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Integrated Spherical Decision-Making Model for Managing Climate Change Risks in Africa

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ABSTRACT

Decision-makers, researchers, practitioners, and stakeholders often struggle with selecting and prioritizing strategies to manage climate change risks. While recent research extensively explores this issue, the emphasis has largely been on regions other than Africa. This is significant, considering Africa's anticipated exposure to various and severe impacts of climate change. This study applied a two-stage model that integrates the Step-Wise Weight Assessment Ratio Analysis (SWARA) and Weighted Aggregated Sum Product Assessment (WASPAS) methods within a unique framework under the influence of spherical fuzzy (SF) conditions. In the initial stage, SF-SWARA determines the relative importance of the criteria, while the subsequent stage involves the SF-WASPAS method to rank the strategies. While the most critical challenges are limited access to finance and inadequacies in climate data, scenarios, and impact models, the solution to be considered is the promotion of a well-coordinated capacity-building programme. Furthermore, a comprehensive sensitivity analysis was conducted to validate the applicability of the proposed model. This research not only identifies and explains the challenges associated with climate change risks management in the African context but also significantly contributes to the body of knowledge by outlining and prioritizing the strategies required to address these challenges.

1. Introduction

Africa is highly vulnerable to climate change [1], which is expected to disrupt water, food, and health systems. These changes could worsen existing issues like poverty and insecurity, impacting economic development [2]. Therefore, prioritizing adaptation measures is crucial in the continent's climate policy to build resilience and reduce vulnerability.

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A growing body of literature explores how African communities [3], supported by civil society and international organizations, innovate in adapting to climate impacts. However, there are valid concerns [4] that the speed and scale of climate change may exceed the ability of African farmers to adapt using their current skills and knowledge. Demographic shifts, including a projected doubling of Africa's population by 2050, complicate matters, demanding a substantial increase in food production amid the rapid impacts of climate change [5]. Given the challenges in agriculture and food security [6], urgent scientific support is needed for decision-making at different scales. Despite the formidable task, there is a rising awareness of the need to adapt, from local to government levels and the donor community [7, 8], emphasizing the importance of coordination, leadership, and acknowledgment of the urgency to adapt [9].

Adapting to climate change in Africa faces challenges on multiple fronts. Improving climate change projections is hindered by a lack of historical weather data in many African nations [10]. Effective adaptation requires strong institutional leadership [11], but barriers such as institutional failures and oversight of emerging climate risks are prevalent [12]. Development deficits contribute to high adaptation costs in Africa, estimated to exceed $100 billion per year by 2050 [13]. Although the United Nations framework convention on climate change (UNFCCC) finance helps, it falls short of the needed scale for comprehensive climate-proofing [14]. These challenges are compounded by societal transitions, increased population, and accelerated urbanization in African nations.

Adapting to climate change in low-income countries, particularly in Africa, is a well-recognized challenge. The UNFCCC introduced national adaptation programmes of action (NAPAs) in 2001 for least developed countries (LDCs) to prioritize adaptation assistance. Despite 33 out of 54 African countries creating NAPAs, their effectiveness in crucial sectors like agriculture and water resources remains uncertain [15] due to challenges such as limited data and technical capacity [16]. Defining national adaptation priorities in Africa remains a significant issue despite NAPA production. Studies reveal poor integration of new agricultural innovations in NAPA documents for countries like Sierra Leone, Gambia, and Chad [13]. To address this, more comprehensive action plans are recommended. In Ethiopia, the Ethiopian programme of adaptation to climate change (EPA-CC) replaced the NAPA due to a lack of strategic vision [17]. Many adaptation initiatives in these countries lack scale and engagement with local institutions and stakeholders, as evident in NAPA documentation [13]. The literature emphasizes the need for a new approach to decision-making processes for adaptation in Africa, given the severity of climate susceptibility in many countries. This study specifically analyzed the challenges of managing climate change risks in Africa and proposed appropriate strategy to address them.

2. Literature Review

Research has employed methodologies such as fuzzy TOPSIS- PROMETHEE II [18], AHP-TOPSIS [19], DPSIR- PROMETHEE [20], 2-Tuple-GDM [21], SF-SWARA-MARCOS [22], and TOPSIS [23] for the evaluation of adaptation scenarios for climate change impacts. Additionally, alternative methodologies have been suggested, including T2NN-MEREC-MARCOS [24], fuzzy Einstein WASPAS [25], fuzzy 2D algorithm [26], IVFF- MEREC-RS-MULTIMOORA [27], IVFF-CRITIC-RS-DNMA [28], C-IFS-FWZIC-ARAS [29] to explore various aspects of climate change.

In Africa, studies on climate change risks have been conducted in countries like South Africa [30], Nigeria [31], Kenya [32], Tanzania [33], Ethiopia [34], and Uganda [35], coupled with an extensive literature review across diverse regions [4, 36-39]. However, there is a scarcity of researchers who have put forth concrete strategies to address climate change risks on the continent. Notably, Adenle et al. [4] stand out as among the rare few who have proposed strategies for managing climate change risks in Africa, although their focus did not specifically prioritize these strategies within the African context.

Considering the limitations of prior research, effectively addressing climate change risks and successfully implementing adaptation activities demands an approach that provides a holistic managerial perspective. This method should explicitly take into account multiple criteria to enhance decision outcomes [40-59]. Multi-criteria decision-making (MCDM) techniques, adept at structuring complex problems and accommodating various criteria, are well-suited for this purpose [55, 60-79]. In this research, an integrated SF-SWARA-WASPAS approach is employed to address previous limitations, evaluating challenges to manage climate change risks in Africa, and putting forth effective strategies.

3. Methodology

3.1 SF-SWARA

In this investigation, the criteria weighting is carried out using the SF-SWARA methodology. The successive steps of SF-SWARA are outlined below.

Step 1. A decision matrix is assigned to every expert where linguistic variable from reference [80] are employed to assess the importance of criteria. Let $\tilde{A}_{jk} = (\mathrm{\mu_{jk}}, \mathrm{v_{jk}}, \mathrm{\pi_{jk}})$ is the SFN for a criterion assessment j by expert k.

Step 2. Aggregations of expert's judgments is done via an SWAM operator.

$$SWAM_{\omega_k}(\tilde{A}_{jk}, \ldots \ldots, \tilde{A}_{jt}) = \omega_1 A\tilde{A}_{j1} + \omega_2 \tilde{A}_{j2} + \cdots \ldots + \omega_t \tilde{A}_{jt}$$

$$\tilde{z}_j = (\mu_j, v_j, \pi_j) = \left\{ \begin{array}{c} \left[1 - \prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{A}_{jk}}\right)^{\omega_k}\right]^{1/2}, \prod_{k=1}^{t} v^{\omega_k}_{\tilde{A}_{jk}}, \\ \left(\left[\prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{A}_{jk}}\right)^{\omega_k} - \prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{A}_{jk}} - \pi^2_{\tilde{A}_{jk}}\right)^{\omega_k}\right]^{1/2} \end{array} \right\} \quad (1)$$

where ω_k-weight of expert k, t- number of experts. j=z_j

Step 3. Each criterion score is calculated as:

$$\text{Score}\ (\tilde{z}_j) = (2\mu_j - \pi_j)^2 - (v_j - \pi_j)^2 \quad (2)$$

Step 4. The score values for criteria are ranked in decreasing order.

Step 5. From the second criterion onward, the comparative significance (c_j) is established by evaluating the disparity between the score values of criterion (j) and its predecessor $(j-1)$.

Step 6. Establish of comparative coefficient (k_j) for each criterion.

$$k_j = \begin{cases} 1, & j = 1 \\ c_j + 1, & j > 1 \end{cases} \quad (3)$$

Step 7. Computation of expected weight for each criterion (q_j).

$$q_j = \begin{cases} 1, & j = 1 \\ \frac{q_{(j-1)}}{k_j}, & j > 1 \end{cases} \quad (4)$$

Step 8. Normalization of recomputed weights for criterion
where n-total number of criteria.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j} \quad (5)$$

3.2 SF- WASPAS

The sequential steps in the SF-WASPAS methodology are outlined as follows:

Step 1. A matrix for evaluating alternatives is created for each expert using linguistic variables. Let $\tilde{X}_{ijk} = \left(\mu_{ijk}, v_{ijk}, \pi_{ijk}\right)$ be an SFN for alternative i assessment regarding criterion j by expert k.

Step 2. Application of SWAM operator for aggregating expert judgments

$$SWAM_{\omega_k}\left(\tilde{X}_{ijk}, \dots \dots, \tilde{X}_{ijt}\right) = \omega_1\tilde{X}_{ij1} + \omega_2\tilde{X}_{ij2} + \cdots \dots + \omega_t\tilde{X}_{ijt}$$

$$\tilde{R}_{ij} = \left(\mu_{ij}, v_{ij}, \pi_{ij}\right) = \begin{Bmatrix} \left[1 - \prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{X}_{ijk}}\right)^{\omega_k}\right]^{1/2}, \prod_{k=1}^{t} v^{\omega_k}_{\tilde{X}_{ijk}}, \\ \left[\prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{X}_{ijk}}\right)^{\omega_k} - \prod_{k=1}^{t} \left(1 - \mu^2_{\tilde{X}_{ijk}} - \pi^2_{\tilde{X}_{ijk}}\right)^{\omega_k}\right]^{1/2} \end{Bmatrix} \tag{6}$$

Step 3. Establishment of weighted decision matrix regarding criteria weights.

Step 4. Computation of WSM $(\tilde{Q}^1)$ for alternative

$$\tilde{Q}_i^1 = \sum_{j=1}^{n} \tilde{R}_{ijw} \tag{7}$$

$$\tilde{R}_{ijw} = \tilde{R}_{ij}w_j = \left(\sqrt{1 - (1 - \mu^2_{\tilde{R}_{ij}})^{w_j}}, v^{w_j}_{\tilde{R}_{ij}}, \sqrt{(1 - \mu^2_{\tilde{R}_{ij}})^{w_j} - (1 - \mu^2_{\tilde{R}_{ij}} - \pi^2_{\tilde{R}_{ij}})^{w_j}}\right)$$

Step 5. Computation of WPM $(\tilde{Q}^2)$.

$$\tilde{Q}_i^2 = \prod_{j=1}^{n} \tilde{R}_{ij}^{w_j} \tag{8}$$

$$\tilde{R}_{ij}^{w_j} = \left(\mu^{w_j}_{\tilde{R}_{ij}}, \sqrt{1 - (1 - v^2_{\tilde{R}_{ij}})^{w_j}}, \sqrt{(1 - v^2_{\tilde{R}_{ij}})^{w_j} - (1 - v^2_{\tilde{R}_{ij}} - \pi^2_{\tilde{R}_{ij}})^{w_j}}\right) \tag{9}$$

Step 6. The combination of WSM and WMP is executed via the threshold value (λ).

$$\lambda\tilde{Q}_i^1 = \left(\sqrt{1 - (1 - \mu^2_{\tilde{Q}_i^1})^{\lambda}}, v^{\lambda}_{\tilde{Q}_i^1}, \sqrt{(1 - \mu^2_{\tilde{Q}_i^1})^{\lambda} - (1 - \mu^2_{\tilde{Q}_i^1} - \pi^2_{\tilde{Q}_i^1})^{\lambda}}\right) \tag{10}$$

$$(1-\lambda)\tilde{Q}_i^2 = \left(\sqrt{1 - (1 - \mu^2_{\tilde{Q}_i^2})^{(1-\lambda)}}, v^{1-\lambda}_{\tilde{Q}_i^2}, \sqrt{(1 - \mu^2_{\tilde{Q}_i^2})^{(1-\lambda)} - (1 - \mu^2_{\tilde{Q}_i^2} - \pi^2_{\tilde{Q}_i^2})^{(1-\lambda)}}\right) \tag{11}$$

Step 7. Performance analysis of alternative via relative weight.

$$\tilde{Q}_i = \lambda\tilde{Q}_i^1 + (1-\lambda)\tilde{Q}_i^2 \tag{12}$$

Step 8. The final scores are determined by de-fuzzifying the SFNs using the score function.

Step 9. Rank of alternatives based on final scores

4. Application

In this study, we have successfully identified four challenges related to climate change risks management based on previous studies and experts' consultations. These challenges include insufficient climate data, scenarios and impacts models (C1), lack of well-coordinated capacity building programme (C2), fragmented adaptation programmes (C3), and limited access to finance (C4). Additionally, we have proposed three potential strategies (Figure1) to address these challenges. To ensure a reliable and consistent evaluation, we conducted interviews with three experts specializing in climate change risks management. These experts were selected carefully based on specific criteria, including their proficiency and extensive experience in policymaking.

Fig. 1. Adopted strategies for climate risks management in Africa

4.1 Weighting criteria

Expert teams employed a questionnaire to gather data on the importance of each criterion. The linguistic indicators, representing the weights assigned to individual criteria by the expert panel using the SF-SWARA method, are detailed in Table 1.

Table 1
Importance of criteria weights

Criteria	E1	E2	E3
C1	VH	H	H
C2	MH	H	VH
C3	H	MH	M
C4	VH	VH	EH

Upon collecting expert opinions, the integration process is executed using SWAM operators, taking into consideration the weights assigned by the experts, as outlined in Table 2. The determination of expert weights involves considering their reputations, which are assessed through factors like experience and expertise in the subject. Throughout the expert interviews, their weights are established accordingly, leading to E1, E2, and E3 having a weight of 0.35, 0.30, and 0.35, respectively.

Table 2
Weights of criteria according to SWAM operator

Criteria	Criterion weight		
	μ	v	π
C1	0.741	0.260	0.601
C2	0.709	0.294	0.632
C3	0.617	0.387	0.703
C4	0.838	0.162	0.496

After adopting the score function definition by Ayyildiz and Taskin [81], the score value is calculated, and the criteria's weights are established through the SF-SWARA method, as illustrated in Table 3.

Table 3
Results of SF-SWARA

Criteria	Score value	s_j	k_j	q_j
C4	1.284		1	1
C1	0.660	0.624	1.624	0.616
C2	0.502	0.158	1.782	0.346
C3	0.181	0.321	2.102	0.164

The final weights for each challenge are determined through the normalization of recalculated weights (q_j) using Eq. 5. As depicted in Figure 2, experts have identified limited access to finance as the most crucial challenge, followed by challenges such as insufficient climate data, scenarios and impacts models, a lack of well-coordinated capacity-building programmes, and fragmented adaptation programmes. The normalized weight assigned to criterion C4 (limited access to finance) is 0.470, while criterion C3 (fragmented adaptation programmes) is given the least consideration with a normalized weight of 0.077.

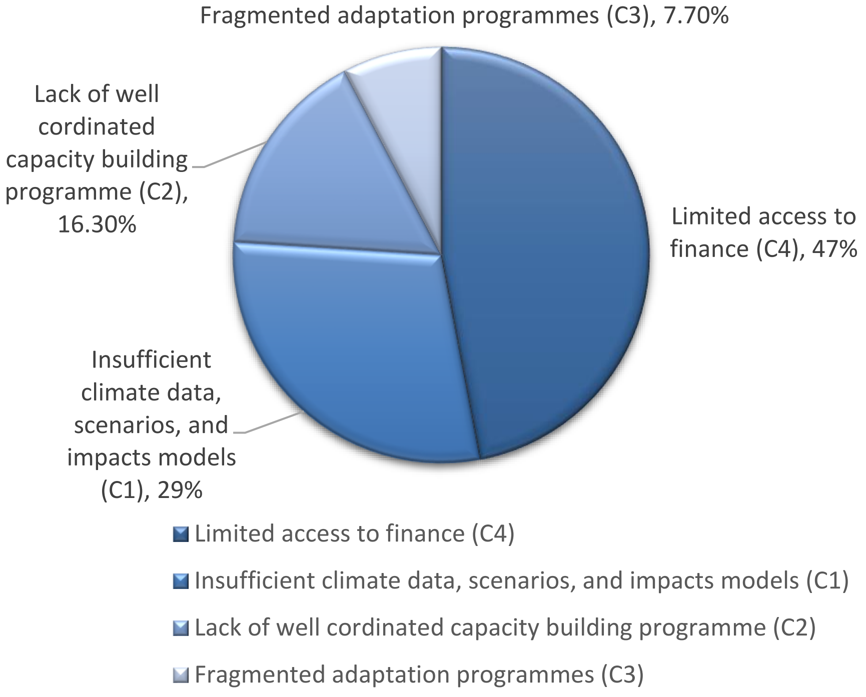

Fig. 2. Weights of challenges to managing climate change risks

4.2 Rank of strategies

Once the significance of criteria is established, the same qualified experts construct the initial decision grid employing linguistic variables to ascertain the most suitable strategy through the SF-WASPAS approach based on these criteria. The initial phase encompasses the conversion of linguistic variables into spherical fuzzy numbers, following the scale outlined in [80]. Following this, expert opinions are consolidated using the SWAM operator to derive expert weights. This sequence culminates in the development of a spherical fuzzy decision matrix, as illustrated in Table 4.

Table 4
Spherical fuzzy decision grid

	Criteria	μ	ϑ	π
S1	C1	0.673	0.339	0.201
	C2	0.700	0.300	0.200
	C3	0.741	0.260	0.166
	C4	0.770	0.230	0.136
S2	C1	0.741	0.260	0.166
	C2	0.591	0.417	0.264
	C3	0.788	0.216	0.145
	C4	0.669	0.332	0.236
S3	C1	0.607	0.397	0.307
	C2	0.873	0.127	0.048
	C3	0.673	0.339	0.201
	C4	0.770	0.230	0.136

Once the weights for each criterion have been determined, they are applied to rank the strategies. Subsequently, the SF-WASPAS steps are executed, and the Weighted Sum Model (WSM) and Weighted Product Model (WPM) for each strategy are calculated using the criteria weights, as detailed in Table 5.

Table 5
The WSM and WPM models

	WSM			WPM		
	μ	ν	π	μ	ν	π
S1	0.999	0.001	0.010	0.256	0.889	0.083
S2	0.999	0.001	0.012	0.248	0.893	0.091
S3	0.999	0.000	0.008	0.258	0.891	0.104

A threshold value (λ) of 0.5 is defined for the combination of the WSM and WPM models. Subsequently, the spherical fuzzy results from the SF-WASPAS method undergo defuzzification. The outcomes obtained through the integrated SF-SWARA-WASPAS methodology are then showcased as final scores, and the strategies are organized based on these final scores, as outlined in Table 6. The obtained ranked is S3 > S1> S2. The third strategy "*S3-Encouraging a well coordinating capacity building programme*" emerges as the most appropriate strategy since it has the highest score.

Table 6
The classification of alternatives

Ranking	Strategy	Final score
2	S1	3.921
3	S2	3.907
1	S3	3.937

5. Sensitivity Analysis

The research framework incorporates sensitivity analysis as a crucial element, serving as a fundamental method to assess the resilience and adaptability of the proposed approach under varying conditions. In order to evaluate the stability of the proposed method, a sensitivity analysis was conducted, which entailed methodically modifying the threshold value in increments of 0.1, ranging from 0 to 1. Following this, the revised threshold values were used to recompute the final scores for strategies, as detailed in Table 7.

Table 7
Sensitivity analysis outcomes

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
S1	1.186	2.556	3.291	3.658	3.836	3.921	3.962	3.982	3.991	3.996	3.998
S2	1.085	2.462	3.225	3.616	3.811	3.907	3.955	3.978	3.989	3.995	3.997
S3	1.202	2.616	3.348	3.698	3.861	3.937	3.971	3.987	3.994	3.997	3.999

The outcomes of the sensitivity analysis demonstrate that altering the threshold value produces the expected impact on the final scores, primarily due to the influence of WSM and WPM. However, even with changes in threshold values, the overall ranking of strategies remained consistent. A visual representation of alternative rankings is illustrated in Figure 3.

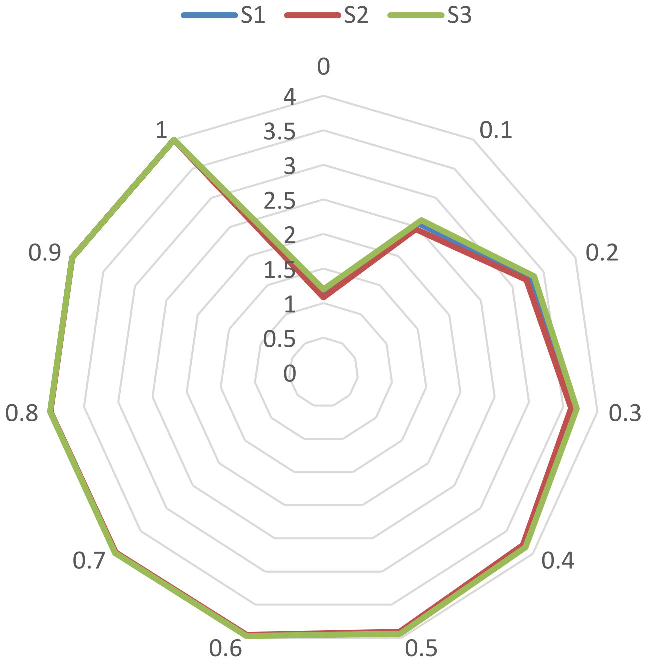

Fig. 3. Sensitivity analysis outcomes

6. Findings and Discussion

Upon reviewing literature and consulting experts, it is clear that climate change risk management faces several challenges. Two main obstacles have been identified, each with the potential to impede the management process of the risks. To assess their importance, the SF-SWARA approach was used to establish criteria values.

Experts highlight that the primary challenge stems from limited access to financial resources, a viewpoint supported by Adenle et al. [4], who assert that the available adaptation finance is insufficient, and the procedures for obtaining it pose challenges to government capacities. Their study [4] includes an interview with a government advisor, indicating that while increased funding from the developed world is necessary for adaptation, the main issues are within African governments. It is not merely a lack of funds but rather a deficiency in institutional capacity to implement adaptation initiatives. According to the government advisor, the solution is not simply injecting more money into adaptation efforts; the real challenge lies in accessing funds without robust institutions. Another national policymaker interviewed in the same study concurred, stating that gaining access to international funds has proven to be very difficult. Despite claims of abundant funds, actual access remains challenging. The United Nations Environment Programme (UNEP) report highlighted that current levels of international funding for adaptation fall short, with approximately USD$1-2 billion annually allocated to Africa specifically for adaptation, compared to a projected need of about USD$5 billion per year in 2020. However, Adenle et al. [4] research emphasizes that even if the necessary funds materialize, the ability to implement adaptation projects at the required scale remains a significant limiting factor. Therefore, there is a crucial need to establish explicit policies and strategies in three key areas. First, there is a necessity for well-defined strategies regarding priorities for adaptation, specifying the purpose of the funds, the required financial resources, and their intended impact. Secondly, it is essential to formulate clear strategies for energy supply systems. Lastly, there is a need for well-thought-out strategies concerning transportation and mobility, including the development of improved concepts. Concurrently, it is imperative to enhance institutional capacity to effectively execute these strategies. In essence, the solution doesn’t solely rely on increased funding; it significantly involves the development of more intelligent strategies in these three domains.

After contending with the challenge of limited access to finance, the subsequent major challenge revolves around insufficient climate data, scenarios, and impact models. These findings resonate with studies by Dinku [82], Carnohan et al. [83], and Gebrechorkos, Hülsmann [84], emphasizing the scarcity and anecdotal nature of effectively-documented historical data related to the experiences of African farmers. These studies underscore that only a handful of nations possess reliable long-term datasets to evaluate regional to local climate changes. In another study conducted by Adenle et al. [4], an interview with an agronomist highlighted the deficiency in instrumental data to track changes over the past century, posing a significant challenge for Africa. The proposed solution involves establishing an expanded and more high-resolution monitoring and observation system on the continent. Yet, the primary obstacle in readying for future impacts, as highlighted by this agronomist, pertains to the restricted comprehension of the potential distribution of climate change impacts, particularly concerning precipitation. At the agricultural decision-making level, a study by Feng, Porporato [85] underscored significant variations in precipitation projections by models, limiting their utility in planning due to differences in magnitude, timing, and direction of projected change. While these concerns echo similar debates in the literature, specific issues related to African projections were reported. For instance, climate scientists interviewed in [4] consistently highlighted the absence of consensus on optimal practices and techniques for downsizing climate projections. This is crucial for understanding uncertainties in regional temperature and precipitation forecasts across the continent. This challenge is amplified by the unclear interaction between land and ocean temperatures, as well as regional and global-scale teleconnections that impact the African climate. Additionally, the validation of models based on Kilroy [86] research is hindered by the scarcity of historical data. Therefore, the key focus should be on enhancing climate data collection, particularly regionally, for more accurate downscaled projections. Additionally, there is a vital need to strengthen resilience to current climate risks. Lastly, it is crucial to address data gaps and improve the quality of climate projections, requiring collaborative action from national governments, donors, and UN agencies to inform effective adaptation in Africa.

The SF-SWARA-WASPAS methodology highlights key challenges in climate change risk management in Africa. It emphasizes the critical role of a well-coordinated capacity-building programme, contingent on effective access to climate finance. The existing service delivery model, especially for capacity building and fund disbursement by implementing agencies, proves ineffective for these challenges. To address this, the recommendation is to establish regional capacity-building hubs in Africa. These hubs should strengthen training, monitoring, and evaluation, facilitating the implementation of adaptation projects aligned with local and national interests, thereby addressing backlogs in fund processing and providing the required capacity and expertise for project execution.

7. Managerial implications

The study provides various managerial insights.

i. The study's findings have the purpose of increasing awareness among the public and policymakers about the challenges of climate change adaptation in Africa and the essential elements needed for successful management and implementation of adaptation activities. This heightened awareness supports the promotion of risk management measures at both national and continental levels. Furthermore, the study provides practical guidance on prioritizing three specific alternatives, thereby enhancing the integration of African nations into continental efforts for managing climate change risks.
ii. The study's insights can provide valuable benefits to government authorities responsible for managing climate change risks in Africa. By incorporating these insights into their strategic planning, authorities can determine where support and action are needed to promote the mainstreaming of adaptation in both the public and private sectors. This informed strategic planning process involves developing a roadmap for action based on the insights derived from the study.

8. Conclusions

This study presents a method for handling climate change risk management in a spherical fuzzy framework, integrating the WASPAS and SWARA techniques. The application of this model was demonstrated in a practical sense using a case study focused on the African continent. The findings highlighted the primary challenges, namely, limited access to finance and inadequacies in climate data, scenarios, and impact models. Furthermore, the research pinpointed the promotion of a well-coordinated capacity-building programme as the most impactful strategy based on the conclusions drawn.

The research offers two significant contributions, each with distinct perspectives. Firstly, it introduces a framework tailored for the management of climate change risks in Africa. This framework outlines an appropriate strategy for a methodical and logical implementation, representing a professional contribution. Secondly, the study makes a scientific contribution by utilizing integrated SWARA and WASPAS methods within a spherical fuzzy environment to address climate change risks in this specific geographical region. This approach is innovative and has been infrequently explored in existing literature.

While the study contributes significantly, it is essential to acknowledge its limitations. Firstly, the proposed methodology lacks a comparative analysis with other fuzzy-based multicriteria approaches specifically addressing this issue, offering an opportunity for future research to undertake such comparisons. Secondly, the study was conducted at a continental level, overlooking the extensive diversity within Africa, encompassing numerous countries and regions, each with its unique conditions and varying levels of development. Subsequent research could focus on comparing different regions or conducting individual country-level analyses to achieve a more comprehensive understanding. Lastly, it is crucial to note that the data collection process involved a limited number of experts. Future research should aim to include a larger and more diverse pool of experts, with clear criteria for their selection to ensure a comprehensive and reliable analysis.

The methodology and findings detailed in this paper bear significant relevance for entities engaged in the management of climate change risks. They provide a framework for assessing the prevailing challenges in the domain of climate change risk management. The results underscore the importance of a proactive approach for African governments, emphasizing the necessity for well-defined strategies that delineate adaptation priorities, specify fund purposes, determine required financial resources, and project their intended impact. Special attention is urged for the improvement of climate data collection, especially at the regional level, to enhance the precision of downscaled projections. The recommendations include fortifying resilience against current climate risks, addressing data gaps, and elevating the quality of climate projections.

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Conflicts of Interests

The authors declare no conflicts of interest.

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