable environment. Implementing unsustainable adaptation strategies that involve expanding agricultural activities and excessive water withdrawal through irrigation can lead to even more catastrophic consequences. Evidence from the review showed an increasing application of unsustainable adaptation strategies as a result of smallholder farmers' perception of climate variability and the growing barriers to innovative CCAS, which have intensified empirical inquiries [4-5, 15, 22] in the field, but however literature on smart and sustainable adaptation strategy is scanty [6].

In the KwaZulu Province of South Africa, climate awareness and perception by forest-dependent communities in Inanda yielded notable adaptation strategies such as engaging or opting for an alternative source of livelihood, sourcing forest products from other forests, and the use of electricity and paraffin, among others. However, evidence of sustainable forest management through regeneration and agroforestry to improve the livelihood of forest-dependent communities and a sustainable environment were absent [15]. This was partly addressed in [22], where sustainable and environmentally friendly adaptation strategies, such as tree planting with soil and water conservation, were employed by smallholder farmers in Eastern Tigray, Ethiopia, to mitigate the adverse impact of climate change. Similarly, [23] using a suitability model incorporated the importance of agroforestry, water conservation, and soil management as effective adaptation strategies in the production of a neglected orphan crop, cocoyam (*Colocasia esculenta* (L)), in Zimbabwe. The report stressed the importance of cocoa yam production in marginal benefits (higher out to fewer land area, fewer labor, and higher revenue) and increased source of balanced diet among diabetic patients, children, and the aged. As a result, shifting or diversifying smallholder farmers' means of livelihood to the production of this neglected crop (cocoyam) will ameliorate both the increasing food insecurity among smallholder farmers and the adverse impact of climate change on the environment.

Similarly, most studies established a growing adverse effect of climate change on rainfed agriculture in Africa [5, 10]. However, leading rainfed agricultural models such as Decision Support System for Agro technology Transfer (DSSAT), Erosion Productivity Impact Calculator (EPIC), Crop Environment Resource Synthesis (CERES) model, the Agricultural Production Systems Simulator (APSIM), CROPWAT, Soil Moisture Accounting Crop-Specific (SMACS) model, and the CLICROP model, highlighted in [4] were not explored to examine their impacts on rainfed agriculture under increasing climate stress in Africa. In addendum, smart and innovative adaptive strategies in agroforestry, fishery, commercial farming, poultry, and dairy value chains are limited in existing climate change adaptation research in Africa. These drawbacks in sustainable adaptation strategies in line

with global best practices in the review could be addressed in toll-access journals, publications ex-ante 2010, textbooks, and periodicals not covered in this study, which increases the bias in the study.

Besides the previously mentioned bias, the review, which highlighted important criteria such as keywords, adaptation strategies, and citations to determine eligibility, revealed that 16.7% of the reports lacked relevant keywords, 26.7% had no citations, and 3.33% did not have comprehensive CCAS to improve food security in Africa amid climate change [19]

6. Conclusions

The findings indicated that smallholder farmers in Africa are susceptible to climate variability owing to overdependence on rainfed agriculture, high input and production costs, poor policy implementation, population pressure, inadequate access to credit facilities, extension services, and information on climate variability to enhance food security [5, 14, 18]. These, in turn, affect their capacity to adopt smart and innovative climate change adaptation strategies to enhance sustainable livelihood and food security in the face of increasing climate variability. Faced with the growing bottleneck, small-scale farmers in Africa resort to crude, indigenous, and small-scale adaptation strategies such as rain prediction, mixed cropping, livelihood diversification, enset production, migration, and destocking, among others to enhance subsistence living and food security [2, 11-12].

After the review, emphasis on research design and theoretical framework, which serve as guides and blueprints in research, is lacking in the study. Only [31] clearly showed these methods in carrying out their research. The undue relevance of smallholder rainfed agriculture limited our horizon on the CCAS strategies employed by commercial farming to enhance food security in Africa. Further empirical investigation should incorporate this shortcoming by accessing a wider scope and works of literature as the review is limited to open access journals and scope spanning 2010 to 2023.

While this study has deepened knowledge of climate change, adaptation strategy, and food security, which immensely benefits farmers, policymakers, academia, and Non-Governmental Organizations (NGOs), there is a need to mitigate the established shortcomings impeding sustainable food security in Africa. As a result, the review advanced the following policy recommendations. Climate change awareness is a necessary but insufficient condition to ameliorate climate change adverse impact on food security. Sustainable and innovative CCAS is a sufficient condition in mitigating climate change impact on the environment while improving food security concurrently.

As such, sustainable agricultural practices such as drip and sustainable irrigation to curtail water withdrawal, water recycling as evident in Israel, rainwater harvesting to enhance soil moisture and curtail runoff erosion, afforestation with taungya system, extension services, and green farming should be intensified by the government and advocacies group to achieve a win-win situation of sustainable environment and food security. These methods, which are, however, capital-intensive, calls for institutional support in advancing credit facilities, inputs, and raw materials to farmers by African governments and multinational organization in order to achieve the SGDs of mitigating extreme poverty and hunger.

Declarations

Source of Funding

This study has not received any funds from any organization.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

Both the authors took part in literature review, research, and manuscript writing equally.

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APPENDIX I: Study Characteristics

SN	Keywords	Journal	Citations	Methodology	Country	Adaptation Strategies	Findings and Recommendations
1	Adaptation, climate change, food security.	Agricultural Socio-Economics Journal.	0	Secondary data, Realist review method.	Sub-Saharan Africa (SSA)	The initial strategies were diet alteration, borrowing from kin, sales of production assets, and migration. However, the growing adverse effect of climate change resulted in the intensification and extensification of agricultural activities as Climate Change Adaptation Strategies (CCAS) to enhance food availability, livelihood diversification as an accessibility strategy, and utilization of neglected crops as CCAS to enhance food utilization in SSA.	The review showed a consistent prediction of production decrease, land degradation, high market prices, increased malnutrition, and increased negative impact on livelihoods. As a result, food availability, accessibility, and utilization strategies were employed by farmers in SSA to enhance productivity and food security. The study recommends that mechanisms in mitigating climate change adverse effects be strengthened to enhance livelihoods and food security in SSA.

2	Climate change adaptation, food security.	Asian and African Studies	1	Primary data collected with questionnaire, interview, Focus Group Discussion (FGD), and observation from 225 participants was used in the report. The method used was Participatory Climate Change Asset Adaptation Appraisal (PCCAA)	Gokwe South District, Zimbabwe.	Asset adaptation, migration, mixed cropping, rainmaking,	Asset mix and availability to farmers is important in ensuring household food security in rural communities in Zimbabwe, however, corruption, inadequate funding, and unfair distribution of presidential input due to political divide impede farmers' capacity to enhance food security in the face of climate variability. It recommends improvement in technology, removal of institutional barriers, and research to mitigate the climate change knowledge gap.
3	Adaptation strategies, climate change.		0	Descriptive research design. Primary data was sourced from farmers and analyzed with descriptive statistics.	Aloga, Volta Region of Ghana	Crop diversification, planting of climate-resistant crops, intercropping, manure, tree planting.	The study revealed that being aware of the adverse effects of climate change, farmers in Aloga employed CCAS such as crop-resistant varieties, crop diversification, mixed cropping, changing cropping calendar, and irrigation to enhance productivity and food security. Thus, it recommends more awareness of the importance of CCAS to farmers in Aloga to mitigate the adverse effect of climate change while improving productivity and food security.
4	Adaptation, climate change	Africa America Journal of Climate Change	0	Secondary data. General Circulation Models (GCMs), MAGICC/SCENGEN	Pandamatenga Plains, Botswana.	Rainwater harvesting, soil moisture enhancement.	The study revealed that in almost 50 percent of the years considered during the simulation period of 2001-2050, the yield reductions are above 50 percent, and in general, sorghum appears to exhibit lower reduction compared to maize, followed by sunflower.
5	Adaptation, climate change	Water and Climate Change	2	Primary data was sourced from 120 farmers in the study via questionnaires and Focused Group Discussions. Secondary data on rainfall and temperature were collected also for the study. The elicited data was analyzed by descriptive statistics, Mann-Kendal trend, Sen's slope estimator, and Multinomial Logit Regression.	Olifants Catchment, South Africa	Notable strategies are improved seeds, fertilizer application, and changing planting dates. Others are the application of pesticides/herbicides, mixed cropping, mulching, adoption of rainwater harvest, irrigation, and planting of trees	The study revealed that most farmers who have perceived the adverse effect of climate change employed adaptation strategies to enhance food security, however, growing bottlenecks such as inadequate access to credit facilities, shortfall in extension services, lack of climate information, market and farm inputs impede farmers ability to adapt to climate variability. It recommends that the government provide smallholder farmers with flexible and affordable credit facilities in order to embark on a more efficient adaptation response to climate change
6	Food security	Agricultural Sciences	0	Review	Africa	Efficient use of water in agricultural activities, waste, and saline water treatment to reduce over-dependence on freshwater, crop diversification,	The review showed efficient water management and utilization as necessary adaptation measures in enhancing agricultural activities, it recommends bold measures such as efficient water harvesting be taken

						sustainable irrigation to minimize water withdrawal, and changing planting dates.	against climate change to curtail depletion of groundwater resources through escalation of evaporation and change of precipitation.
7	None	Heliyon	68	Primary data was sourced from 150 households in the communities via interviews, FGD, and questionnaires. The study used ethnography design and employed content analysis and descriptive statistics to analyze the responses.	Gowrie Kunkua and Soe Kabre communities of the Savanna Agro-Ecological Zone, Northern Ghana	Off-farm strategies are selling household assets, migration of households, decreasing food consumption/changing diets, while on-farm strategies include changing planting dates, use of drought tolerant crop varieties, and soil conservation	The result showed that smallholder farmers use various coping, on-farm, and off-farm adaptation strategies to ameliorate the negative impacts of climate and ecological changes on their livelihood. There is a need to intensify information sharing among smallholder farmers and relevant institutions to ameliorate the adverse effect of climate variability on smallholder farmers.
8	Climate change, household food security.	International Journal Agricultural Sustainability	24	Both primary and secondary data were utilized for the study.	Zimbabwe	Cultivation of Dambos (seasonal wetlands)	The results showed cultivation of dambos as an effective adaptive strategy to climate variability as yields from cultivation of Dambos average 2–3 t ha ⁻¹ than upland cultivation where yields are less than 1 t ha ⁻¹ . It recommends the need for research into a sustainable use of Dambos to mitigate land degradation.
9	None	Frontiers in Climate	0	Primary data from 202 households was retrieved and analyzed with Analysis of Variance (ANOVA). A field experiment on SWRT was also conducted.	Makueni Country, South-east Kenya.	Early planting, decline in cultivated area, and water harvesting.	The field experiment using Sub-surface Water Retention Technology (SWRT) showed a 50, 70, 150, and 170% increase in maize grain yield, cob numbers, cob weight, and maize Stover biomass, respectively, as against the control group without SWRT. It recommends the need for synergy among stakeholders to mitigate the adverse effects of climate variability.
10	Adaptation strategies and climate change.	Sustainability	9	Questionnaires and interviews were used to elicit responses from 1,783 farm households. Logit regression and Matching techniques were employed to analyze the responses.	Four regions (Tillaberi, Dosso, Maradi, and Zinder) in Niger	Climate-resilient crop varieties, improved agronomic practices, irrigation and water conservation practices, crop diversification, income diversification, and agroforestry.	The result from matching techniques showed a significant positive impact of adaptation strategies on household income and food security as farmers employing CCAS have higher tendencies of increasing household income by 7721.526 FCFA and food security by 7% to 9% than households with no CCAS. It recommends advocacies on the adverse effect of climate variability and farmers' adaptive capacity to climate variability with improved institutional factors such as credit facilities, market, and extension services to strengthen farmers' adaptive capacity.
11	Climate change and food security	Plant People Planet	3	Secondary data (1997-2019). Generalized Least Square Regression Model	South-West, Ethiopia	Enset production	The use of a perennial drought-resistant crop, enset by farmers in Southwest Ethiopia, correlates positively with food security in Ethiopia due to high yield and resistance to adverse climate.
12	Climate Change adaptation, food security	Climate Change	8	Primary data through questionnaire administration to 440 herders across 8 group ranches (Il'Ngwesi,	Kenya	Water and pasture management, destocking, the use of areas not prone to diseases, and precise	The study showed a significant positive effect of CCAS on the food security of pastoral communities in Kenya as climate adapters are likely to

				Ilpolei, Koiija, Kuri Kuri, Makurian, Murupusi, 402 Munichoi, and Tiamamut ranch) in Kenya. Endogenous Switching Regression and Logit		selection of settlement areas.	be 27%-points food insecure if they did not adopt strategies to mitigate the adverse effect of climate variability. It recommends consistency in climate change information dissemination on early warning and changing dynamics on strategies to enhance food security.
13	Coping strategy, climate variability.	Agriculture and Food Security	41	Cross-sectional survey research design. Questionnaires were administered to source primary that from 395 randomly selected smallholder farmers in northern Uganda. Descriptive statistics was used to present the adaptation strategies employed by the farmers, while binary Logistic Regression was used to infer the factors influencing farmers' adaptive strategies in the region.	Apac and Amuru districts of Northern Uganda.	Planting drought-resistant varieties, use of improved seeds and chemical fertilizers, use of pesticides and crop varieties, tree planting, and fallowing of garden.	The result, however, showed planting of crop varieties, drought-resistant crop varieties, and fallowing as the dominant adaptive strategies among farmers in Apac and Amuru districts of Northern Uganda. It recommends that government and development partners intensify advocacies adverse effects of climate variability while strengthening efforts on extension services, credit facilities, and thrift to enhance the adaptive capacity of smallholder farmers and food security in Northern Uganda.
14	Adaptation, climate, food security	Cogent Food and Agriculture	5	Relevant primate data was elicited from 138 households, while secondary data on rainfall and temperature trends were employed. It adopted explanatory and descriptive research designs and the Tobit model, Ordered Logistic Regression, Mann-Kendal Test, and Precipitation Concentration Index for data analysis.	Basona Worena District, Central Highland of Ethiopia.	Mixed cropping, agroforestry, irrigation, and Soil and water conservation methods such as stone bund, trench, mulching, area closure, strip cropping, contour ploughing, check dam, and crop rotation were employed as adaptation strategies to enhance food security in Bosana Worena District.	Despite the use of biophysical, technological, and economic adaptation measures, the households' food security (access and utilization) was not at an acceptable level. The study thus recommends water harvesting, agroforestry, livelihood diversification, and sustainable ways of enhancing food security in the district.
15	Adaptation strategies, climate change.	Trees, Forest and People	6	Primary data was collected from 150 households with the instrument of questionnaire. Cluster analysis and multinomial logit regression were used to analyze the field data.	Inanda KwaZulu-Natal Province of South Africa.	The adaptation strategies employed by the households are starting small businesses, crop and livestock production, home gardening, finding informal employment, buying forest products, getting forest products from alternative forests, the use of paraffin and electricity, changing the time and date of the forest visits	The study deduced that households with adequate awareness of climate variabilities such as temperature and rainfall with capacity in human capital are less likely to exert pressure on forest frontiers. It recommends the need for public-private partnerships on sustainable forest management to enhance the livelihood of forest fringe communities and climate change mitigation.
16	None	Sustainability	7	Panel data was used with secondary data spanning 2010 to 2016. Panel Probit Model (PPM), Propensity Score Matching (PSM), and Difference-in-difference (DID) regression were used to analyze the data.	Nigeria.	Crop diversification, Irrigation, off-farm activities, and soil conservation measures.	The result of PSM indicated that households adopting Climate Change Adaptation Strategies (CCAS) had 9% higher food security than households with no CCAS. In addition, DID result showed a significant positive effect of CCAS on food security. It recommends the need for farmers' education and quality adversary services to mitigate climate change adverse impact and intensify food security.

17	Climate change, food security.	International Journal of Climate Change Strategies and Management	3	Primary data was sourced from 72 farmers, while thematic content analysis was used to analyze the responses.	Mogalakwena community, Limpopo Province, South Africa.	Rainfall prediction, using fertilizer, growing exotic crops and using extension services, changing crops and planting season, crop diversification, and the use of climate-resistant crops.	The result showed that farmers are aware of the adverse effect of climate variability on food security, which resulted in adopting the aforementioned indigenous and innovative adaptation strategies to ameliorate the increasing adverse effect of climate change on food security.
18	Food security	Regional Environmental Change	88	Review	Sub-Saharan Africa	Risk management, diversification, sustainable intensification	The study revealed that despite the potential solutions proffered by the three smart adaptation strategies, growing constraints such as small farm sizes, multi-functionality of the livestock herd, poor access to markets and relevant knowledge, land tenure insecurity and the common property status of most grazing resources impedes farmers adaptive capacity to enhance crop and livestock production. It recommends the need for integrated, system-oriented impact assessments and realistic consideration of the adoption constraints in smallholder systems.
19	None	Pan African Medical Journal-One Health.	0	Primary data was elicited from 872 respondents and analyzed with descriptive statistics and logistic regression.	Benue State, Nigeria.	No strategy mentioned	The result showed a high awareness of climate variability but a poor adaptive capacity to enhance food security in the face of climate change.
20	Adaptation strategies, climate change.	Land	3	Primary data. Probit and Household Dietary Diversity Score (HDDS)	Ogun State, Nigeria.	Improved varieties, changing planting and harvesting periods, soil and water conservation, agrochemicals, mixed cropping, animal husbandry, mulching, and sales of crops.	Households with CCAS have higher food security by 3 units and 3.2 units decline in food insecurity as against non-adapting households. It recommends that policies that will incentivize farmers to adopt CCAS be put in place to enhance food security.
21	Adaptation, climate change, food security.	Sustainability	1	Primary data was sourced from 485 respondents through semi-structured interviews and questionnaires. Descriptive Statistics and thematic analysis	KwaZulu-Natal, South Africa	Water storage in tanks, digging water canals and water from the river ground, water collection from the dam, crop sales, large purchase of water for gardening and livestock, food purchase crop intensification against rainy-day, water conservation during droughts and recycling grey water, less ploughing of land to retain moisture, crop rotation to enhance soil fertility.	Climate variability affects agricultural activities' available household water and adversely impacts food security. It recommends the government's need for an inclusive approach to mitigate the impact of climate change.
22	Adaptation strategy, climate change	Heliyon	5	Primary data from 485 respondents. Descriptive Statistics, Multinomial Logistic Regression (MNLr).	Eastern Tigray, Ethiopia	Soil and water conservation, afforestation, improved seeds, irrigation, off-farm income	The MNLr result showed education, livestock holding, cooperative membership, extension services, farmers' income, and climate change perception as positive determinants of CCAS, while age, distance to market, and agroecology are negative determinants of CCAS. It

							recommends incorporating farmers' resource base and outlook in climate change public policy to mitigate its impact on their livelihood.
23	None	Mitigation and Adaptation Strategies for Global Change	0	Secondary data. Suitability model.	Zimbabwe	Agroforestry, water conservation, and soil management.	Cocoyam production is higher under agroforestry and increases in canopy microclimate variation. It recommends agroforestry as an effective climate change adaptive measure in cocoyam production.
24	Climate change, food security	Agronomy	22	Secondary data, thematic review.	Africa	Strategies such as integrated soil fertility management framework and soil conservation evident in the review are skewed towards efficient maize production in Africa	The review showed that while most African countries have adopted Climate Smart Agriculture (CSA) to enhance food security, the majority are yet to implement Climate Smart Agriculture Investment Plans (CSAIPs) to enhance food security. It recommends the development of a policy framework embedded in CSAIPs to enhance food security.
25	Climate change, adaptation strategies, food security	Climate Risk Management	2	Primary data was elicited from 540 farmers across six counties in Kenya. Multivariate Probit, Censored Least Absolute Deviation (CLAD), and Propensity Score Matching (PSM)	Kenya	Planting drought-tolerant crop varieties, mixed cropping, planting early maturing crops, livelihood diversification	Among other combinations of CCAS, farmers who adopt four strategies have their food security status increased by 14-18%, exhibiting a significant positive effect of CCAS on food security in Kenya. It recommends that further inquiries on CCAS in Kenya should employ time series data as the study relied solely on cross-sectional data.
26	Adaptive capacity, climate variability	Climate Risk Management	1	Primary data was elicited from 106 households with questionnaires in Uganda. Mann-Whitney-Wilcoxon Test and Generalized Linear models were used in the study.	Rakai and Nwoya, Uganda.	Off-farm income, livestock sales, and reduction in food consumption were ex-post strategies while switching crops constituted the ex-ante strategies.	Variability of production was large for all crops, with almost doubling of yields under good conditions and halving of yields in bad years. It recommends that policy be geared towards strengthening farmers' asset base and capacity to withstand shocks.
27	Adaptation strategies, climate change, food insecurity	Cogent Food and Agriculture	9	Cross-sectional survey data from 365 households in eastern Ethiopia. Three-State Probit Mode.	Eastern region, Ethiopia.	Improved varieties, Irrigation, and intercropping.	The study revealed paradoxically that irrigation and intercropping as CCAS recede adaptation of improved potato varieties in the study. It recommends that farmers' adaptive capacity be strengthened while policy formulation should encompass the socio-demographic attributes of farmers.
28	Adaptation strategies, climate change, food security.	Climate Change	50	Primary data was sourced from 308 maize farmers PSM and Multinomial Logit Model (MLM)	Koutiala and Bougouni, Southern Mali.	Organic fertilizers, changing planting dates, and growing short-duration crop varieties.	The result showed that adaptive strategies such as the use of organic fertilizers and short-duration maize varieties intensify maize productivity with a positive effect on food security in Southern Mali. It recommends the use of organic fertilizers and short-duration maize varieties as CCAS to improve maize yield and food security in Mali.
29	Climate Change	Ecological Processes	25	Primary data was sourced from 156 Carmel-owning households with Key Informant Interviews	Borana Zone, Southern Ethiopia.	Carmel management.	The study deduced that the receptive nature of cattle to climate change and the adaptive nature of Carmel to

				(KII), Focus Group Discussion (FGD), Surveys, and Observation. Descriptive statistics was used to analyze the responses.			climate change with high milk yield resulted in Carmel's management as climate CCAS by Borana pastoralists to enhance livelihood diversification and food security in Ethiopia. It thus recommends advocacies and measures to enhance the value chain in Carmel milk to enhance sustainable livelihood and food security of Pastoral communities in Ethiopia.
30	Adaptation strategies, climate change, food security	Cogent Social Sciences	14	Primary sourced from 346 maize farmers in Ngaka Modiri Molema. Southern Province, South Africa. Two-stage regression model.	Ngaka Modiri Molema. Southern Province, South Africa	Low tillage, crop rotation, planting of climate-tolerant maize, and mixed cropping were the dominant strategies employed to enhance food security.	It avails that CCAS enhances the food security of smallholder maize farmers in Ngaka Modiri Molema. Southern Province, South Africa. There is a need to intensify the adaptive capacity of smallholder farmers to enhance livelihood and food security.