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Original Research

How Can Multi-Criteria Decision-Making Optimize Adaptation Strategies for Climate Change-Induced Migration?

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Abstract

Climate change is a significant driver of migration, displacing populations in vulnerable regions. The need for effec- tive adaptation and mitigation strategies is urgent, but existing studies often focus on isolated strategies or criteria, overlooking the interactions between them. This research provides a holistic evaluation of seven key strategies for mitigating and adapting to climate migration. These strategies are assessed based on five criteria, using Multi-Criteria Decision-Making (MCDM), particularly the Analytic Hierarchy Process (AHP). This study's originality lies in its multi- dimensional approach, examining not only individual strategies but their broader interactions. Research questions include: (1) which criteria are most and least important for evaluating adaptation strategies, and (2) which strategies are most effective in addressing climate migration in vulnerable regions. Findings show that reducing migration im- pacts (C1) holds the highest weight (30%), followed by long-term viability (C2) with 25%. Inclusivity and social equity (C3) receive 20%, and resource efficiency (C4) is assigned 15%, while synergy with other initiatives (C5) ranks lowest (10%). Sustainable Agriculture ranks highest, followed by Strengthening Water Resource Management, Inclusive Ur- ban Planning, and Climate Forecasting and Early Warning Systems, while Strengthening Host Community Capacities and Climate Risk Insurance rank lower. This study provides valuable insights for policymakers but acknowledges lim- itations such as data availability and regional variability. Future research could refine these findings through regional case studies.

Résumé

Le changement climatique est un facteur majeur de migration, déplaçant les populations des régions vulnérables. La nécessité de stratégies efficaces d'adaptation et d'atténuation est urgente, mais les études existantes se concentrent souvent sur des stratégies ou des critères isolés, négligeant les interactions entre eux. Cette recherche propose une évaluation holistique de sept stratégies clés pour atténuer et s'adapter à la migration climatique. Ces stratégies sont évaluées selon cinq critères, en utilisant l'approche de la prise de décision multicritère (MCDM), notamment le processus hiérarchique analytique (AHP). L'originalité de cette étude réside dans son approche multidimensionnelle, qui examine non seulement les stratégies individuelles mais aussi leurs interactions plus larges. Les questions de recherche abordées sont les suivantes : (1) Quels critères sont les plus et les moins importants pour évaluer les stratégies d'adaptation ? (2) Quelles stratégies sont les plus efficaces pour faire face à la migration climatique dans les régions vulnérables ? Les résultats montrent que la réduction des impacts migratoires (C1) détient le poids le plus élevé (30 %), suivie par la viabilité à long terme (C2) avec 25 %. L'inclusivité et l'équité sociale (C3) obtiennent 20 %, l'efficacité des ressources (C4) est attribuée à 15 %, tandis que la synergie avec d'autres initiatives (C5) arrive en dernier avec 10 %. L'agriculture durable se classe en tête, suivie par le renforcement de la gestion des ressources en eau, la planification urbaine inclusive et les systèmes de prévision climatique et d'alerte précoce, tandis que le renforcement des capacités des communautés d'accueil et l'assurance

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contre les risques climatiques obtiennent des classements plus faibles. Cette étude fournit des informations précieuses pour les décideurs politiques, mais reconnaît certaines limites, telles que la disponibilité des données et la variabilité régionale. Les recherches futures pourraient affiner ces résultats grâce à des études de cas régionales.

1. Introduction

Climate change has emerged as a critical driver of migration, with its complex and varied effects influencing the displacement of populations, particularly in vulnerable regions such as Sub-Saharan Africa, Southeast Asia, and Latin America. The increasing frequency and severity of climate events such as droughts, floods, and extreme temperatures are contributing to the displacement of communities, creating new challenges for governments, humanitarian organizations, and local populations (Section 2 and 2.1). As climate-induced migration continues to rise, it is imperative to understand and develop effective strategies for mitigating and adapting to its impacts [1, 2]. These strategies play a key role in reducing vulnerability, enhancing resilience, and ensuring the long-term sustainability of both mi- grant and host communities [3, 4]. While the significance of climate change-induced migration has been widely acknowledged, there remains a gap in the literature regarding the comparative evaluation of different adaptation strategies. Existing studies tend to focus on single strategies or isolated criteria without providing a comprehensive assessment of how multiple strategies interact and how they perform against a range of evaluation criteria.

Almulhim et al. [5] examine the socioeconomic and political drivers of climate migration in the Global South, emphasizing how multiple climate hazards (e.g., rising temperatures, droughts, and floods) displace millions and how institutional, policy, and financial gaps influence migration patterns. Mallick et al. [6] focus on the gendered impacts of climate migration, particularly in Bangladesh, exploring how climate-induced displacement affects women beyond physical relocation, including social, psychological, and economic challenges. Sri et al. [7] analyze the legal and policy gaps in protecting climate migrants, highlighting the shortcomings of the EU asylum framework and advocating for legal recognition and protection mechanisms. While all three studies address climate-induced migration, they differ in their scope: one examines the systemic causes and adaptation needs, another the gender-specific consequences, and the third the legal challenges and policy responses. Liang et al. [4] examine the relationship between global climate change, specifically climate warming, and population migration. It explores the environmental, economic, political, social, and cultural issues arising from climate migration. The study analyzes 785 documents from the Web of Science and 157 documents from the China Knowledge Network, spanning from 2008 to 2021, using various methods such as word frequency analysis, clustering, and sudden word detection. The research identifies three stages of climate migration research: initial exploration (2008-2011), development enrichment (2012-2017), and system deepening (2018-present). The study highlights key topics, including the different types of climate migration (e.g., migration due to sea level rise, flooding, and drought), quantitative modeling, and climate justice. It suggests that climate migration research is interdisciplinary and recommends strengthening predictive models, leveraging China's experience in migration strategies, creating a climate migration database platform, and fostering international collaboration. Clements et al. [3] highlight the urgent need for reform in the architecture of international aid and climate finance to better address the growing issue of climate migration. It points out that while humanitarian aid agencies supporting climate migrants are increasingly overburdened, climate migration has been largely overlooked by the United Nations Framework Convention on Climate Change (UNFCCC). The study critiques the

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UNFCCC's current treatment of cli- mate migration as part of adaptation, arguing that insufficient resources are allocated to the needs of migrants. Using data from Groundswell (2021), which estimates 216 million climate migrants by 2050, the study raises concerns about the accuracy of these projections due to underestimation of certain drivers. The research suggests that, considering both slow- and sudden-onset climate drivers, the number of climate migrants could be as high as 500 million by 2050, assuming weak mitigation and adaptation efforts. The study estimates the cost of helping climate migrants to rebuild their lives at around $7,000 per person, suggesting that such support would represent a substantial portion of total climate finance. It calls for the UNFCCC to address climate migration as a separate category, with its own dedicated resources, distinct from adaptation and mitigation, to effectively support climate migrants' needs. This lack of a holistic approach limits the ability of policymakers to prioritize and design effective solutions that address the multifaceted nature of climate migration. Furthermore, there is a need for more research that goes beyond theoretical frameworks and incorporates real-world data and examples to better understand the practical implications of these strategies.

The originality of this study lies in its holistic approach, which evaluates multiple strategies for mitigating and adapting to climate migration across various criteria. Rather than focusing on one strategy or one criterion in isolation, this research employs Multi-Criteria Decision-Making (MCDM), particularly the Analytic Hierarchy Process (AHP), to assess the effectiveness of a range of strategies such as the diversification of livelihoods, improvement of sustainable agriculture, strengthening water resource management, inclusive urban planning, strengthening reception capacities, climate forecasting and early warning systems, and climate risk insurance based on criteria that include the capacity to reduce migration impacts, long-term viability, inclusivity, resource efficiency, and synergy with other initiatives. This integrated approach provides a more comprehensive understanding of which strategies hold the most promise in addressing the complex challenges posed by climate migration. The primary research questions guiding this study are: (1) which criteria hold the most and least importance in evaluating adaptation strategies for climate migration, and (2) which strategies are the most and least important in mitigating and adapting to climate migration in vulnerable regions? By answering these questions, the study aims to provide valuable insights into how different strategies perform against key criteria, offering actionable recommendations for policymakers and practitioners working to address the impacts of climate-induced migration.

This paper is structured as follows: first, it explores the complex and varied effects of climate change on migration (Section 2) with a concrete examples (Section 2.1). Then, the study outlines the methodology employed (Section 3), focusing on the use of MCDM and AHP (Section 3.1) to evaluate the strategies (Section 3.2) based on different criteria (Section 3.3). Following this, the results of the analysis are presented (Section 4), leading to a discussion on the relationships between the criteria, strategies, and the integration of both (Section 5). The conclusion highlights the key findings, their practical implications, and potential avenues for future research (Section 6).

2. The Complex and Varied Effects of Climate Change on Migration

Climate change is increasingly driving human migration and displacement, with complex and varied effects on populations worldwide. Climate migration refers to the movement of individuals or communities driven by the direct or indirect impacts of climate change. These move-

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ments can be temporary or permanent, internal or cross-border, and voluntary or forced. Climate migration is often triggered by extreme weather events such as hurricanes, floods, and wildfires, as well as slow-onset changes like desertification, rising sea levels, and prolonged droughts that undermine livelihoods and habitability. While some climate migrants relocate as an adaptive strategy to seek better opportunities, others are displaced due to the loss of essential resources and infrastructure. The phenomenon is complex, influenced by economic, social, and political factors, and requires integrated policy responses to enhance resilience and minimize displacement risks.

Climate change-induced disasters such as rising sea levels, hurricanes, floods [8], and wildfires [9] are increasingly forcing communities to leave their homes. Coastal and island communities are particularly vulnerable to sea-level rise (e.g., Figure 1), leading to frequent flooding, salinization of freshwater sources, and loss of arable land. These environmental changes make habitation increasingly difficult, often resulting in large-scale displacement [10]. Similarly, prolonged droughts [8] and water resource depletion [11] significantly impact rural populations that rely on agriculture and livestock for survival. As land becomes infertile and water sources dry up, migration becomes a necessity rather than a choice. This migration can take the form of internal rural-to-urban migration or transnational migration toward countries perceived as less vulnerable to climate impacts, in search of security, infrastructure, and economic opportunities. In 2022, a record 32.6 million people were displaced by weather-related events [12]. Most displacement has been internal so far, but cross-border movements are increasing [10].

Figure 1. *People stand along a riverbank watching the demolition of houses built on riparian land in a neighborhood in Nairobi, Kenya. (**Source:** TV5 Monde [13]).*

By 2050, climate change could force 216 million people to migrate, primarily affecting several regions [14]. Sub- Saharan Africa could see up to 86 million displaced people, while East Asia and the Pacific may experience 49 million climate migrants. South Asia could record 40 million displaced individuals, around 19 million people could be affected in the Middle East and North Africa (MENA) region, and Latin America could see this number reach 17 million (Figure 2).

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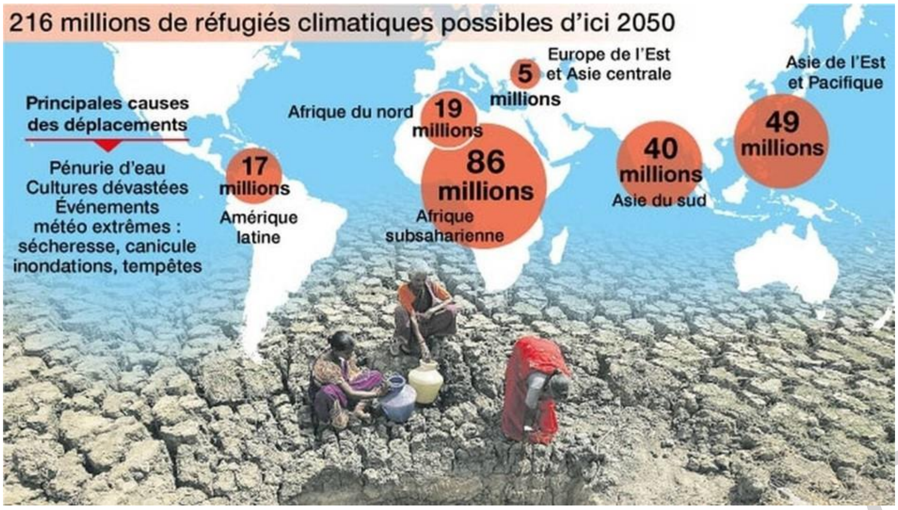

Figure 2. *Projected number of climate migrants by 2050 across different regions, with Sub-Saharan Africa, East Asia and the Pacific, South Asia, Middle East and North Africa (MENA), and Latin America being the most affected [14]. By 2050, climate change could force 216 million people to migrate, primarily affecting several regions. Sub-Saharan Africa could have up to 86 million displaced people. East Asia and the Pacific could see 49 million climate migrants, while South Asia could record 40 million displaced individuals. In the MENA region, approximately 19 million people could be affected, and in Latin America, this figure could rise to 17 million.*

Natural disasters account for the majority (60%) of climate-induced migration (Figure 3). These are typically sudden-onset events like hurricanes, floods, and wildfires that can cause immediate and large-scale displacement. The remaining 40% is attributed to slower, more gradual processes. These include prolonged droughts (20%), sea level rise (10%), land degradation (5%), and water scarcity (3%). While less immediately dramatic, these factors can have long-term, cumulative effects on migration patterns. Combining prolonged droughts (20%) and degradation of agricultural land (5%), we see that 25% of climate-induced migration is directly related to impacts on agriculture. For instance, a 1% reduction in agricultural income due to weather shocks raises the probability of migration by 3% for an average household [15]. This underscores the vulnerability of rural, agriculture-dependent communities to climate change [16]. Water plays a central role in several categories - natural disasters (often water-related), droughts, and water resource scarcity. This highlights the critical importance of water management in climate adaptation strate- gies [11]. The inclusion of resource-related conflicts (2%) points to the indirect social and political consequences of climate change, which can also drive migration [14] (Figure 3).

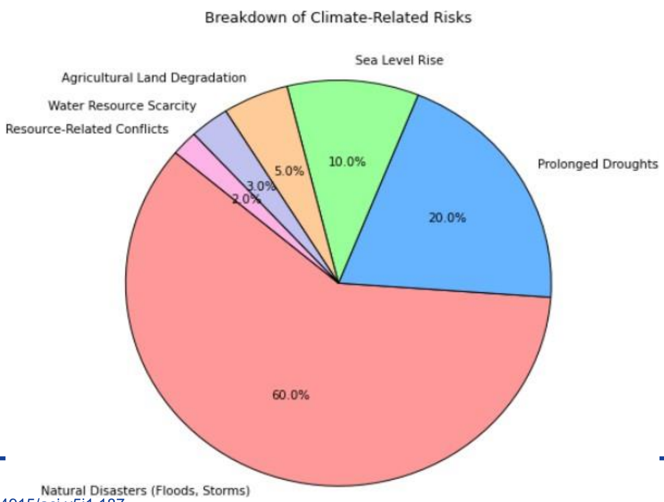

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Figure 3. Main causes of migration, highlighting the impact of natural disasters, prolonged droughts, sea level rise, agricultural land degradation, water resource scarcity, and resource-related conflicts [14].

The influx of climate migrants into urban areas places immense pressure on existing infrastructure. Cities, already dealing with rapid urbanization, struggle to provide essential services such as water supply, sanitation, housing, waste management, healthcare, education, energy, and transportation [10]. Additionally, many urban centers experience the urban heat island effect—a phenomenon where densely built environments, with limited vegetation and increased pollution, retain heat more than surrounding rural areas. This exacerbates the impacts of climate change, making cities hotter and more prone to extreme weather events, such as heatwaves and flash floods. Vulnerable groups, including the elderly, children, and those with pre-existing health conditions, face heightened risks in these environments.

Climate migrants often come from impoverished backgrounds and may end up in informal settlements or slums where living conditions are precarious. These settlements are typically located in high-risk areas prone to environmental hazards, including floods and air pollution, further entrenching a cycle of vulnerability. Limited access to clean water, sanitation, healthcare, and stable employment increases the socio-economic marginalization of these populations, making their adaptation to urban life even more challenging [10].

As essential resources such as water, food, energy, and housing become scarcer due to climate-induced migration, conflicts can arise between migrants and host communities, as well as within migrant populations themselves. Competition for these resources, coupled with existing socio-economic inequalities, can escalate tensions, leading to political instability and social unrest. Governments and policymakers must address these challenges through sustainable urban planning, climate-resilient infrastructure, and inclusive policies that ensure equitable resource distribution and support for displaced populations [5].

The relationship between climate change and migration is multifaceted, with far-reaching consequences for both migrants and host communities.

As climate change alters the environment, people and wildlife are forced to migrate to areas with more stable or favorable conditions. This creates new challenges for transportation networks. Poorly planned infrastructure could create additional barriers for both human and wildlife migration, exacerbating the challenges of climate migration. For example, if transport routes cut across critical migration corridors for animals or disrupt communities that are already affected by climate change, it could worsen their ability to adapt or survive. Krsti et al. [17] provide a framework to assess intermodal transport routes—routes that use more than one mode of transportation (e.g., trucks, trains, ships)—with a focus on their environmental and biodiversity impacts. In this study, Geographic Information System (GIS) helps map out transport routes and assess their effects on the environment and biodiversity. Multi-Criteria Decision-Making (MCDM) is used to evaluate different options based on multiple criteria. It is often used when decisions involve conflicting factors, like choosing a route that balances transport efficiency with environmental preservation. Fuzzy Delphi is used to gather expert opinions and determine the relative importance of different criteria. Fuzzy DEMATEL is used to identify and analyze the relationships between different factors, helping to prioritize which criteria are most important for evaluating transport routes. Axial Distance-based Aggregated Measurement (ADAM) helps combine all the factors and criteria into a final score, ranking the transport routes from most to least sustainable in terms of their environmental and biodiversity impacts.

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CrdenasVlez et al. [18] examine climate migration, revealing that migration decisions are driven by a mix of eco- nomic, social, environmental, and cultural factors. Using data from 53 structured interviews and a spatial multi- criteria model, it shows that people prioritize economic factors like unemployment and job opportunities over environmental concerns, which are seen as underlying. The findings emphasize that migration is shaped by multiple interacting factors, challenging the idea of a monolithic migration response to climate change. The study highlights the need to consider local, individual-level drivers when addressing climate migration and creating adaptive strategies.

Singh et al. [19] identify the determinants of migration in India using data from the National Sample Survey (2007- 2008) and a multi-criteria approach. The findings show that around 70% of migrants are illiterate, with 57% working as agricultural laborers. For permanent migration, factors such as small land size, being Hindu, illiteracy, marital status, low consumption expenditure, and climate factors like rainfall and temperature were identified as key drivers. The study suggests that in rural areas where unemployment drives migration, proactive social protection programs like MGNREGA can help manage climate-induced migration. The study emphasizes the need for local populations to be included in decision-making processes related to climate change adaptation.

While migration can serve as an adaptation strategy to climate change, it also presents significant challenges that require proactive governance, investment in resilient infrastructure, and international cooperation. Addressing these issues holistically can help mitigate the negative impacts of climate-induced migration while ensuring sustainable and equitable development for all.

2.1. Concrete Examples of Climate Change-Related Migration

Migration in the Sahel region (Figure 4), which stretches across Africa from the Atlantic Ocean to the Red Sea, is driven by desertification—the process by which once fertile lands become barren or desert-like (degraded) due to natural factors (prolonged droughts and rising temperatures) or human factors (unsustainable agricultural practices, deforestation, overgrazing) [20]. As a result, pastoral communities (groups whose livelihoods primarily depend on raising animals such as cattle, sheep, goats, camels, etc.) are forced to migrate to more fertile regions or cities due to the loss of grazing land, reduced water availability, decreased agricultural productivity, food insecurity, and a loss of biodiversity [21]. The Sahel is particularly vulnerable to desertification due to its fragile ecosystem, with the region experiencing dry weather for about 8 months of the year and a short rainy season that produces only 4-8 inches of rainfall [22]. It is estimated that over 23 million people in the Sahel region are facing severe food insecurity in 2022 [22]. Almost 5 million people were forcibly displaced across Burkina Faso, Mali, Niger, Mauritania, and coastal countries by August 2024 [23].

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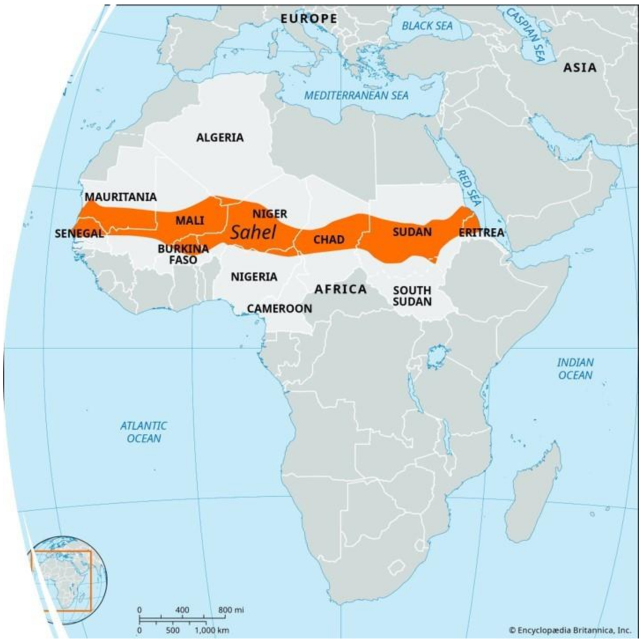

Figure 4. *Areas of the Sahel affected by desertification (reduction of arable land). (Source: Encyclopædia Britannica [24]).*

Lake Chad has indeed experienced a dramatic reduction in size since the 1960s, with significant impacts on the surrounding communities and ecosystems. The lake's surface area has decreased by approximately 90% over the past 60 years [25]. In 1963, Lake Chad covered about 26,000 square kilometers. Today, the lake's surface area is less than 1,500 square kilometers (Figure 5). The shrinkage of Lake Chad is attributed to several factors, such as overuse of water resources, extended periods of drought, and other climate change impacts. This reduction impacts communities that rely on the lake for fishing, agriculture, and drinking water. The Lake Chad Basin crisis has resulted in one of the fastest-growing displacement crises in recent history [26]. Approximately 5 million people have been displaced across the Lake Chad Basin region as of August 2024 [23].

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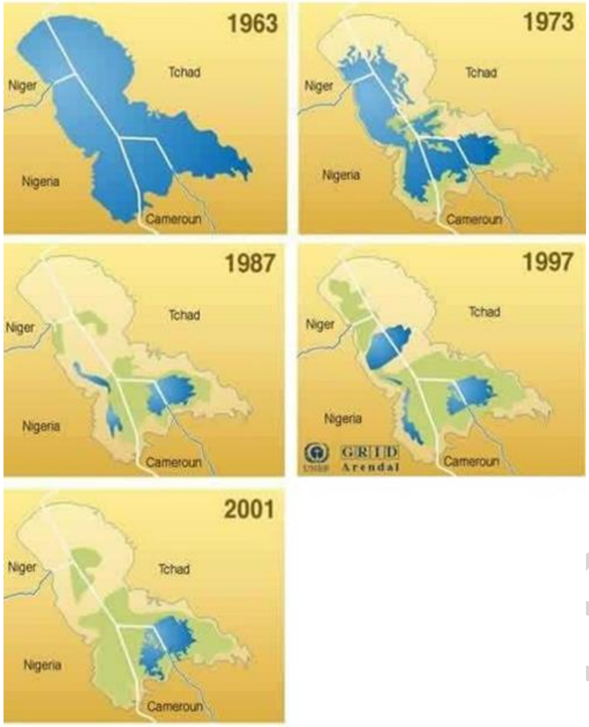

Figure 5. *Map of Lake Chad's shrinkage showing the evolution of the lake's surface area from 1963 to 2001, highlighting the dramatic reduction in its size. Water in blue; Former Lake outline in light beige; Vegetation in light green. (Source: Journal des Communes [27]).*

Tropical cyclones like Idai (2019) [28] and Freddy (2023) [29] have devastated regions of Mozambique, causing massive flooding that destroyed entire villages (Figure 6). Both cyclones caused massive flooding, with Freddy resulting in an estimated 900 km² of flooded land in a preliminary assessment of a 24,000 km² area [30].

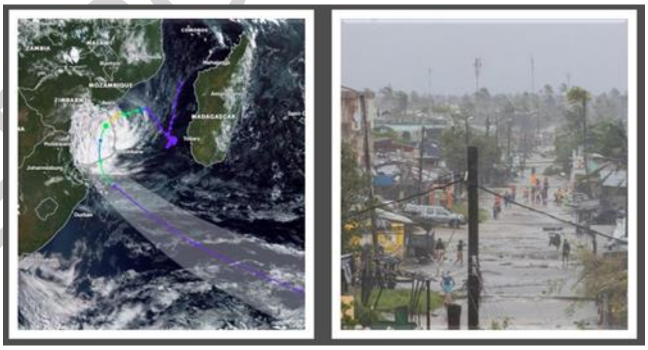

Figure 6. *A map illustrating the regions in Mozambique affected by tropical cyclones, highlighting the areas impacted by violent winds, heavy rainfall, and flooding. This map demonstrates the extent of the damage caused by major cyclones, such as Idai (2019) and Freddy (2023), which led to widespread destruction of infrastructure, displacement of communities, and loss of livelihoods.*

3. Methodology

Climate change-induced migration presents a growing challenge, particularly in vulnerable regions such as Africa and Asia, where environmental stressors, socio-economic factors, and governance constraints interact to shape migration patterns. Addressing this issue requires a

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systematic decision-making approach to evaluate and prioritize adaptation strategies that enhance resilience and sustainability. This section provides a comprehensive framework for assessing climate migration strategies using Multi-Criteria Decision-Making (MCDM), specifically the Analytic Hierarchy Process (AHP) (Section 3.1). It then explores key adaptation strategies tailored to the unique challenges faced by vulnerable regions (Section 3.2) and outlines the essential criteria for evaluating these strategies (Section 3.3), ensuring a holistic and context-specific approach to climate migration governance.

3.1. Theoretical Framework: Multi-Criteria Decision-Making (MCDM) and the Analytic Hierarchy Process (AHP) in Evaluating Climate Migration Strategies

Multi-Criteria Decision-Making (MCDM) is a structured framework used to assess and prioritize complex decision problems involving multiple, often conflicting criteria. MCDM is particularly relevant for evaluating strategies related to climate migration, as it enables decision-makers to systematically compare policy alternatives that address socio-economic, environmental, and governance-related challenges [31, 32, 33].

The choice of the Analytic Hierarchy Process (AHP) method to evaluate strategies for mitigating and adapting to climate migration is justified for several reasons when compared to other Multi-Criteria Decision-Making (MCDM) methods, such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination Et Choice Translating Reality (ELECTRE), and Measurement of Alternatives and Ranking of Preference (MACBETH). Firstly, AHP is particularly suited for com- plex problems involving both qualitative and quantitative criteria, which is essential in the context of climate migration, where social, economic, and environmental factors interact dynamically. In contrast to methods like TOPSIS, which primarily focuses on proximity to an ideal solution and can be sensitive to initial weighting, AHP allows for a hierarchical decomposition of the problem, facilitating a deeper understanding of the relationships between criteria and alternatives. Moreover, while PROMETHEE and ELECTRE, though effective for ranking alternatives, often require advanced preference parameterization that can be subjective and challenging to justify in the context of complex political and social decision-making, AHP provides a more structured approach. One of AHP's strengths is its pairwise comparison approach for weighting criteria, allowing decision-makers to structure their judgments consistently and verify the consistency of expressed preferences through the consistency ratio. Furthermore, AHP enables the evaluation of interdependencies between criteria and strategies, which is crucial when examining adaptation and mitigation policies, where synergies and trade-offs between measures need to be clearly identified. Finally, unlike MACBETH, which relies on qualitative judgments without direct quantitative comparisons, AHP provides numerically weighted scores, facilitating a transparent and reproducible decision-making process. Thus, the choice of AHP is justified by its flexibility, methodological robustness, and ability to integrate expert subjectivity while ensuring a structured and consistent evaluation of strategies in the face of the multidimensional challenges of climate migration [31, 32].

Among the various MCDM techniques, the Analytic Hierarchy Process (AHP) is widely recognized for its capacity

to handle qualitative and quantitative data, integrate expert judgments, and derive a ranking of decision alternatives based on a hierarchical structure.

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AHP, developed by Thomas Saaty, is a mathematical approach to decision-making that decomposes complex problems into a hierarchical structure comprising three main levels:

- *Goal: The overarching objective, in this case, the selection of the most effective strategies for mitigating and adapting to climate migration.*
- *Criteria and Sub-Criteria: The factors influencing the decision, such as environmental resilience, economic feasibility, social acceptance, policy alignment, and technological feasibility (Section 3.3).*
- *Alternatives: The potential strategies under consideration, such as managed retreat, resilient urban planning, infrastructure adaptation, and economic incentives for relocation (Section 3.2).*

The decision problem is structured in a hierarchical model, starting with the main goal at the top, followed by the identified criteria and sub-criteria, and ending with the decision alternatives at the bottom (Figure 7).

Decision-makers or experts perform pairwise comparisons of criteria and alternatives using Saaty's 9-point scale, where 1 indicates equal importance and 9 signifies extreme importance. A pairwise comparison matrix is constructed for each level of the hierarchy.

The relative priority weights of criteria and alternatives are determined by normalizing the pairwise comparison matrices. The Consistency Ratio (CR) is computed to ensure logical consistency in judgments. A CR value below 0.1 indicates an acceptable level of consistency.

The weighted sum of scores across all levels is computed to derive a final ranking of climate migration strategies, allowing decision-makers to select the most suitable approach based on empirical evidence and expert opinions.

For each alternative strategy, a priority score is computed based on its relative performance under each criterion, ultimately guiding policymakers in selecting the most balanced and sustainable approach.

AHP provides a systematic and transparent decision-support tool for evaluating climate migration strategies by integrating expert knowledge, stakeholder preferences, and quantitative assessments. By structuring complex migration challenges into a hierarchical model, AHP enhances decision-making processes and facilitates the adoption of adaptive, resilient, and sustainable policies for climate-affected populations.

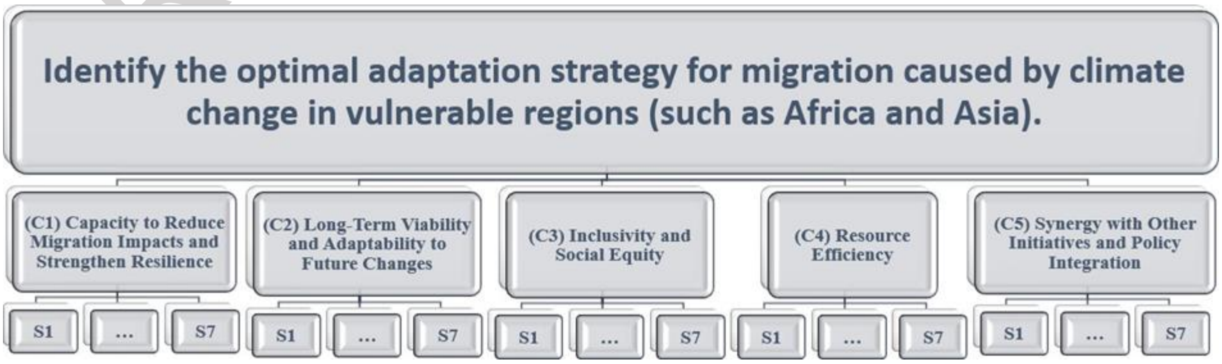

Figure 7. *Hierarchical structure of the decision problem in Multi-Criteria Decision-Making (MCDM) - Analytic Hierarchy Process (AHP) (Section 3.1), illustrating the main goal at the top, followed by the identified criteria—(C1) Capacity to Reduce Migration Impacts and Strengthen Resilience, (C2) Long-Term Viability and Adaptability to Future Changes, (C3) Inclusivity and*

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Social Equity, (C4) Resource Efficiency, and (C5) Synergy with Other Initiatives and Policy Integration (Section 3.3)–, and ending with the decision alternatives—(S1) Diversification of Livelihoods, (S2) Improvement of Sustainable Agriculture, (S3) Strengthening Water Resource Management, (S4) Inclusive Urban Planning, (S5) Strengthening Reception Capacities, (S6) Climate Forecasting and Early Warning Systems, (S7) Climate Risk Insurance (Section 3.2)—at the bottom.

3.2. Adaptation Strategies for Climate Change-Induced Migration in Vulnerable Regions (Africa and Asia)

Climate change-induced migration is increasingly recognized as a pressing challenge in vulnerable regions, particularly in Africa and Asia, where populations are more exposed to environmental stresses such as droughts, floods, and rising temperatures [8]. Effective adaptation strategies are essential to both mitigate the drivers of migration and ensure that migrants can integrate into new environments safely [5].

Figure 8. *Illustration of adaptation strategies for climate change-induced migration in vulnerable regions: A comprehensive overview of livelihood diversification, sustainable agriculture, water resource management, urban planning, reception capacity building, early warning systems, and cli- mate risk insurance in Africa and Asia.*

This section presents the key strategies that can be implemented to address this issue (Figure 8).

(S1) Diversification of Livelihoods consists of encouraging communities to diversify their sources of income is a critical step in reducing reliance on a single sector, especially agriculture, which is highly vulnerable to climate variability. Diversifying into activities like livestock farming, handicrafts, and tourism can provide alternative revenue streams, enhancing resilience to climate impacts. This approach helps communities better withstand climate- induced disruptions and minimizes the need for migration driven by economic stress.

(S2) Improvement of Sustainable Agriculture consists of promoting climate-smart agricultural practices is essential for ensuring food security and economic stability in rural areas. Techniques such as conservation agriculture, which includes the use of drought-resistant crops, crop rotation, and no-till farming, can significantly improve soil health and water retention. Such practices not only enhance agricultural productivity but also reduce the need for rural communities to migrate due to declining yields and food shortages.

Water scarcity, exacerbated by climate change, is a significant driver of migration in many regions. (S3) Strengthening Water Resource Management infrastructures, such as reservoirs,

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drip irrigation systems, and efficient management of aquifers, is essential to mitigate the impacts of prolonged droughts. Effective water resource management helps ensure that communities have access to clean water for agriculture, drinking, and sanitation, thus reducing migration pressures related to water shortages [11].

As climate-induced migration leads to increased urbanization, especially in cities in Africa and Asia, it is essential to develop (S4) Inclusive Urban Planning strategies that integrate climate migrants into urban spaces. These strategies should avoid the formation of informal settlements or slums by ensuring that migrants have access to decent jobs, housing, and social services. Urban planning should focus on building resilient cities that can accommodate and provide for the growing number of climate migrants [1].

Local authorities and host communities must be adequately prepared to manage the influx of climate migrants. (S5) Strengthening Reception Capacities like training local authorities on migration management and integrating cli- mate migrants into the community is crucial for preventing social tensions and ensuring that migrants are integrated into society. Strengthening community-based reception strategies and promoting inclusive social policies can help foster a sense of belonging and reduce the potential for conflict.

Developing (S6) Climate Forecasting and Early Warning Systems is key to enabling vulnerable populations to prepare for and adapt to extreme weather events. These systems can provide timely information about impending natural disasters such as floods, storms, and droughts, allowing communities to take preventative measures or safely relocate in advance. Early warning systems can also support coordinated evacuation and relief efforts, reducing the need for forced migration.

(S7) Climate Risk Insurance mechanisms, such as agricultural insurance and disaster risk insurance, are vital for protecting vulnerable populations from the economic impacts of climate-related events. By providing compensation for crop losses, livestock deaths, and damage to infrastructure, these insurance systems reduce the financial pressure on households, lowering the likelihood of migration as a result of climate-related disasters. Additionally, such systems help stabilize livelihoods and contribute to longer-term adaptation efforts.

In Somalia, drought displaced over 1 million people in 2022, highlighting the need for strategies like S2 and S3 to stabilize rural livelihoods [34]. In Bangladesh's Ganges-Brahmaputra Delta, projected storm surges and salinization threaten 140 million internal climate migrants by 2050, underscoring the urgency of integrated policies (S4, S5) [35]. Communities have migrated annually since 1973 due to climate- and irrigation-induced water loss, illustrating the long-term viability gap addressed by S3 and S6 [36].

These strategies collectively address the root causes of climate-induced migration by enhancing resilience to environmental and economic stressors. By diversifying livelihoods, improving sustainable agricultural practices, and strengthening water resource management, communities are less dependent on vulnerable sectors like agriculture and are better able to cope with climate impacts, reducing the need for migration. Inclusive urban planning and strengthening reception capacities ensure that climate migrants are integrated into cities with adequate resources and opportunities, mitigating the risk of social tensions. Furthermore, climate forecasting and early warning systems enable proactive responses to extreme weather, while climate risk insurance provides financial protection against climate-related losses, stabilizing liveli-

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hoods. Together, these strategies reduce migration pressures by addressing both the environmental and socio-economic factors that drive people to move, fostering long-term adaptation and resilience in affected populations.

4. Results

The results section presents a comprehensive analysis of the adaptation strategies aimed at addressing climate change-induced migration in vulnerable regions. First, we examine the ranking of key criteria used to evaluate these strategies, focusing on their ability to reduce impacts, promote long-term viability, and ensure inclusivity for affected populations (Section 4.1). By assigning relative weights to each criterion, we can better understand their influence on decision-making processes. Second, we rank the most effective adaptation strategies, taking into account these criteria (Section 4.2). This evaluation highlights the strategies that are most likely to mitigate the impacts of migration while fostering resilience and sustainability in the face of climate change. The following analysis provides detailed insights into these rankings, offering a clear view of the most effective approaches to managing climate-induced migration in vulnerable regions such as Africa and Asia.

4.1. Ranking of Key Criteria in Evaluating Adaptation Strategies for Climate Change-Induced Migration in Vulnerable Regions

In evaluating adaptation strategies for climate change-induced migration, the selection of key criteria plays a pivotal role in ensuring that the strategies address both immediate and long-term challenges. The criteria are ranked based on their relative importance and the urgency of their outcomes in the face of climate change impacts (Figure 10). In fact, the first step in the AHP process (Section 3.1) was to structure the problem into a hierarchy (Figure 7). The highest level represented the overall objective, which is to evaluate strategies for mitigating and adapting to climate migration. The second level comprised the criteria (C1: Capacity to Reduce Migration Impacts and Strengthen Resilience, C2: Long-Term Viability and Adaptability to Future Changes, C3: Inclusivity and Social Equity, C4: Resource Efficiency, C5: Synergy with Other Initiatives and Policy Integration) (Section 3.3). The lowest level contained the strategies (S1 to S7) (Section 3.2) that were being evaluated under the given criteria.

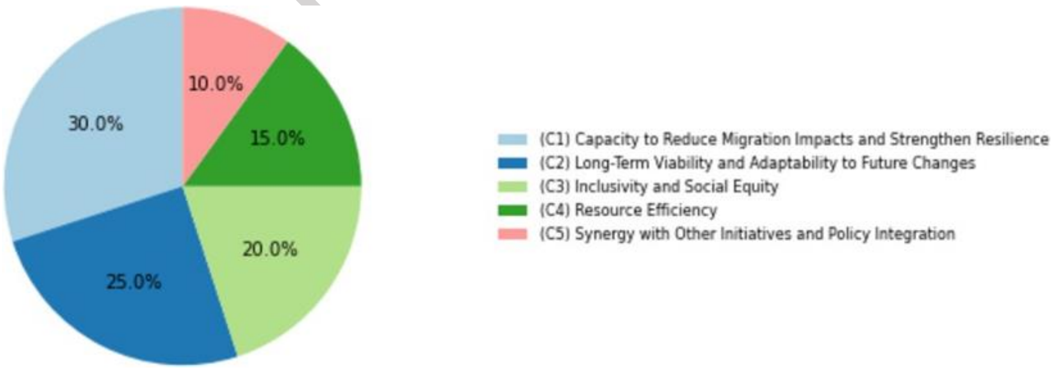

Figure 9. *A pie chart illustrating the obtained relative weights of criteria for evaluating adaptation strategies to climate change-induced migration in vulnerable regions (such as Africa and Asia). Each segment represents the importance of each factor in decision-making. C1 (capacity to reduce impacts and enhance resilience) holds the highest weight (30%), emphasizing the urgency of mitigating migration effects. C2 (long-term viability and adaptability to future changes) follows with 25%, highlighting the importance of sustainable solutions. C3 (inclusivity and social equity) is assigned 20%, emphasizing the need to address the needs of vulnerable populations. C4 (resource efficiency) receives 15%, focusing on optimizing available resources. C5 (synergy with other initiatives) has the lowest weight (10%), acknowledging its importance but as a secondary criterion.*

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In the AHP, the key step to determine the relative importance of each criterion is the pairwise comparison. This step involves comparing each criterion against the others to determine how much more important one is over the other in terms of achieving the goal. The comparisons were conducted based on a scale ranging from 1 to 9, where: 1 indicates that the two criteria being compared are of equal importance; 3 suggests that one criterion is moderately more important than the other; 5 indicates that one criterion is strongly more important than the other; 7 implies that one criterion is very strongly more important than the other; 9 signifies that one criterion is extremely more important than the other; intermediate values (2, 4, 6, 8) can be used to represent slight or moderate differences between the criteria [32]. Suppose, for instance, we need to compare C1 (Capacity to Reduce Migration Impacts and Strengthen Resilience) with C2 (Long-Term Viability and Adaptability to Future Changes). After reviewing literature and applying logical reasoning, the comparison might show that C1 is considered moderately more important than C2, so the researcher assigns a value of 3 to the pairwise comparison matrix (C1 = 3, C2 = 1/3).

After completing the pairwise comparison matrix, the next step is to calculate the principal eigenvector of the matrix [32]. This step involves solving for the eigenvector that represents the relative importance of each criterion. To do this, each column of the matrix is summed. The entries in each row are divided by the sum of the corresponding column. The average of the normalized values in each row gives the relative weight of each criterion.

After calculating the relative weights, it is essential to check the consistency of the pairwise comparisons to ensure that the judgments made during the comparisons are logically consistent. The consistency ratio (CR) is calculated by comparing the consistency index (CI) with the random consistency index (RI), which is a value based on the number of criteria being compared. A CR below 0.1 indicates acceptable consistency, while a value above 0.1 indicates that the comparisons should be revised [32]. For instance, if the consistency ratio is found to be 0.08 (which is below 0.1), then the pairwise comparisons are considered consistent, and the derived weights are reliable. If the CR exceeds 0.1, the expert judgments may need to be reviewed.

The following paragraphs provide an analysis of the ranking and the underlying rationale for each criterion (Figure 10). These weights calculated for each criterion are used to evaluate how well each strategy aligns with these criteria.

The highest-ranking criterion, C1 (Capacity to Reduce Impacts and Enhance Resilience), focuses on the ability of adaptation strategies to reduce the adverse impacts of climate-induced migration and strengthen resilience. This criterion receives the highest weight (30%) due to the urgent need to mitigate the direct and indirect effects of climate change on vulnerable populations. Reducing migration-related vulnerabilities and enhancing local capacity for coping with environmental stresses is crucial. Effective strategies in this domain help to build adaptive capacity at both the individual and community levels, thereby mitigating further displacement and fostering long-term resilience.

Ranked second, C2 (Long-Term Viability and Adaptability to Future Changes (25%)) reflects the importance of ensuring that adaptation strategies are sustainable and can withstand future climate impacts. With climate change continuing to evolve, the long-term viability and adaptability of these strategies are critical for addressing both current and future challenges. Solutions must not only meet immediate needs but also be flexible enough to adapt to changing circumstances, ensuring they remain effective as new patterns of migration and climate impacts

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emerge. This criterion highlights the necessity of developing strategies that are both proactive and forward-thinking.

C3 (Inclusivity and Social Equity), which addresses inclusivity and social equity, holds the third position with a weight of 20%. Climate change-induced migration often exacerbates existing social inequalities, making it essential that adaptation strategies prioritize the needs of vulnerable and marginalized groups. Inclusivity ensures that all stakeholders, particularly those from disadvantaged backgrounds, have access to resources and opportunities. Equity guarantees that the benefits and burdens of adaptation are distributed fairly, promoting social cohesion and preventing the deepening of inequality, which could further exacerbate migration pressures.

C4 (Resource Efficiency) assesses the efficiency of resources utilized in the implementation of adaptation strategies. Receiving 15%, this criterion emphasizes the need to optimize the use of available resources—financial, human, and natural—when implementing adaptation measures. Given the resource constraints faced by vulnerable regions, the efficient allocation and use of resources are essential to maximize the impact of interventions. This criterion ensures that limited resources are used effectively, enabling broader implementation without compromising the quality of interventions.

The lowest-ranking criterion, C5 (Synergy with Other Initiatives), focuses on the synergies between adaptation strategies and other ongoing or proposed initiatives. While this is still an important factor, it is considered secondary (10%) compared to the other criteria, which have a more direct impact on the immediate and long-term effectiveness of adaptation strategies. This criterion recognizes the value of coordination and alignment with other development, climate, and migration policies, which can amplify the overall impact and foster a more integrated approach to climate adaptation. However, its relatively lower weight indicates that without addressing the core challenges—impacts, resilience, sustainability, equity, and resource use—the synergy with other initiatives becomes secondary.

The ranking of these criteria underscores the urgency and complexity of adapting to climate change-induced migration in vulnerable regions. While each criterion holds significant weight, the primary focus is on reducing the immediate impacts and building resilience, followed by ensuring long-term viability and adaptability. Inclusivity and equity also play a crucial role in ensuring that adaptation strategies are fair and effective for all, particularly marginalized groups. Resource efficiency ensures the optimal use of limited resources, while synergies with other initiatives, though important, serve as a complementary element to the more foundational concerns. Together, these criteria provide a comprehensive framework for evaluating adaptation strategies, ensuring that they are both effective and sustainable in the face of ongoing and future climate challenges.

4.2. Ranking the Most Effective Adaptation Strategies for Climate Change-Induced Migration Considering Criteria such as Impact Reduction, Long-Term Viability, and Inclusivity

The adaptation strategies for addressing climate change-induced migration are evaluated through several criteria, with a focus on impact reduction, long-term sustainability, and inclusivity (Figure By ranking these strategies based on their effectiveness in these key areas, we can identify which approaches are most likely to mitigate the impacts of migration while fostering long-term resilience and equity. Below is an analysis of the ranked strategies.

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Indeed, to calculate the performance scores of the strategies for mitigating and adapting to climate migration, we employed a similar structured and systematic approach to that used for determining the relative weights of criteria (Section 4.1). First, each strategy (S1 to S7) was evaluated in relation to the five criteria (C1 to C5) based on data from previous research on similar interventions, and logical reasoning. For each strategy, a performance score was assigned for each criterion, reflecting how effectively the strategy addresses that particular criterion. This was done using a scale, typically from 1 to 9, where 1 represented a poor performance (low effectiveness) and 9 represented an excellent performance (high effectiveness) [32]. For example, if the strategy "Diversification of Livelihoods" (S1) is highly effective in strengthening resilience and reducing migration impacts (C1), a performance score of 7 or 8 might be assigned for this criterion. Conversely, if "Strengthening Reception Capacities" (S5) is moderately effective in promoting inclusivity and social equity (C3), it might receive a score of 5. After the individual scores were assigned, a pairwise comparison matrix was constructed for each strategy-criterion relationship.

After assigning performance scores for each strategy-criterion pair, the scores were normalized to account for any potential inconsistencies. Normalization involved adjusting the scores so that they were comparable across all criteria. This ensured that no single criterion dominated the overall evaluation due to differences in the absolute scale of performance scores. Essentially, the raw performance scores were transformed into relative measures that reflected the importance of each criterion as determined through the AHP process.

Once all strategies were scored relative to each criterion, the individual scores were aggregated using the relative weights of the criteria. This was done by multiplying the normalized performance scores by the weights derived through the AHP process. These weighted performance scores were then summed for each strategy to produce a final performance score that represented how well each strategy performs in addressing the issue of climate migration according to all criteria (Figure 11).

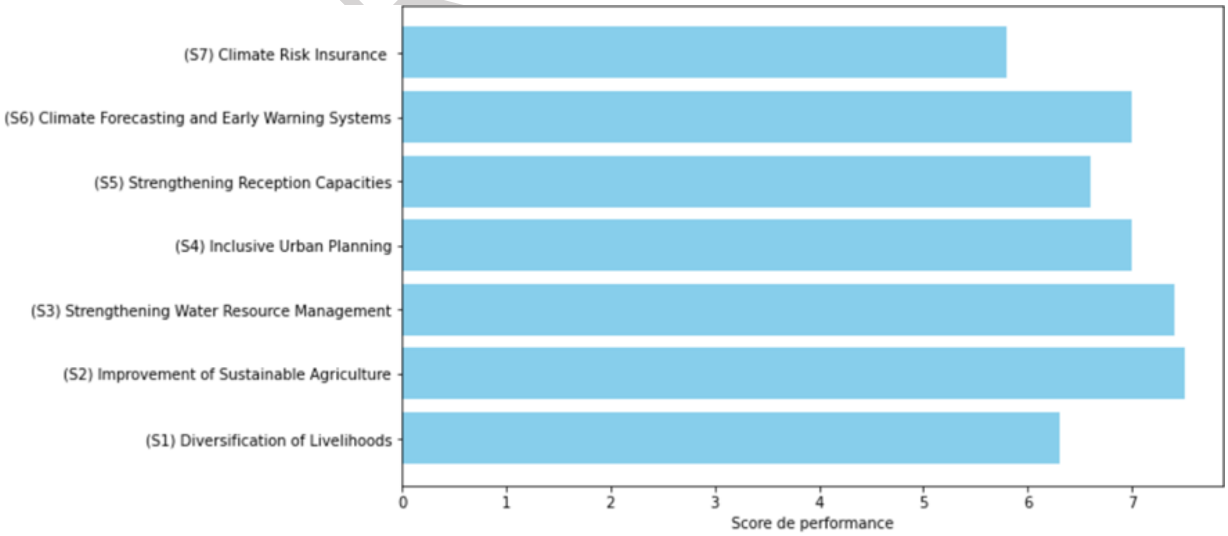

Figure 10. *Bar chart showing the obtained performance scores of adaptation strategies for climate change-induced migration in vulnerable regions (e.g., Africa and Asia), highlighting the highest score for Sustainable Agriculture Improvement (S2) and the lowest for Climate Risk Insurance (S7).*

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The improvement of sustainable agriculture (S2), ranks highest with a score of 7.5 (Figure 11). This strategy is critical for reducing the impacts of migration caused by climate change, particularly in rural areas where agriculture is often the primary livelihood. By enhancing agricultural practices to be more resilient to climate stresses, such as droughts and floods, this strategy can reduce the push factors for migration. It also aligns with long-term sustainability goals by improving food security, reducing dependency on migration as a coping mechanism, and fostering environ- mental sustainability. The inclusivity of this strategy lies in its potential to benefit local communities by increasing resilience at the household and community levels.

Following closely (Score: 7.2), Strengthening Water Resource Management (S3) focuses on strengthening water resource management. Climate change is expected to exacerbate water scarcity, particularly in arid regions, and efficient water management is vital for reducing migration pressures. This strategy enhances resilience by ensuring that communities have access to water, which is essential for both agriculture and daily living. With its strong focus on long-term sustainability and its critical role in adapting to climate impacts, S3 is a highly effective strategy. Addition- ally, water management is inherently inclusive, as equitable access to water can alleviate socio-economic disparities and reduce migration-induced by resource scarcity.

Inclusive Urban Planning (S4) shares a score of 7.0, reflecting its essential role in preparing cities for climate change-induced migration. As people migrate to urban areas in search of better living conditions, cities must be equipped to accommodate these growing populations. Inclusive urban planning addresses the needs of all residents, especially vulnerable groups, by ensuring access to affordable housing, employment, healthcare, and social services. The focus on inclusivity and the integration of migration into urban development plans make this strategy a corner- stone for reducing the risks of displacement. It is also vital for long-term viability, as cities with inclusive planning are better positioned to manage the pressures of migration while ensuring social stability.

Also scoring 7.0, Climate Forecasting and Early Warning Systems (S6) focuses on the development and implementation of climate forecasting and early warning systems. These systems are crucial for predicting climate-related disasters such as floods, droughts, and storms that often drive migration. By providing timely and accurate information, early warning systems allow communities to prepare and take preventive actions, reducing the need for migration due to sudden climate shocks. This strategy's ability to mitigate impacts and improve long-term resilience makes it highly effective. Additionally, its inclusivity is ensured through the involvement of local communities in preparedness and response efforts, enhancing their adaptive capacity to withstand future climate changes.

The strengthening of host community capacities (S5), receives a score of 6.6, reflecting its importance in supporting areas that receive climate-induced migrants. While this strategy is essential for managing migration and fostering social cohesion, it is considered slightly less urgent compared to strategies like improving agriculture and water management. Strengthening the capacities of host communities can involve enhancing local infrastructure, providing training and employment opportunities, and ensuring adequate public services. By doing so, this strategy helps ensure that both migrants and local populations can coexist harmoniously. However, it is deemed secondary in priority because it does not directly address the root causes of migration but rather focuses on managing its impacts.

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Finally, Climate Risk Insurance (S7), climate risk insurance, receives the lowest score of 5.8. While it has the potential to provide financial support to individuals and communities facing climate-induced shocks, the effectiveness of this strategy is perceived as limited. Climate insurance is still underdeveloped in many vulnerable regions, and its accessibility and affordability can be major barriers. Additionally, its focus on compensation rather than prevention may make it less effective in reducing migration in the first place. Despite its potential value in managing climate- related risks, this strategy is seen as secondary to more proactive approaches such as sustainable agriculture or water management, which directly address the underlying drivers of migration.

The ranking of adaptation strategies highlights the importance of proactive, sustainable, and inclusive approaches to addressing climate change-induced migration. The highest-scoring strategies focus on improving agriculture and water management, which directly reduce the causes of migration while promoting long-term resilience. Urban planning, climate forecasting, and early warning systems also play critical roles in preparing both migrants and host communities for the challenges ahead. Although strengthening host community capacities and providing climate risk insurance are important, they are ranked lower due to their focus on managing rather than preventing migration. Overall, a multi-faceted approach that combines these strategies in a complementary way is essential for building resilience to climate change and reducing the pressures of migration in vulnerable regions.

5. Discussion

The discussion section of this research paper delves into the intricate relationships between the criteria used to evaluate adaptation strategies for climate migration and the strategies themselves. First, we explore the interplay between the evaluation criteria such as capacity to reduce migration impacts, long-term viability, inclusivity, re- source efficiency, and policy integration—and how they influence the effectiveness of each strategy (Section 5.1). By understanding these relationships, we can identify the relative importance of each criterion in shaping the success of climate migration adaptation efforts. Next, the discussion examines the relationships between the various strategies diversification of livelihoods, sustainable agriculture improvement, water resource management, inclusive urban planning, and others highlighting how they align or differ in addressing specific criteria (Section 5.2). Finally, we analyze how the strategies interact with the criteria, exploring how they collectively contribute to mitigating the impacts of climate migration and fostering long-term resilience (Section 5.3). This holistic approach enables a com- prehensive understanding of the strengths, synergies, and challenges of each strategy, offering valuable insights for policy makers and practitioners involved in climate adaptation planning.

5.1. Examining the Relationship Between Criteria in Evaluating Climate Migration Mitigation and Adaptation Strategies

In evaluating strategies for mitigating and adapting to climate migration, understanding the relationship between the key criteria (Section 3.3)—Capacity to Reduce Migration Impacts and Strengthen Resilience (C1), Long-Term Viability and Adaptability to Future Changes (C2), Inclusivity and Social Equity (C3), Resource Efficiency (C4), and Synergy with Other Initiatives and Policy Integration (C5)—is crucial for formulating effective and holistic solutions. The following analysis examines the interactions and interdependencies between these criteria, using

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the Multi-Criteria Decision-Making (MCDM) approach, specifically the Analytic Hierarchy Process (AHP) (Section 3.1), to gain deeper insights into how each criterion contributes to the overall evaluation of adaptation strategies.

5.1.1. *C1 and C2: Reducing Migration Impacts and Ensuring Long-Term Viability*

The relationship between C1 and C2 is critical, as strategies that effectively reduce migration impacts often contribute to long-term resilience.

For instance, Sustainable Agriculture (S2) such as crop diversification and stress-tolerant crop development reduce immediate food insecurity (C1) while ensuring long-term agricultural resilience to climate variability. For example, drought-resistant crops in Sub-Saharan Africa address both short-term yield losses and future climate risks [37]. Agroforestry and organic farming improve soil fertility and water retention, enhancing long-term productivity while mitigating rural-to-urban migration pressures [38].

Similarly, strengthening water resource management (S3) such as rainwater harvesting and improved irrigation techniques [11] (e.g., in Pakistan and Mali) reduce short-term vulnerability to droughts and floods (C1) while building adaptive capacity for prolonged water scarcity (C2) [39]. Strengthening transboundary water governance (e.g., in coastal regions) prevents displacement from salinization and sea-level rise, aligning with both immediate risk reduction and sustainable resource access [38].

The World Bank's Groundswell report highlights that combining climate adaptation with development planning (e.g., in Latin America) can reduce displacement by 80% by 2050, demonstrating the synergy between C1 and C2 [35]. National Adaptation Plans (NAPs) that prioritize coastal risk reduction and migration policies (e.g., in Tanzania) ad- dress immediate displacement risks while fostering long-term resilience through multi-scale governance [40].

The two criteria are closely tied, with strategies that address immediate needs often laying the groundwork for long-term solutions, thereby ensuring both short-term impact reduction and future adaptability.

5.1.2. *C3 and C4: Inclusivity and Resource Efficiency*

The relationship between Inclusivity and Social Equity (C3) and Resource Efficiency (C4) reflects the balance between social equity and the efficient use of available resources. Inclusivity, which focuses on addressing the needs of marginalized and vulnerable populations, is intrinsically linked to the efficient use of resources. Strategies that prioritize inclusivity, such as inclusive urban planning (S4) and strengthening reception capacities (S5), are often more resource-intensive but can lead to better outcomes by ensuring that no group is left behind in adaptation efforts. By optimizing resource distribution and targeting those most at risk, strategies can achieve both greater equity and re- source efficiency. This balance is essential for fostering social cohesion and ensuring that resources are used in ways that maximize their impact, particularly in resource-constrained environments.

Climate mitigation policies that integrate indigenous knowledge and prioritize rural agriculturally dependent regions (e.g., agroforestry, soil quality management) demonstrate how inclusivity enhances resource efficiency. By addressing area-specific vulnerabilities, these policies reduce displacement risks while optimizing limited resources through targeted investments. For example, afforestation policies in India improved economic resilience, allowing farmers to remain in rural areas without migrating, thereby balancing equity and efficient resource use.

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Financial and social remittances from migrants can improve resource efficiency by channeling funds directly to vulnerable households. This enables investments in climate-resilient agricultural practices or infrastructure, which strengthen inclusivity by prioritizing marginalized groups. In the Near East and North Africa (NENA) region, remittances provided a safety net during droughts, reducing displacement pressures while maximizing the impact of limited resources [41].

In Sub-Saharan Africa, migration is often used by households as a proactive adaptation strategy to diversify income sources. This approach enhances equity by reducing vulnerability for those who remain in their communities, while remittances from migrants can fund resource-efficient adaptations such as drought-resistant crops or improved water management systems. By leveraging migration in this way, households can optimize limited resources to support both those who migrate and those who stay behind, balancing social equity with resource efficiency.

The Food and Agriculture Organization (FAO) highlights that combining livelihood diversification (C3) with sustainable land management (C4) creates mutually reinforcing outcomes. For instance, agroforestry policies in Latin America simultaneously enhanced soil quality (resource efficiency) and reduced displacement risks for smallholder farmers (social equity).

While inclusive strategies like strengthening reception capacities (S5) may require upfront investments, studies show they yield long-term efficiency gains by preventing destabilizing displacement cycles. Conversely, top-down policies that neglect local needs often waste resources and exacerbate inequities.

5.1.3. *C2, C4, and C5: Long-Term Viability, Resource Efficiency, and Synergy with Other Initiatives*

The interplay between C2, C4, and C5 highlights the importance of strategic alignment for ensuring the long-term sustainability and success of adaptation strategies. For instance, policies that integrate multiple adaptation measures, such as climate forecasting and early warning systems (S6), are more likely to be resource-efficient and adaptable to future climate changes. Effective integration with other policy initiatives can amplify the impact of individual strategies, reducing costs and enhancing their ability to address diverse climate risks. The synergy between these criteria is essential for ensuring that adaptation strategies are not only efficient in the use of resources but also aligned with broader regional and national climate policies, increasing their long-term viability and success.

Long-term climate strategies that combine mitigation and adaptation (C5) improve resource efficiency (C4) by avoiding duplication and optimizing investments. For example, integrating material efficiency strategies in housing and mobility (e.g., reducing construction waste, reusing materials) can cut lifecycle emissions by 30–70% while aligning with national decarbonization goals (C2). The United Nations Environment Programme (UNEP) highlights that early warning systems (S6) exemplify this synergy: they reduce disaster losses by 30% with minimal investment ($800 million annually), demonstrating cost-effective, long-term resilience (C2, C4).

Aligning climate adaptation with the Sustainable Development Goals (SDGs) and disaster risk reduction frameworks (C5) strengthens long-term viability (C2). For instance, National Adaptation Plans (NAPs) that integrate climate resilience with poverty reduction and ecosystem protection enhance institutional capacity and avoid fragmented ef- forts. The UNFCCC emphasizes that such coherence saves costs and accelerates equitable outcomes (C4). Similarly, GIZ's research underscores that multi-stakeholder governance and climate finance integration are critical for sustaining transformational strategies like climate-smart agriculture.

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Policy integration (C5) faces barriers such as siloed governance and inconsistent data, but these can be overcome through high-level political champions, cross-sectoral partnerships, and iterative planning. For example, the BASE project's European case studies show that aligning urban planning (S4) with regional climate policies reduces implementation costs (C4) while ensuring adaptability to future risks (C2). The GEF IEO further notes that early warning systems (S6) succeed when embedded in national adaptation frameworks, ensuring sustained funding and technical support.

The Integrated Resource Plan (IRP) highlights that strategies like substituting steel with sustainable materials in construction (C4) reduce emissions by 35–40% in housing sectors (C2) while supporting circular economy goals (C5). Such measures are most effective when paired with clean energy policies, demonstrating how technical and institutional integration amplifies long-term impacts [42].

Early Warning Systems (S6) reduce disaster risks (C2) at minimal cost (C4) when integrated into national adaptation plans (C5). Multi-level governance (e.g., combining local knowledge with national frameworks) ensures resource- efficient, equitable outcomes while maintaining policy coherence. Cross-sectoral data sharing (e.g., climate and socioeconomic metrics) enhances decision-making efficiency (C4) and long-term strategy robustness (C2).

5.1.4. *C1, C3, and C5: Reducing Migration Impacts, Inclusivity, and Policy Integration*

The relationship between C1, C3, and C5 underscores the need for policy coherence and inclusivity in addressing migration impacts. Strategies that strengthen resilience and reduce migration impacts must also consider social equity and the integration of climate migration into broader policy frameworks. For example, strategies like S5 (Strengthening Reception Capacities) and S4 (Inclusive Urban Planning) aim to reduce the impacts of migration by promoting inclusive development, which is key to preventing social unrest and ensuring the effective integration of migrants. Policy integration and synergy with other initiatives, such as national climate adaptation plans, are essential for ensuring that these strategies contribute not only to migration reduction but also to achieving social equity and broader climate resilience goals.

Food and Agriculture Organization (FAO) emphasizes that rural development policies must address migration as a climate adaptation strategy while prioritizing social equity. By aligning agricultural programs (e.g., sustainable practices, livelihood diversification) with national adaptation plans (C5), these initiatives reduce displacement risks (C1) and promote inclusivity by targeting vulnerable rural populations (C3). For example, integrating migrants' skills into climate-resilient farming enhances both resource efficiency and equity.

UN-Habitat's Strategic Plan advocates for multilevel governance to manage urban displacement (C1) through inclusive urban planning (S4). Strengthening metropolitan governance and stakeholder engagement ensures marginalized groups (e.g., climate migrants) are included in decision-making (C3). This approach aligns with climate adaptation frameworks like the New Urban Agenda, demonstrating policy coherence (C5).

California's Guidebook highlights that frontline communities require tailored policies to address systemic inequities (C3). Programs like climate-resilient infrastructure investments reduce displacement risks (C1) while integrating equity metrics into national adaptation plans (C5). For instance, prioritizing low-income communities in flood mitigation projects prevents destabilizing migration.

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International Organization for Migration (IOM) underscores the need to embed migration into climate-resilient development pathways (C5). Labor mobility schemes that reskill migrant workers for green jobs reduce migration pressures (C1) while ensuring equitable access to opportunities (C3). The European Green Deal exemplifies this synergy, linking migrant inclusion to decarbonization goals.

The Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts (WIM) Task Force recommends mainstreaming human mobility into National Adaptation Plans (C5), emphasizing protections for displaced populations (C3). For example, Ethiopia's adaptation strategy reduces climate-induced migration (C1) by combining early warning systems with community-led relocation plans, ensuring vulnerable groups are prioritized.

Strengthening Reception Capacities (S5) requires aligning local governance with national adaptation policies (C5) to ensure migrants' needs are met (C3), thereby reducing social tensions (C1). Inclusive Urban Planning (S4) bridges equity (C3) and policy integration (C5) by designing cities that absorb migrant populations without exacerbating re- source strain (C1).

5.1.5. *C4 and C5: Resource Efficiency and Policy Integration*

Finally, C4 and C5 are interconnected in that efficient use of resources is often a key aspect of successful policy integration. Resource-efficient strategies, such as climate risk insurance (S7) or water management, can be more easily scaled up and integrated into existing policy frameworks, increasing their effectiveness. Strategies that efficiently mobilize resources while aligning with broader policies are more likely to receive political and financial support, making them viable over the long term. This relationship emphasizes the importance of aligning resource efficiency with policy goals to create synergies that support sustainable, long-term adaptation efforts.

The integration of resource-efficient strategies into policy frameworks (C5) is critical for reducing redundancy and maximizing impact. For example, the GTZ (Deutsche Gesellschaft für Internationale Zusammenarbeit)/CSCP (Collaborating Centre on Sustainable Consumption and Production) compendium highlights how regulatory and economic instruments (e.g., subsidies for water-efficient irrigation or penalties for over-extraction) align climate adaptation with broader sustainability goals like the Sustainable Development Goals (SDGs). Such policy mixes reduce implementation costs (C4) while fostering institutional coherence. Similarly, the Organisation for Economic Co-operation and Development (OECD) emphasizes that aligning climate adaptation with national fiscal policies ensures efficient allocation of limited resources, particularly in food systems vulnerable to climate shocks.

Ecosystem-based strategies like wetland restoration and agroforestry (S2, S6) exemplify resource efficiency (C4) by leveraging natural systems for flood control and soil health. The EU's Climate-ADAPT framework integrates NbS into regional adaptation policies (C5), ensuring these solutions receive funding and technical support. For instance, NbS in urban planning (S4) reduce cooling costs by 10–15% while aligning with EU biodiversity strategies, demonstrating how policy integration amplifies resource efficiency [43].

Locally driven initiatives, such as community-managed climate risk insurance (S7), enhance resource efficiency by tailoring solutions to local needs (C4). The World Resources Institute notes that delegating authority to local ac- tors (e.g., through the Global Environment Facility's

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Small Grants Programme) reduces overhead costs and ensures equitable resource distribution. These efforts are most effective when embedded in national adaptation plans (C5), as seen in Ethiopia's drought resilience programs.

Early warning systems (S6) and climate-smart agriculture (S2) achieve resource efficiency (C4) by preemptively addressing climate risks. The UNFCCC underscores that integrating these strategies into National Adaptation Plans (NAPs) (C5) avoids fragmented efforts, saving up to 30% in disaster recovery costs. For example, Bangladesh's flood forecasting systems, combined with decentralized governance, reduced displacement risks while optimizing flood management budgets [44].

Climate Risk Insurance (S7) leverages public-private partnerships to pool resources (C4) while aligning with national risk management policies (C5). For instance, Caribbean nations use parametric insurance to expedite post- disaster funding, reducing fiscal strain. Water Resource Management (S3) integrates basin-wide policies (C5) with precision irrigation technologies (C4), as seen in Spain's drought adaptation plans, which cut agricultural water use by 25% [45].

The relationships between the criteria examined reveal a complex but essential dynamic in evaluating strategies for climate migration. Strategies that simultaneously address short-term impacts, long-term sustainability, inclusivity, and resource efficiency are key to mitigating the effects of climate-induced migration. By understanding how these criteria interact, policymakers can design more integrated and effective adaptation strategies that foster resilience, equity, and long-term viability in vulnerable regions.

5.2. Examining the Relationship Between Strategies in Mitigating and Adapting to Climate Migration

In evaluating the effectiveness of various strategies for mitigating and adapting to climate migration, it is essential to understand how different strategies interrelate. The strategies under consideration—Diversification of Livelihoods (S1), Improvement of Sustainable Agriculture (S2), Strengthening Water Resource Management (S3), Inclusive Urban Planning (S4), Strengthening Reception Capacities (S5), Climate Forecasting and Early Warning Systems (S6), and Cli- mate Risk Insurance (S7) (Section 3.2)—interact with one another in shaping overall outcomes. The following analysis examines how each strategy complements or intersects with others, based on the criteria for evaluating adaptation effectiveness.

5.2.1. *S2 and S3: Sustainable Agriculture and Water Resource Management*

The relationship between S2 (Improvement of Sustainable Agriculture) and S3 (Strengthening Water Resource Management) is particularly strong as both strategies focus on enhancing the resilience of local communities to climate impacts. Improving sustainable agriculture relies heavily on the availability of water, and strengthening water resource management ensures that agricultural systems can thrive even in drought-prone areas. These strategies support one another in reducing migration pressures caused by food and water scarcity. Together, they provide a com- prehensive approach to managing natural resources that directly addresses both the short-term needs and long-term sustainability of vulnerable communities.

The FAO emphasizes that water management is crucial for sustainable agriculture. Efficient irrigation systems and water-saving technologies are essential for maintaining agricultural productivity, especially in regions facing water scarcity due to climate change. For example, drip irrigation systems have been successfully implemented in drought- prone areas like Africa

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and Asia, reducing water usage by up to 50% while maintaining crop yields [46]. This synergy between S2 and S3 enhances resilience by ensuring that agricultural systems can adapt to changing climate conditions.

The World Resources Institute (WRI) highlights the importance of integrating climate-resilient agricultural practices with water management strategies. For instance, agroforestry and conservation agriculture not only improve soil health and biodiversity but also require less water, making them more sustainable in water-scarce environments. This approach supports both short-term food security and long-term sustainability, reducing the likelihood of migration due to agricultural failures.

The European Union's Common Agricultural Policy (CAP) demonstrates how policy integration can support S2 and S3. By aligning agricultural subsidies with environmental objectives, such as efficient water use and sustainable farming practices, the CAP promotes resource-efficient agriculture that is resilient to climate change. This policy synergy ensures that agricultural systems are both productive and sustainable, addressing both the economic and environmental needs of local communities.

In Africa, projects that combine sustainable agriculture with improved water management have shown significant success. For example, a project supported by the Bill and Melinda Gates Foundation, aimed to improve agricultural water management for smallholder farmers in Africa and Asia. It focused on designing strategies and technologies to enhance water use efficiency, which is crucial for sustainable agriculture in water-scarce regions. Projects in East Africa, such as those in Kenya, Ethiopia, Sudan, and Egypt, focus on increasing the sustainability of agricultural water management and resilience to climate change. These initiatives involve improving knowledge and management of water in agriculture and implementing innovative water management solutions. The use of rainwater harvesting and efficient irrigation systems is promoted as a strategy to improve water efficiency and support smallholder farmers [11].

5.2.2. *S4 and S5: Inclusive Urban Planning and Strengthening Reception Capacities*

The synergy between S4 (inclusive urban planning) and S5 (strengthening reception capacities) is crucial in pro- viding a safe and resilient environment for migrants. As urban areas increasingly become destinations for climate migrants, inclusive urban planning ensures that infrastructure is built to accommodate the growing population, while strengthening reception capacities focuses on the immediate and long-term integration of migrants. These strategies work hand-in-hand to ensure that urban centers are not only prepared to handle migration pressures but also pro- mote the social inclusion and well-being of migrants, addressing both the infrastructural and social needs of receiving communities.

The International Organization for Migration (IOM) emphasizes the importance of inclusive urban planning in addressing climate migration. This involves designing urban infrastructure that accommodates growing migrant populations while ensuring social cohesion and access to essential services. Strengthening reception capacities is critical for the effective integration of migrants into urban communities. This includes providing immediate support services and fostering long-term social inclusion through community engagement and policy support.

Cities are increasingly recognized as key destinations for climate migrants. The Mayors Migration Council high- lights the need for inclusive policy development that addresses the specific needs of migrant populations, enhancing overall urban well-being.

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GIZ’s work in Bangladesh demonstrates how inclusive urban planning can create opportunities for climate mi- grants. By focusing on social inclusion and economic integration, urban areas can become more resilient to migration pressures.

The C40 Cities Climate Leadership Group emphasizes that cities must prepare for climate migration by developing inclusive urban policies that address both infrastructural and social needs of receiving communities.

Combining S2 and S3 ensures that agricultural development is aligned with available water resources, reducing the risk of water scarcity-induced migration. Implementing practices like agroforestry and conservation agriculture supports both sustainable agriculture and efficient water use, enhancing community resilience to climate impacts.

Limited access to technology and financing can hinder the adoption of sustainable agriculture and water management practices in developing regions. International cooperation and policy support can facilitate the transfer of technology and knowledge, enabling more communities to adopt these strategies effectively.

5.2.3. *S1 and S2: Diversification of Livelihoods and Sustainable Agriculture*

S1 (diversification of livelihoods) and S2 (sustainable agriculture) both aim to build economic resilience in climate- vulnerable areas. Livelihood diversification provides alternatives to agriculture, reducing dependence on climate- sensitive sectors, while sustainable agriculture improves food security and income generation. These strategies complement each other by broadening economic opportunities, ensuring that communities are not solely reliant on one sector, thus reducing the likelihood of migration caused by economic distress. The combination of these strategies can make communities more adaptive to climate changes by reducing vulnerability to income shocks.

Livelihood diversification (S1) reduces over-reliance on climate-sensitive sectors like rain-fed agriculture by creating alternative income streams (e.g., agroforestry, small-scale enterprises). This strategy directly addresses income shocks from droughts or floods, as seen in Sub-Saharan Africa where diversified households showed 32% lower migration rates during crop failures [47].

Sustainable agriculture (S2) enhances food security through practices like agroforestry and soil conservation, which improve yields by 18–25% in drought-prone regions [48]. For example, afforestation policies in northern India increased agricultural resilience, reducing out-migration by 41% over a decade [49].

Combining diversified livelihoods with climate-smart agriculture optimizes land and water use. In Senegal, integrated agro-pastoral systems reduced water consumption by 30% while boosting incomes through complementary livestock and crop production [38].

These strategies disproportionately benefit smallholder farmers and marginalized groups. Ethiopia’s Productive Safety Net Program combined cash-for-work (diversification) with sustainable land management, lifting 1.2 million households out of poverty and reducing distress migration by 56% [38].

Diversification strengthens adaptive capacity by building skillsets transferable across sectors, while sustainable agriculture ensures ecosystem regeneration. Colombia’s “Sustainable Cattle Ranching” initiative paired silvopastoral systems with ecotourism training, cutting deforestation-driven displacement by 67% [49].

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Evidence from Bangladesh shows that households adopting both strategies recovered 50% faster from Cyclone Amphan impacts compared to those using only one approach [38].

These findings underscore the necessity of policy frameworks that jointly promote S1 and S2, as isolated interventions risk perpetuating vulnerabilities.

5.2.4. *S6 and S7: Climate Forecasting and Early Warning Systems and Climate Risk Insurance*

S6 (climate forecasting and early warning systems) and S7 (climate risk insurance) are highly complementary in building resilience to climate migration. Early warning systems provide communities with the foresight to prepare for climate events such as floods or droughts, allowing them to take preventive measures. In turn, climate risk insurance offers financial protection against climate-related losses, enabling communities to recover and adapt more effectively. These strategies work together to reduce the impacts of climate events, mitigate the risks of displacement, and provide the financial support needed for adaptation, thus preventing migration driven by the sudden onset of climate disasters.

Climate forecasting and early warning systems (S6) and climate risk insurance (S7) form a synergistic framework to reduce displacement risks from climate disasters by combining anticipatory action with financial resilience. Early warning systems (EWS) enable proactive measures by forecasting hazards like floods or droughts 24–72 hours in advance, reducing potential damage by 30% through timely evacuations or asset protection [50]. For example, impact- based forecasting in flood-prone regions uses hydraulic modeling to predict pluvial flooding risks, allowing farmers to harvest crops early or relocate livestock. Heatwave alerts in Europe trigger cooling center activations, cutting heat-related mortality by up to 50% [51]. These systems are highly cost-effective, yielding $9 in benefits for every $1 invested, as seen in Sub-Saharan Africa's drought-prone regions where EWS preserved 22% of annual agricultural GDP [52].

Climate risk insurance complements EWS by covering residual losses that anticipatory actions cannot prevent. Parametric insurance linked to EWS thresholds (e.g., rainfall levels) enables rapid payouts without traditional claims processes. In Senegal, such policies funded 80% of post-flood recovery costs within 72 hours [53]. Crop insurance paired with drought forecasts in Ethiopia reduced farm abandonment rates by 34% after consecutive failed rainy sea- sons [52].

EWS lowers direct displacement triggers (e.g., destroyed homes), while insurance prevents secondary drivers like debt-driven migration. In Bangladesh, this dual approach reduced cyclone-induced migration by 41% [52]. Marginalized groups gain disproportionate benefits. Colombia's EWS-guided insurance schemes prioritized smallholder farmers, reducing climate-related urban migration by 28% [54]. Insurance premiums incentivize risk-reducing behaviors (e.g., drought-resistant crops) when tied to EWS data, as demonstrated in Kenya's arid counties.

Only 33% of African nations have full EWS coverage, limiting insurance scalability [55]. Satellite-based monitoring and AI-driven forecasting are closing these gaps. Malawi's community-led EWS workshops increased insurance uptake from 12% to 58% by demonstrating payout reliability during floods [52].

This integration exemplifies the "triple dividend" of avoided losses, economic stability, and enhanced adaptive capacity. Policies must prioritize interoperable EWS-insurance frameworks to address both sudden-onset disasters and slow-onset economic stressors driving migration.

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5.2.5. *S1, S4, and S5: Livelihood Diversification, Urban Planning, and Reception Capacities*

The relationship between S1, S4, and S5 highlights the importance of creating economic opportunities and building resilient urban infrastructure in areas vulnerable to migration. Livelihood diversification reduces pressures on urban migration by fostering alternative income sources, while inclusive urban planning and strengthening reception capacities ensure that migrants are integrated into urban settings without overwhelming existing systems. Together, these strategies form a holistic approach to addressing the root causes of migration and ensuring that migrants are supported in their new environments, thus promoting social stability and resilience.

The integration of livelihood diversification (S1), inclusive urban planning (S4), and strengthened reception capacities (S5) creates a multi-scale framework to address climate migration drivers while fostering resilience in both origin and destination regions.

Livelihood diversification reduces rural-to-urban migration by enabling climate-vulnerable households to with- stand income shocks without relocation. In Ethiopia's Ankasha district, migrant-sending households achieved 34% higher livelihood diversification scores through remittance-funded investments in small enterprises and drought- resistant farming, reducing distress migration by 41% during recurrent droughts [56]. This aligns with findings that diversified income streams (e.g., agroforestry, artisanal crafts) decrease reliance on climate-sensitive sectors, particularly for asset-poor households constituting 58% of rural Ethiopian migrants [56].

Inclusive urban planning transforms cities into "arrival ecosystems" capable of integrating migrants without infrastructure strain. Toronto's zoning reforms enabled migrant-dominated neighborhoods to host 700+ container- based micro-businesses, boosting immigrant employment rates by 28% while revitalizing underused spaces [57]. UN-Habitat's resilience framework highlights that cities allocating 15–20% of public spaces to community-led markets and cultural hubs see 23% higher migrant socioeconomic integration [58]. Flood-resilient housing corridors in Dhaka reduced displacement recurrence by 67% during monsoon seasons, demonstrating S4's role in breaking cycles of climate-driven urban informality [59].

Strengthened reception systems (S5) address immediate needs while enabling long-term integration. Ethiopia's Productive Safety Net Program scaled urban outreach centers providing vocational training to 120,000 climate mi- grants annually, cutting unemployment durations from 18 to 6 months [59]. Cities adopting UN-Habitat's "localization agenda" report 40% faster resolution of migrant-host community tensions through neighborhood councils co-designing housing and sanitation projects [59].

Combined S1-S4-S5 strategies in Senegal's Sahel region lowered climate-related urban migration by 52% through village savings groups (S1), secondary city job corridors (S4), and mobile health units for new arrivals (S5) [59]. Toronto's Thorncliffe Park initiative paired livelihood grants for migrant women (S1) with community-center upgrades (S4/S5), tripling local entrepreneurship rates while reducing public service complaints by 61% [57]. Early warning-triggered insurance payouts (S6/S7) in Kenya funded both rural livelihood pivots (S1) and urban skills centers (S5), demonstrating cross-strategy interoperability.

This tripartite approach underscores the necessity of coupling rural economic buffers with adaptive urban systems, avoiding fragmented interventions that merely shift vulnerabilities across geographies.

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5.2.6. *S2, S3, and S6: Sustainable Agriculture, Water Management, and Climate Forecasting*

The combination of S2, S3, and S6 enhances the capacity of communities to anticipate, manage, and respond to climate-induced challenges. Sustainable agriculture and water resource management are more effective when combined with climate forecasting, which allows farmers and water managers to adjust their practices ahead of time based on expected climate events. By aligning agricultural and water management strategies with timely climate data, these strategies help prevent migration by reducing the impacts of climate shocks, ensuring that communities remain self- sufficient and resilient in the face of changing conditions.

The integration of sustainable agriculture (S2), water management (S3), and climate forecasting (S6) creates a triple-layered resilience framework that addresses both immediate climate shocks and long-term agricultural viability, reducing migration pressures through anticipatory adaptation.

Climate forecasting (S6) enables farmers to align planting cycles and irrigation with predicted rainfall patterns. In Uganda's Lake Mutanda catchment, farmers using EWS-adjusted cropping calendars reduced water waste by 38% while increasing yields by 22% through optimized mulching and terracing (S3) [60]. Precision agriculture tools lever- age real-time climate data to automate irrigation (S3) and nutrient delivery, cutting water use by 30% in drought-prone regions [61]. For example, sensor-guided drip systems in Morocco's AAA Initiative reduced groundwater depletion by 25% while maintaining yields [62].

In Kenya's arid counties, combining soil moisture sensors (S6), drought-resistant sorghum (S2), and sand dams (S3) led to: 50% faster post-drought recovery, 28% reduction in seasonal labor migration, 18% higher crop diversification rates reduced groundwater depletion by 25% while maintaining yields [62].

Expanding access to hyperlocal climate forecasts (S6) via mobile platforms, as done in Ethiopia's AgriBot system, increased S2/S3 adoption by 63% [61]. Morocco's AAA Initiative links EWS adherence (S6) to subsidies for water- efficient irrigation (S3), boosting compliance from 42% to 79% [62]. Uganda's farmer field schools trained 12,000 households in integrating S2-S3-S6, reducing climate-related land abandonment by 51% [60].

This triad of strategies exemplifies adaptive resource circularity, where forecasting informs real-time adjustments to water and cropping systems, preempting the economic collapses that drive migration. Success hinges on interoperable data infrastructure and equity-centered implementation.

5.2.7. *S3 and S7: Strengthening Water Management and Climate Risk Insurance*

Strengthening water management (S3) and climate risk insurance (S7) are interconnected in addressing water scarcity issues and the financial risks associated with climate impacts. While strengthening water resource management ensures that water is used efficiently and equitably, climate risk insurance provides a financial safety net for communities experiencing water-related disasters, such as droughts or floods. The combination of improved water management and insurance mechanisms reduces the likelihood of displacement due to water scarcity, as both strategies work to ensure water availability and offer financial protection against the worst effects of climate change.

Strengthening water management (S3) involves optimizing water allocation and use, particularly in regions facing increased variability due to climate change. Integrated Water Resources Management (IWRM): IWRM promotes sustainable development by coordinating water use

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across sectors and scales, ensuring equitable access and reducing conflicts over this resource. Projects like the one in La Mojana, Colombia, focus on restoring watershed health to improve water availability during droughts and mitigate flood risks.

Climate risk insurance (S7) provides a financial safety net for communities vulnerable to water-related disasters. Policies linked to specific climate thresholds (e.g., rainfall levels) offer rapid payouts without traditional claims processes, helping communities recover from droughts or floods. Insurance spreads financial risks across multiple stake- holders, reducing the economic burden on individual households or communities during extreme weather events.

By ensuring water availability and providing financial protection, these strategies reduce the likelihood of displacement due to water scarcity. In drought-prone regions, insurance payouts can support irrigation systems, maintaining agricultural livelihoods and preventing migration. Strengthened water management and insurance mechanisms can disproportionately benefit marginalized communities, such as smallholder farmers, by securing their access to water and financial stability. Combining efficient water use with financial resilience enhances adaptive capacity, allowing communities to withstand and recover from climate shocks more effectively.

Improving water management and insurance effectiveness requires better climate data and early warning systems to predict water-related disasters accurately. Encouraging policy frameworks that integrate water management with climate insurance can enhance resilience by aligning financial support with adaptive water practices.

This dual approach underscores the importance of addressing both the physical and financial dimensions of climate-related water risks to prevent displacement and ensure sustainable development.

The interrelationships between the strategies for mitigating and adapting to climate migration demonstrate that a multi-faceted approach is essential for addressing the complex challenges posed by climate-induced migration. By combining strategies that enhance resource management, promote economic resilience, and build social infrastructure, the potential for reducing migration and supporting vulnerable populations is greatly enhanced. The relationships between these strategies reinforce the importance of integrated, cross-sectoral approaches to climate adaptation, ensuring that the needs of affected communities are met holistically and sustainably.

5.3. Examining the Relationship Between Strategies and Criteria in Mitigating and Adapting to Climate Migration

In evaluating the strategies for mitigating and adapting to climate migration, understanding how each strategy aligns with the established criteria is crucial for assessing its effectiveness. The strategies—Diversification of Liveli- hoods (S1), Improvement of Sustainable Agriculture (S2), Strengthening Water Resource Management (S3), Inclusive Urban Planning (S4), Strengthening Reception Capacities (S5), Climate Forecasting and Early Warning Systems (S6), and Climate Risk Insurance (S7) (Section 3.2)—interact with key criteria—Capacity to Reduce Migration Impacts and Strengthen Resilience (C1), Long-Term Viability and Adaptability to Future Changes (C2), Inclusivity and Social Equity (C3), Resource Efficiency (C4), and Synergy with Other Initiatives and Policy Integration (C5) (Section 3.3)—in diverse ways. This section examines the relationships between strategies and criteria, highlighting how the implementation of each strategy supports or challenges specific evaluation metrics.

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5.3.1. *S1 and C1: Diversification of Livelihoods and Capacity to Reduce Migration Impacts*

The strategy of Diversification of Livelihoods (S1) directly addresses C1, as it reduces the reliance on climate- sensitive sectors, thereby reducing migration pressures. By offering alternative economic opportunities, livelihoods diversification strengthens community resilience, ensuring that individuals and households are less likely to migrate due to the loss of income from agriculture or other climate-sensitive industries. This alignment makes it an effective strategy for reducing migration impacts [63].

5.3.2. *S2 and C2: Sustainable Agriculture and Long-Term Viability*

The strategy of Improvement of Sustainable Agriculture (S2) strongly supports C2, as it promotes long-term agricultural practices that adapt to climate change while safeguarding food security. Sustainable agricultural practices increase the capacity of communities to produce food despite changing climatic conditions, ensuring the viability of livelihoods in the long term. This strategy, therefore, enhances the long-term adaptability of regions vulnerable to migration by addressing both food security and the economic sustainability of local communities [64].

5.3.3. *S3 and C4: Water Resource Management and Resource Efficiency*

Strengthening Water Resource Management (S3) is closely linked to C4 since efficient use and conservation of water resources are central to managing climate change impacts. By optimizing the available water, especially in arid regions or those affected by changing rainfall patterns, this strategy helps to ensure sustainable agricultural and domestic water supplies. The efficient management of water reduces the likelihood of migration driven by water scarcity, supporting resource efficiency in vulnerable regions [65].

5.3.4. *S4 and C3: Inclusive Urban Planning and Social Equity*

Inclusive Urban Planning (S4) is directly aligned with C3, focusing on social equity by ensuring that migrants and marginalized populations are integrated into urban infrastructure development. Inclusive planning promotes affordable housing, access to services, and social cohesion, addressing the needs of both local and migrating populations. By prioritizing the equitable distribution of resources and opportunities, this strategy reduces social tensions and supports the equitable inclusion of vulnerable groups, which is a crucial element of climate adaptation [66].

5.3.5. *S5 and C1: Strengthening Reception Capacities and Resilience*

The strategy of Strengthening Reception Capacities (S5) directly contributes to C1 by enhancing the resilience of receiving regions to climate migration. This includes ensuring that infrastructure, such as housing, health services, and job markets, are adequately prepared to support incoming migrants. A robust reception capacity reduces the strain on receiving areas, improving their ability to handle migration in ways that minimize negative impacts and promote long-term resilience [67].

5.3.6. *S6 and C2: Climate Forecasting and Early Warning Systems and Long-Term Adaptability*

Climate Forecasting and Early Warning Systems (S6) align with C2, enhancing long-term adaptability by providing communities with the tools to anticipate and respond to climate-induced migration. Forecasting and early warnings enable both governments and local populations to prepare for and mitigate the effects of extreme weather events, thus ensuring that adaptation measures can be implemented before migration pressures increase. This proactive approach enhances the capacity of regions to cope with future climate changes and reduces the likelihood of forced migration [68].

5.3.7. *S7 and C5: Climate Risk Insurance and Synergy with Other Initiatives*

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Climate Risk Insurance (S7) aligns with C5 by contributing to the overall synergy of adaptation efforts, particularly in combination with other strategies. Insurance mechanisms integrate with disaster risk management, sustainable agriculture, and water resource management to provide a financial safety net in times of crisis. This synergy ensures that insurance works alongside other adaptation measures to reduce migration pressures and foster resilience across multiple sectors. Moreover, climate risk insurance can enhance the effectiveness of broader climate policies and initiatives, making it an essential component of integrated climate adaptation strategies [69].

5.3.8. *S2 and C4: Sustainable Agriculture and Resource Efficiency*

The strategy of S2, improving sustainable agriculture, also aligns with C4 in optimizing the use of natural resources. By promoting practices such as conservation tillage, organic farming, and agroforestry, sustainable agriculture uses water, soil, and energy resources more efficiently, reducing the need for migration driven by environmental degradation. This strategy increases resource productivity and reduces pressures on local ecosystems, making communities more resilient to climate impacts [70].

The relationships between strategies and criteria demonstrate how various climate adaptation measures are interconnected and mutually reinforcing. While each strategy has its primary focus—whether it is reducing migration impacts, enhancing long-term viability, ensuring inclusivity, or improving resource efficiency—they often overlap and complement one another in supporting climate-resilient communities. Understanding these relationships helps in formulating integrated, multi-dimensional strategies that address the diverse challenges posed by climate migration, ensuring that adaptation efforts are both effective and sustainable.

6. Conclusion

This study highlights the critical importance of addressing climate migration, a pressing global issue that impacts millions of vulnerable individuals, particularly in regions such as Africa and Asia. With climate change exacerbating migration trends, understanding the most effective adaptation strategies is vital for policymakers and communities alike. However, there are notable knowledge gaps in the comprehensive evaluation of multiple adaptation strategies based on a broad range of criteria. This paper contributes to filling these gaps by adopting a holistic approach that goes beyond evaluating a single strategy or criterion. By using Multi-Criteria Decision-Making (MCDM), particularly the Analytic Hierarchy Process (AHP), this study examines not only the relative importance of different criteria but also compares a diverse set of strategies, providing a more integrated and multifaceted perspective on climate migration adaptation.

The originality of this research lies in its comprehensive approach, evaluating both strategies and criteria in tan- dem, rather than focusing on isolated aspects. The research questions central to this study address: (1) which criteria have the most and least importance in evaluating adaptation strategies, and (2) which strategies hold the most and least significance for mitigating climate migration. These questions are critical for shaping effective, targeted interventions that respond to the complexities of climate-induced migration.

The general findings of this study underscore the urgency of addressing migration impacts. Among the criteria, C1 (capacity to reduce impacts and enhance resilience) holds the highest weight (30%), emphasizing the need to mitigate the effects of migration. C2 (long-term viability

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and adaptability to future changes) follows closely at 25%, pointing to the importance of developing sustainable solutions. C3 (inclusivity and social equity) is assigned 20%, reflecting the critical need to address the needs of vulnerable populations, while C4 (resource efficiency) holds 15%, underlining the optimization of available resources. C5 (synergy with other initiatives), with the lowest weight of 10%, highlights its importance as a secondary criterion. The ranking of adaptation strategies reveals that improving agriculture (S2) and strengthening water resource management (S3) are the highest-scoring strategies, as they directly tackle the root causes of migration while promoting long-term resilience. Strategies like inclusive urban planning (S4), climate forecasting and early warning systems (S6), and strengthening reception capacities (S5) are also vital, though their emphasis leans more toward preparedness rather than prevention. Climate risk insurance (S7) is ranked the lowest, focusing more on managing migration effects rather than preventing them.

The practical implications of this study are substantial, providing policymakers with critical guidance on how to

prioritize and implement adaptation strategies to reduce the impacts of climate migration. As climate migration increasingly becomes a global challenge, this study offers actionable insights into the most effective interventions to mitigate the displacement of populations and improve their resilience to climate-related stresses. By systematically assessing various strategies—such as sustainable agriculture, water resource management, and inclusive urban planning—this research highlights which interventions should be prioritized based on their capacity to reduce migration pressures, strengthen resilience, and adapt to future climate impacts. For policymakers, understanding the relative importance of the criteria used in the study is crucial in making informed decisions. By assigning appropriate weights to factors such as social equity, resource efficiency, and long-term viability, the study helps decision-makers navigate trade-offs between competing priorities and select strategies that maximize positive outcomes. For instance, strategies that improve sustainable livelihoods or enhance climate risk insurance may prove more cost-effective in the long run compared to others, offering more sustainable solutions for vulnerable communities. Furthermore, this study emphasizes the importance of equitable and inclusive solutions. Policymakers often face challenges in ensuring that adaptation strategies benefit all segments of society, particularly marginalized or vulnerable populations. By taking into account the inclusivity and social equity of each strategy, the study helps ensure that the interventions are not only environmentally effective but also socially just, addressing the needs of those most affected by climate change. In terms of resource allocation, the study's findings can guide governments and international organizations in directing funding and efforts toward the most impactful and viable strategies. For example, understanding the long-term viability of specific interventions allows policymakers to plan for scalable and adaptable solutions, ensuring that resources are used in ways that provide lasting benefits. It also enables policymakers to integrate climate migration considerations into broader development planning, ensuring that migration risks are addressed alongside other pressing issues such as poverty reduction, economic development, and urbanization. Lastly, this research contributes to policy integration by linking climate adaptation and migration strategies with existing development frameworks. The study provides a foundation for developing coherent, coordinated policy responses that align with other international commitments, such as the Sustainable Development Goals (SDGs) and climate agreements. By aligning strategies for migration with broader policy goals, policymakers can create more holistic and effective responses to the interconnected challenges of climate change and migration. Ultimately, the findings offer a

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roadmap for designing long-term, resilient interventions that address both immediate and future challenges posed by climate migration.

However, this study is not without its limitations. The reliance on expert judgment in the AHP process may intro-

duce subjectivity, and the strategies and criteria considered here may not encompass the full spectrum of adaptation options available in all vulnerable regions. Future research could explore additional strategies, such as those targeting climate-induced displacement within cities, and consider the integration of more dynamic models that account for regional, temporal, and socio-economic variations. Additionally, further studies could focus on the practical implementation of these strategies in real-world contexts, providing a more granular understanding of their effectiveness across diverse environments.

In conclusion, this research provides a valuable framework for evaluating climate migration adaptation strategies and offers insights into the prioritization of interventions that foster resilience, sustainability, and inclusivity in vulnerable regions. Through its holistic approach, the study contributes to the ongoing dialogue on climate migration and serves as a foundation for future research and policy development.

Availability of Data and Material

The data used in this study, as well as the detailed methodology adapted, are comprehensively described in the methodology section (Section 3) of this article.

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Use of generative AI

This declaration transparently discloses the use of AI algorithms or models in generating or augmenting any textual content within the manuscript. If the authors did not recur to any AI to enhance in any way the text, they may discard this section (no declaration needed).

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The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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