Reports

Global Resilience Nexus: Forging a Sustainable Future

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Abstract: The global resilience nexus: Forging a sustainable future presents a groundbreaking framework designed to enhance global resilience through interconnected components. At its core is the cultivation of inclusive community networks, fostering collaboration, engagement and collective action. By uniting policymakers, practitioners and community members, the framework facilitates the co-creation of robust solutions. Knowledge sharing and mapping play a pivotal role, enabling the exchange of best practices, lessons learned and inventive ideas. This aids in identifying knowledge gaps, directing resilience-building efforts and fostering a culture of mutual learning and cooperation. The framework explored the intricate relationship between climate change and migration, focusing on vulnerable regions like Puerto Rico, Haiti, Senegal, Moldova and Bangladesh. By delving into the experiences of these communities, it aimed to devise strategies addressing challenges in environmental change, population dynamics, human security and public policy. The goal was to amplify adaptive capacities, reduce vulnerabilities and foster sustainable solutions for climate-induced migration and host communities. Acknowledging the pivotal role of minerals in the transition to renewable energy and the digital economy, the framework confronted associated risks like environmental degradation and social disparities. Through cross-regional and cross-sectoral stakeholder dialogues, it fostered consensus-building for policies that advance a more resilient supply chain, emphasizing environmental, social and governance considerations. Another facet addressed the convergences of environmental change, security and conflicts, scrutinizing how environmental stressors contribute to conflicts and human insecurity. The framework examined the role of sustainable environmental practices in conflict prevention and peacebuilding, aiming to cultivate a more resilient and peaceful world. Finally, it tackled global food insecurity exacerbated by climate change, inflation, the COVID-19 pandemic and geopolitical tensions. Recognizing the need to fortify agricultural systems and enhance access to nutritious food, it aimed to amplify resilience through sustainable agriculture practices, innovative food production methods and inclusive policies, ensuring food sovereignty for all.

Keywords: Global Resiliency, Sustainable Future, Climate Change, Environmental and Social Factors, Governance, Food Security

Introduction

The recent pandemic has compelled societies to urgently seek sustainable solutions for confronting these worldwide challenges. Global resiliency is defined as the capacity of communities, regions and nations to effectively respond to and recover from global challenges, such as climate change, economic instability and social inequalities (Carmen *et al.*, 2022). It involves building adaptive capabilities, fostering collaboration and implementing strategies that enable societies to withstand shocks, adapt to changing circumstances and thrive in the face of adversity (Duchek, 2020). Indeed, global resiliency is an essential quality that equips communities, regions and nations to confront and navigate the increasingly complex and interconnected challenges of our world. It entails the development of robust systems, policies and strategies that enhance preparedness, response and recovery capabilities.

By building adaptive capacities, societies can effectively withstand and rebound from a range of threats, including natural disasters, economic downturns, public health crises and social disruptions. At the core of global resiliency lies the recognition of interdependencies and the need for collaboration (Pavez *et al.*, 2022). It involves forging partnerships and fostering cooperation among diverse stakeholders, including governments, communities, civil society organizations, businesses and academia. By working together, these actors can pool resources, knowledge and expertise to tackle shared challenges, address systemic vulnerabilities and implement comprehensive solutions.

A sustainable future goes hand in hand with global resiliency, aiming to create a world that meets the needs of the present generation while ensuring the ability of future generations to thrive (United Nations, 2023). It involves integrating environmental, social and economic considerations to establish a harmonious and balanced approach to development. Sustainable practices encompass responsible resource management, the reduction of carbon emissions, the preservation of biodiversity, the promotion of social equity and the adoption of inclusive and ethical economic models (Hariram, 2023). A sustainable future is crucial for several reasons. First, it recognizes the finite nature of our planet's resources and the urgent need to transition to more sustainable practices to mitigate environmental degradation and climate change. By embracing sustainability, we can protect ecosystems, conserve biodiversity and mitigate the impacts of global warming, thus safeguarding the natural systems upon which life depends (IPCC, 2022). Second, a sustainable future promotes social equity and inclusivity, striving to eradicate poverty, reduce inequalities and ensure access to basic needs, such as clean water, sanitation, healthcare, education and economic opportunities (IADB, 2023). It recognizes that social stability, cohesion and well-being are integral to resilience and sustainable development (Sachs, 2015). Third, a sustainable future is closely tied to economic stability and prosperity. By embracing sustainable business practices and investing in green technologies, societies can unlock new economic opportunities, generate jobs and foster innovation. It offers a pathway for economic growth that is aligned with environmental preservation and social well-being, ultimately contributing to long-term stability and prosperity. Lastly, a sustainable future is crucial for fostering peace and stability. Environmental degradation, resource scarcity and social inequalities can act as drivers of conflict. By addressing these underlying issues, promoting sustainable resource management and encouraging the equitable distribution of resources, we can create conditions for peaceful coexistence, cooperation and conflict prevention. Global

resiliency and a sustainable future are inextricably linked and mutually reinforcing. They provide a framework for addressing the complex challenges of our time and creating a world that is better prepared, environmentally responsible, socially just, economically prosperous and harmoniously interconnected. By embracing global resiliency and striving for a sustainable future, we can navigate the uncertainties of the present and build a more secure, equitable and thriving world for current and future generations (Le Blanc, 2015).

The framework is visually encapsulated in a comprehensive figure that vividly illustrates the intricate interconnections between its various components. This visual representation serves as a powerful roadmap, delineating how each facet synergistically contributes to the overarching goal of building global resilience. It vividly portrays the pivotal role of inclusive community networks, knowledge sharing and mapping, climate change and migration strategies, critical minerals resilience, environmental change and security initiatives and food security interventions. The figure underscores the dynamic and interdependent nature of these components, highlighting their collective impact on fostering a sustainable and resilient future. By providing a visual blueprint, this figure offers a holistic perspective, guiding stakeholders toward a deeper understanding of how these components work in concert to address the complex challenges of our rapidly changing world.

The Global Resilience Framework

The global resilience nexus: Forging a sustainable future is a groundbreaking framework designed to address the complex interplay of global challenges in our rapidly changing world. This visionary approach recognizes the urgent need to build resilience on a global scale, acknowledging that traditional siloed solutions are insufficient in the face of interconnected crises. At its core, this framework places a strong emphasis on inclusivity, collaboration and collective action within local communities, drawing together policymakers, practitioners and community members. Through this inclusive network, diverse perspectives and expertise converge, allowing for the co-creation of robust and adaptable solutions. This collaborative ethos forms the bedrock for a multifaceted approach that not only addresses pressing issues such as climate change, migration, critical minerals, environmental security and food insecurity but also empowers communities, fosters sustainability and promotes peace. Now let's embark on a deeper exploration into the specific components of this comprehensive framework.

Inclusive Community Networks

Inclusive community networks: The component of "inclusive community networks" within the global resilience framework is centered around the development of resilient networks at the local community level. It recognizes that building resilience starts from the ground up, within the communities themselves (Berkes and Ross, 2013). The goal is to create networks that are inclusive, collaborative and participatory, involving diverse stakeholders such as policymakers, practitioners and community members. First and foremost, inclusivity lies at the heart of this component. It seeks to ensure that the voices and perspectives of all community members, particularly marginalized and vulnerable groups, are heard and valued in the resilience-building process. Inclusivity fosters a sense of ownership, empowerment and collective responsibility among community members, enhancing their capacity to navigate challenges effectively.

Collaboration is another key element of inclusive community networks. It encourages partnerships and cooperation between different stakeholders within the community, as well as with external actors such as NGOs, businesses and government agencies. Collaborative efforts enable the pooling of resources, expertise and knowledge, maximizing the collective impact of resilience-building initiatives (CIF, 2023). By working together, community networks can tap into a wide range of skills, experiences and perspectives, leading to more comprehensive and effective solutions.

Active participation of all stakeholders is vital in shaping resilience strategies (Aldunce *et al*., 2021). Policymakers, practitioners and community members are encouraged to actively engage in the decision-making processes related to resilience planning and implementation. This participatory approach ensures that resilience strategies are contextually relevant, responsive to local needs and reflective of the aspirations and concerns of the community. It empowers individuals and communities to take ownership of their resilience journey, fostering a sense of agency and self-determination.

The development of inclusive community networks also involves capacity-building and knowledge-sharing activities (Noya and Clarence, 2009). It equips community members with the necessary skills, information and tools to identify and address resilience challenges. Capacity-building initiatives may include training programs, workshops and awareness campaigns that enhance individuals'' understanding of resilience concepts and their ability to implement resilience measures. Moreover, knowledge-sharing platforms provide opportunities for communities to learn from one another, exchange best practices and access relevant resources and expertise.

By fostering the development of resilient networks at the local community level, the global resilience framework recognizes that the strength of a community lies in its collective ability to adapt and withstand challenges. Inclusive community networks create a sense of social cohesion, mutual support and shared responsibility (Moustakas, 2023). They promote a culture of resilience, where community members are actively engaged, informed and equipped to navigate the complexities of the changing world. Ultimately, these networks contribute to building sustainable, adaptive and thriving communities that are better prepared to face global challenges and promote the well-being of their members.

Case Studies and Examples of Inclusive Community Networks

Case study 1: Transition towns (United Kingdom) (Quilley, 2011) Transition towns are a grassroots movement that aims to build resilience and sustainability at the community level. It encourages local communities to come together and develop their initiatives to address environmental and social challenges. Transition towns promote inclusivity by engaging policymakers, practitioners and community members in shaping resilience strategies. Through collaborative efforts, communities develop projects such as community gardens, renewable energy installations and local food networks, fostering a sense of ownership, collaboration and empowerment.

Case Study 2: Kerala's community-based disaster management (India) (Ali and George, 2022) Kerala, a state in India prone to annual monsoon floods, has implemented a community-based disaster management approach. This initiative emphasizes the involvement of local communities in disaster preparedness, response and recovery. It promotes inclusivity by actively engaging community members, including women, marginalized groups and local leaders, in decision-making processes and resilience-building activities. Through training programs, workshops and the establishment of local disaster management committees, Kerala has fostered resilient networks that effectively respond to flood-related challenges.

Case study 3: Resilient cities network (global) (Martin-Moreau and Ménascé, 2018) The resilient cities network is a global network that brings together cities to address urban resilience challenges. It promotes inclusivity by encouraging collaboration and participation among policymakers, practitioners and community members. The network facilitates knowledge sharing, capacity building and peer learning among member cities. For example, the city of Rotterdam in the Netherlands actively engages local stakeholders, including businesses, community organizations and residents, in the development and implementation of its climate adaptation strategies. This inclusive approach has led to the creation

of innovative solutions and the building of resilient networks within the city.

Case study 4: Participatory budgeting (Porto Alegre, Brazil) In Porto Alegre, Brazil (De Sousa Santos, 1998), participatory budgeting has been implemented to foster inclusive community networks. This initiative allows community members to directly participate in decision-making processes regarding the allocation of public funds. Through inclusive deliberation and collaboration, community members actively engage in shaping resilience strategies by prioritizing investments in infrastructure, social programs and environmental initiatives. This approach not only empowers the community but also promotes transparency, accountability and effective resource allocation.

Case Study 5: Community resilience building in Post-disaster Recovery (Christchurch, New Zealand) (Dionisio and Pawson, 2016) Following the devastating earthquake in 2011, Christchurch, New Zealand, embraced an inclusive community resilience-building approach during its postdisaster recovery. Community-led initiatives were encouraged to rebuild and revitalize the city. The involvement of policymakers, practitioners and community members in shaping resilience strategies allowed for a collective vision and ownership of the recovery process. Community groups, businesses and residents worked together to develop innovative solutions, such as the creation of community gardens, pop-up spaces and sustainable housing projects, fostering a strong sense of resilience and community cohesion.

These case studies and examples demonstrate how inclusive community networks can be fostered by promoting collaboration, participation and engagement among policymakers, practitioners and community members. By involving diverse stakeholders in shaping resilience strategies, communities can build resilient networks that address environmental, social and economic challenges, ultimately enhancing their capacity to adapt and thrive in the face of adversity.

Knowledge Sharing and Mapping

Knowledge sharing and mapping: The component of "knowledge sharing and mapping" within the global resilience framework plays a crucial role in enhancing global resilience by establishing a platform for the exchange of valuable insights, best practices and innovative ideas (Fig. 1). It recognizes the power of knowledge as a catalyst for informed decision-making, effective planning and the implementation of resilient strategies (Aghazadeh Ardebili and Padoano, 2020). At its core, knowledge sharing enables stakeholders from diverse backgrounds, sectors and regions to learn from one another's experiences. Lessons learned from successful resilience initiatives can be shared, highlighting effective strategies, tools and approaches that

can be replicated or adapted in different contexts. By disseminating this knowledge, stakeholders can avoid reinventing the wheel and benefit from the collective wisdom of others, ultimately accelerating the pace of resilience-building efforts. Additionally, knowledge sharing fosters collaboration and the creation of networks among stakeholders. Facilitating connections and dialogue, encourages the exchange of ideas, promotes partnerships and stimulates innovation. This collaborative approach enables stakeholders to tap into a broader pool of expertise, resources and perspectives, leading to more robust and comprehensive resilience solutions.

Mapping knowledge resources is a complementary aspect of this component (Alvarez-Meaza et al., 2020). It involves systematically identifying, organizing and categorizing existing knowledge in the field of resilience. By mapping knowledge, stakeholders can gain a comprehensive understanding of the available resources, identify gaps and areas of weakness and prioritize areas for further development. This mapping process helps to ensure that efforts are focused on addressing critical knowledge gaps and that resources are allocated effectively. The knowledge mapping process can involve the creation of databases, repositories, or interactive platforms that house a variety of resources, including research studies, reports, case studies, guidelines and toolkits (Osmundson et al., 1999). These knowledge repositories serve as a centralized hub where stakeholders can access and contribute to a wealth of information, fostering continuous learning and collaboration.
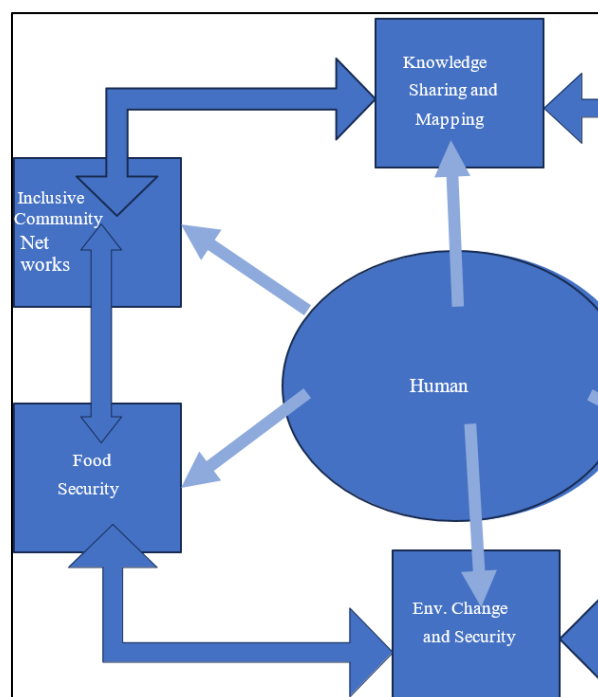

Fig. 1: Components of the global resilience framework

Moreover, knowledge mapping enables stakeholders to identify emerging trends, innovative practices and cutting-edge research that can inform and shape resilience strategies. It allows for the identification of new technologies, methodologies and approaches that have the potential to enhance resilience and adaptability in the face of evolving challenges. By staying abreast of the latest knowledge, stakeholders can proactively respond to emerging risks and seize opportunities to strengthen global resilience.

Ultimately, the component of knowledge sharing and mapping within the global resilience framework helps to create a culture of learning, collaboration and continuous improvement. It promotes the dissemination of valuable knowledge, fosters collaboration and facilitates the identification of knowledge gaps and areas for further development. By leveraging knowledge and insights, stakeholders can make informed decisions, design effective resilience strategies and enhance the overall resilience of communities, regions and nations.

Case Studies and Examples of Knowledge Sharing and Mapping

Case study 1: Global Resilience Partnership (GRP): The global resilience partnership is an initiative that focuses on knowledge sharing and mapping to enhance global resilience (GRP, 2023). It brings together a diverse range of stakeholders, including governments, research institutions, NGOs and communities, to share lessons learned, best practices and innovative ideas. The partnership utilizes an online platform to facilitate the exchange of knowledge and experiences related to resilience-building efforts. By mapping knowledge resources, identifying gaps and prioritizing areas for further development, the GRP supports evidence-based decision-making and promotes collaboration in building resilience worldwide.

Case study 2: Rockefeller Foundation 100 Resilient Cities (RFF, 2022) The 100 Resilient Cities program, supported by the Rockefeller Foundation, aims to help cities around the world become more resilient to social, economic and environmental challenges. As part of this initiative, a knowledge-sharing platform was established to enable cities to share their experiences, strategies and best practices for building resilience. The platform allows cities to map their resilience challenges and solutions, providing a valuable resource for other cities facing similar issues. This knowledge-sharing and mapping approach enhances the global understanding of urban resilience and enables cities to learn from one another's successes and challenges.

Case study 3: International Network on Disaster Risk Reduction (DRRNet, 2022): The International Network on Disaster Risk Reduction (DRRNet) is a global network that promotes knowledge sharing and collaboration in disaster risk reduction. It brings together organizations, researchers and practitioners working in the field of disaster risk reduction to exchange information, share research findings and identify best practices. Through conferences, workshops and online platforms, DRRNet facilitates the mapping of knowledge resources and fosters collaboration to enhance global resilience against disasters.

Case study 4: Climate Adaptation Knowledge Exchange (CAKE) (CakeX, 2023) The Climate Adaptation Knowledge Exchange (CAKE) is an online platform that provides a space for practitioners, policymakers and researchers to share knowledge and resources related to climate change adaptation. It features case studies, tools and best practices from around the world, allowing users to access and contribute to a wealth of information on climate resilience. By mapping and organizing knowledge in a user-friendly manner, cake supports informed decision-making and enables practitioners to learn from each other's experiences in building resilience to climate change.

These case studies and examples demonstrate how knowledge-sharing and mapping initiatives contribute to enhancing global resilience. By establishing platforms for sharing lessons learned, best practices and innovative ideas and by mapping knowledge resources, gaps can be identified and prioritized areas for further development can be determined. This approach fosters collaboration, enables evidence-based decision-making and promotes the exchange of valuable knowledge and experiences, ultimately strengthening global resilience efforts.

Climate Change and Migration

Climate change and migration: The component of "climate change and migration" within the global resilience framework focuses on understanding and addressing the intricate relationship between climate change and migration. It acknowledges that climate stressors can have significant impacts on population dynamics, human security and foreign policy, particularly in regions such as Senegal, Moldova and Bangladesh which are highly vulnerable to climate-related challenges (IOM, 2023). Climate change has the potential to disrupt ecosystems, alter weather patterns and exacerbate natural disasters, leading to environmental degradation, resource scarcity and livelihood insecurity (Adger *et al.*, 2005). These adverse impacts can create conditions that drive people to migrate in search of better opportunities, safety and survival. Understanding the challenges faced by communities affected by climate change-induced migration is crucial for developing strategies that mitigate the risks and enhance resilience.

This component seeks to explore the complex dynamics between climate change and migration,

considering both the environmental and socioeconomic factors at play. It involves comprehensive research and analysis to understand the push and pull factors of migration in the context of climate stressors. By examining case studies in regions like Senegal, Moldova and Bangladesh, stakeholders can gain insights into the specific challenges faced by affected communities, including displacement, loss of livelihoods, social disruptions and human security concerns (IOM, 2022).

Based on this understanding, strategies can be developed to address the impacts of climate stress on population dynamics, human security and foreign policy. These strategies may include interventions that focus on climate adaptation and mitigation, the creation of sustainable livelihood opportunities, social protection mechanisms and the provision of essential services to communities affected by climate-induced migration. The aim is to build the resilience of both the communities experiencing migration and the receiving communities, ensuring that their needs are met and their rights are protected.

Furthermore, the component of climate change and migration recognizes the importance of a multi-sectoral and multi-stakeholder approach in addressing these challenges (IOM, 2010). It involves collaboration between governments, international organizations, civil society and affected communities to develop and implement coordinated responses. This collaborative approach ensures that the strategies and policies developed are holistic, contextually relevant and inclusive, taking into account the perspectives and needs of all stakeholders. By addressing the impacts of climate change on migration, the Global resilience framework aims to minimize the negative consequences and maximize the opportunities associated with population movements. It seeks to foster resilience among communities affected by climate-induced migration, supporting their adaptation efforts, ensuring their human security and integrating them into sustainable development pathways. Ultimately, this component contributes to building a more resilient and equitable world where the challenges posed by climate change and migration are effectively addressed and communities are empowered to thrive in the face of environmental changes.

Case Studies and Examples of Climate Change and Migration

Case study 1: Senegal rural-urban migration (World Bank, 2023) Senegal is experiencing the impacts of climate change, including sea-level rise, coastal erosion and increasing temperatures. These environmental changes have significant implications for livelihoods and food security, particularly in rural areas dependent on agriculture and fishing. As a result, many rural residents are migrating to urban areas in search of better opportunities and resources. Organizations such as the International Organization for Migration (IOM) are working in Senegal to study the climate change-migration nexus and develop strategies to support migrants and the communities they leave behind. By understanding the challenges faced by communities affected by climate stress and migration, interventions can be designed to enhance resilience, promote sustainable livelihoods and ensure social cohesion.

Case study 2: Moldova climate-induced displacement (World Bank, 2021) Moldova, a landlocked country in Eastern Europe, is vulnerable to climate change impacts such as droughts, floods and extreme temperatures. These environmental challenges can lead to displacement, as communities face difficulties in agriculture, water availability and economic stability. The United Nations Development Programme (UNDP) has supported projects in Moldova to address climate-induced displacement by strengthening local capacities, supporting sustainable agriculture practices and promoting climate-resilient infrastructure. By integrating climate change adaptation and migration strategies, Moldova aims to minimize the negative impacts of climate stress on population dynamics, human security and foreign policy.

Case study 3: Bangladesh climate refugees Bangladesh is highly susceptible to climate change, with a significant portion of its population living in low-lying coastal areas prone to cyclones, flooding and sea-level rise. These environmental challenges have led to an increase in climate refugees, as people are forced to migrate due to the loss of homes, livelihoods and agricultural productivity. The government of Bangladesh, in collaboration with international organizations like the IOM and UNDP, is implementing initiatives to address climate-induced migration and protect the rights of climate refugees. These efforts involve creating adaptive strategies for coastal communities, developing resilient infrastructure and promoting sustainable livelihood options. By focusing on the impacts of climate stress on migration and human security, Bangladesh is working towards a comprehensive approach that integrates climate resilience and social protection.

These case studies highlight the complex relationship between climate change and migration, particularly in regions like Senegal, Moldova and Bangladesh. By understanding the challenges faced by communities affected by climate stress and migration, strategies can be developed to address the impacts on population dynamics, human security and foreign policy. These include interventions to support sustainable livelihoods, enhance resilience, protect the rights of migrants and promote social cohesion. By integrating climate change adaptation and migration strategies, these regions aim to mitigate the negative consequences of climate change and foster more resilient communities.

Case study 4. San Pedro, Belize (Pacheco, 2018): This is a town in the southern part of Ambergris Caye, an island off the coast of Belize. It is a popular tourist destination and a major source of income for the country. However, it is also facing the threats of sea level rise, coastal erosion, coral bleaching and storm surges, which have damaged its infrastructure, economy and environment (Raworth, 2017). Many residents have decided to relocate to the mainland or other countries, such as the United States, Canada, or Mexico, in search of better opportunities and security[1].

Case study 5. Barbuda, Antigua and Barbuda (IOM, 2021): This is a small island in the eastern Caribbean, with a population of about 1,600 people. It is known for its pristine beaches, wildlife and cultural heritage. However, in 2017 it was devastated by Hurricane Irma, which destroyed 95% of its buildings and forced the entire population to evacuate to the neighboring island of Antigua Canada.

Case study 6. La Barquita, Dominican Republic: This is a low-income neighborhood in Santo Domingo, the capital city of the Dominican Republic. It is located along the Ozama River, which frequently overflows due to heavy rainfall and storm surges. The residents of La Barquita have suffered from flooding, landslides, water contamination and disease outbreaks for decades. In 2016, the government launched a relocation project to move about 1,500 families from La Barquita to a new housing complex on higher ground, with improved facilities and services[3].

Critical Minerals Resilience

The component of "critical minerals resilience" within the Global Resilience Framework focuses on addressing the rising demand for critical minerals, driven by the global transition to renewable energy and the rapid development of the digital economy. It recognizes the importance of these minerals in supporting key industries and technologies while acknowledging the associated environmental, social and governance risks. Critical minerals are essential for the production of renewable energy systems, energy storage technologies, electric vehicles and digital devices. However, their extraction, processing and supply chain operations can have significant environmental and social impacts, such as habitat destruction, water pollution and human rights violations. Therefore, it is crucial to develop strategies and policies that promote the resilience of the critical minerals supply chain while minimizing these risks.

The component involves leading cross-regional and cross-sectoral stakeholder dialogues to foster collaboration and consensus-building (IRENA, 2023). Governments, industry stakeholders, civil society organizations and local communities come together to discuss and develop policies that promote a resilient

supply chain for critical minerals. These dialogues provide a platform for sharing knowledge, experiences and best practices, facilitating the development of comprehensive and effective strategies. The focus of these dialogues is on promoting resilient supply chain policies that address environmental, social and governance risks. This includes measures to ensure responsible sourcing and extraction practices, as well as transparency and accountability throughout the supply chain. By mitigating environmental impacts, protecting the rights of local communities and promoting good governance, stakeholders can build a resilient supply chain that supports sustainable development and minimizes negative externalities.

Cross-regional and cross-sectoral stakeholder dialogues in critical minerals resiliency should convene experts, policymakers and industry leaders from diverse regions and sectors to address the complex challenges associated with the extraction and utilization of critical minerals. These dialogues typically should feature structured discussions, workshops and collaborative sessions focused on topics such as responsible sourcing, environmental sustainability and governance practices. The outcomes should include actionable strategies, consensus-building on ethical supply chain policies and innovative approaches to balancing mineral demand with environmental and social responsibilities. By fostering a collaborative environment and drawing on a broad spectrum of expertise, these dialogues will ultimately play a pivotal role in informing policies that drive responsible critical minerals sourcing, extraction and utilization on a global scale. They will ensure that policies strike a balance between meeting the demands of a transitioning global economy and safeguarding the environment and local communities.

Additionally, the component emphasizes the need to diversify sources of critical minerals to reduce dependency on a few regions or countries. This can involve exploring alternative mining locations, developing innovative recycling and circular economy practices and investing in research and development to identify substitutes for critical minerals. Diversification helps to minimize supply chain vulnerabilities, reduce geopolitical risks and enhance global resilience in the face of disruptions. Furthermore, the component recognizes the importance of integrating sustainability criteria into decision-making processes related to critical minerals. This includes considering environmental and social impacts in the assessment of mining projects, promoting responsible practices and supporting the development of green technologies that reduce the reliance on critical minerals.

Successful diversification strategies in critical minerals sourcing are exemplified by companies like

Lynas Corporation, which operates Rare Earth Element (REE) mines in Australia and a processing plant in Malaysia, providing an alternative supply route to China. Glencore, a multinational mining company, has diversified its cobalt sourcing by operating mines in the Democratic Republic of Congo (DRC) and Canada. Syrah resources, through its Balama graphite project in Mozambique, contribute to reducing dependence on traditional graphite sources. SQM, based in Chile, has played a crucial role in diversifying the global supply of lithium, leveraging China' 's significant lithium reserves. Impala Platinum, operating mines in South Africa and Canada, showcases successful diversification in Platinum Group Metals (PGMs) sourcing. These case studies underscore the importance of geographically diverse operations in mitigating geopolitical risks and ensuring a stable, responsible and resilient global supply chain of critical minerals.

By addressing the increasing demand for critical minerals and promoting resilient supply chain policies, the global resilience framework aims to ensure the sustainable and responsible development of these resources. It strives to balance the need for critical minerals with the protection of the environment, the well-being of communities and the promotion of good governance. Ultimately, this component contributes to building a more resilient and sustainable future where critical minerals are sourced and utilized responsibly and ethically.

Case Studies and Examples of Critical Minerals Resilience

Case study 1: Responsible sourcing of Cobalt in the Democratic Republic of Congo (DRC) (IRENA, 2023) The Democratic Republic of Congo is a major producer of cobalt, a critical mineral used in the production of lithium-ion batteries for electric vehicles and renewable energy storage systems. However, the extraction of cobalt in the DRC has been associated with environmental degradation, human rights violations and child labor. To address these challenges, cross-sectoral stakeholder dialogues have been initiated by organizations like the Responsible Minerals Initiative (RMI) and the Global Battery Alliance (GBA). These dialogues bring together governments, mining companies, civil society organizations and international bodies to develop responsible sourcing policies, improve transparency and mitigate the environmental, social and governance risks associated with cobalt production.

Case study 2: Sustainable extraction of rare Earth elements in Greenland (IRENA, 2023) Greenland has vast deposits of Rare Earth Elements (REEs), critical minerals essential for various clean technologies, including wind turbines, electric vehicles and energy-efficient lighting. Recognizing the importance of responsible extraction, Greenland has engaged in cross-regional stakeholder

dialogues to develop sustainable mining practices. The government has collaborated with international partners, such as the European Union and Nordic countries, to support the development of a robust regulatory framework that ensures environmental protection, community engagement and fair labor practices. By promoting resilient supply chain policies for REEs, Greenland aims to mitigate the environmental and social impacts associated with mining activities and foster the sustainable development of its critical minerals sector.

Case study 3: The World Economic Forum's mining and metals blockchain initiative. The World Economic Forum has launched the mining and metals blockchain initiative to promote responsible sourcing and resilient supply chain management in the mining sector. By utilizing blockchain technology, stakeholders across the value chain can track the origin and movement of critical minerals, ensuring transparency and reducing the risk of unethical practices. This initiative brings together mining companies, governments and technology providers to establish standards and protocols for responsible mineral sourcing, thereby mitigating environmental, social and governance risks.

Case study 4: United States critical minerals strategy (Foreign Policy, 2023) Recognizing the importance of critical minerals for national security and economic competitiveness, the United States has developed a comprehensive critical minerals strategy. This strategy involves cross-sectoral stakeholder dialogues, including government agencies, industry representatives and environmental organizations, to identify vulnerabilities in the supply chain and develop resilient policies. The aim is to reduce dependence on foreign sources and promote domestic production, while also addressing environmental concerns and ensuring responsible extraction practices.

These case studies and examples demonstrate the efforts being made to address the increasing demand for critical minerals and promote resilient supply chain policies. Through cross-regional and cross-sectoral stakeholder dialogues, strategies are being developed to mitigate environmental, social and governance risks associated with critical mineral extraction. These initiatives emphasize responsible sourcing, transparency and collaboration among stakeholders, ultimately contributing to the sustainable development of critical mineral sectors and the transition to a renewable energy and digital economy.

Environmental Change and Security

Environmental change and security: The component of "environmental change and security" within the global resilience framework aims to investigate and understand the interconnections between environmental change, health, population dynamics, conflicts and foreign policy

(Wilson Center, 2023a). It recognizes that environmental stressors can have far-reaching implications for human security and the potential to escalate conflicts, while also emphasizing the importance of sustainable environmental practices in conflict prevention. This component involves comprehensive research and analysis to explore how environmental change, such as climate change, deforestation and resource scarcity, affects human health, population dynamics and socioeconomic conditions (Tilman and Clark, 2014). By understanding these interconnections, stakeholders can identify the drivers of conflicts and vulnerabilities that arise from environmental stressors, enabling more targeted and effective interventions.

The focus is on analyzing how environmental stressors impact human security, including access to clean water, food security, displacement and vulnerability to diseases. By examining these impacts, stakeholders can develop strategies and policies that address the root causes of conflicts and contribute to conflict prevention. This may involve promoting sustainable environmental practices, resource management and climate resilience measures that mitigate the risks and reduce tensions. Moreover, this component recognizes the role of environmental change and security in shaping foreign policy. Environmental concerns are increasingly intertwined with national and international security considerations. By analyzing the linkages between environmental change and conflicts, stakeholders can inform foreign policy decisions that promote peace, stability and sustainability. This includes promoting dialogue, cooperation and diplomatic efforts to address environmental challenges and prevent conflicts.

Additionally, the component highlights the importance of sustainable environmental practices as a means of conflict prevention. By adopting and promoting sustainable practices, such as renewable energy, conservation and ecosystem restoration, stakeholders can mitigate environmental stressors, promote social stability and reduce the likelihood of conflicts arising from resource competition (The White House, 2023). The component also recognizes the need for collaboration and coordination among different actors, including governments, international organizations, civil society and local communities. By working together, stakeholders can share knowledge, experiences and best practices, foster cooperation and implement joint initiatives that address the complex challenges at the intersection of environmental change, health, population dynamics, conflicts and foreign policy.

By investigating the interconnections between environmental change and security, the global resilience framework seeks to inform policies and actions that promote conflict prevention, sustainable environmental practices and the protection of human security. It recognizes that environmental challenges are not isolated issues but have significant implications for

social, economic and political stability. By addressing these challenges holistically, stakeholders can contribute to building a more resilient and peaceful world, where the well-being of people and the environment are mutually reinforced.

Case Studies and Examples of Environmental Change and Security

Case Study 1: Lake Chad Basin (Relief, 2023) climate change and conflict the lake Chad Basin, located in West Africa, has experienced significant environmental changes, including prolonged droughts and the shrinking of Lake Chad itself. These environmental stressors have contributed to conflicts and insecurity in the region, as competition for dwindling resources, such as water and arable land, has escalated. The Lake Chad Basin commission, in collaboration with regional and international partners, has implemented initiatives that address the interconnections between environmental change, population dynamics and conflicts. By promoting sustainable environmental practices, restoring ecosystems and supporting livelihood diversification, these efforts aim to prevent conflicts and enhance human security in the region.

Case study 2: Sudan environmental degradation and Darfur conflict (Macauley, 2016). The Darfur conflict in Sudan has been influenced by environmental degradation, particularly desertification and competition over land and water resources. Prolonged droughts and land degradation in the region have exacerbated tensions between pastoralists and farmers, leading to violent conflicts. The United Nations Environment Program (UNEP) conducted an assessment that highlighted the linkages between environmental change, resource scarcity and the Darfur conflict. The findings informed interventions that focus on sustainable natural resource management, land restoration and conflict resolution to address the root causes of the conflict and promote environmental security.

Case study 3: The United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is an international treaty that addresses the global challenge of climate change (UNFCCC, 2023). It recognizes the interconnections between environmental change, human security and conflicts. Through its processes and mechanisms, such as the Warsaw International mechanism for loss and damage and the Adaptation Fund, the UNFCCC supports initiatives that enhance resilience, promote sustainable environmental practices and contribute to conflict prevention.

Case study 4: Environmental peacebuilding initiatives Various organizations and initiatives focus on environmental peacebuilding, which involves leveraging natural resources, environmental cooperation and sustainable practices to prevent conflicts and promote

peace. The environmental peacebuilding program, led by the United Nations Environment Program, supports projects in conflict-affected regions, such as the Democratic Republic of Congo, Colombia and Iraq, to address the environmental drivers of conflicts. These initiatives aim to promote sustainable livelihoods, restore ecosystems and foster cooperation among communities, ultimately contributing to conflict prevention and peacebuilding.

These case studies and examples highlight the importance of understanding the interconnections between environmental change, health, population dynamics, conflicts and foreign policy. Analyzing the impacts of environmental stressors on human security and working towards conflict prevention through sustainable environmental practices, initiatives and organizations contribute to peacebuilding, resilience and the promotion of sustainable development.

Food Security in a Changing World

Food security in a changing world: The component of "food security in a changing world" within the global resilience framework addresses the pressing issue of escalating global food insecurity, which is exacerbated by various factors including climate change, inflation, the COVID-19 pandemic and geopolitical tensions (Figs. 1-3) (World Bank, 2011). It recognizes the urgent need to develop strategies that strengthen agricultural systems, improve access to nutritious food and enhance resilience in the face of multifaceted threats (World Bank, 2023). Climate change poses significant challenges to agricultural productivity, with extreme weather events, changing rainfall patterns and rising temperatures affecting crop yields and livestock production. In addition, inflation, economic instability and geopolitical tensions can disrupt food supply chains and exacerbate food insecurity (WFP, 2019). The ongoing COVID-19 pandemic has further strained food systems, leading to disruptions in production, distribution and access to food.

This component involves developing comprehensive strategies to address these challenges and enhance global food security. It includes measures to strengthen agricultural systems through sustainable and climate-smart practices, such as promoting efficient water management, diversifying crops and adopting resilient farming techniques. Investing in agricultural research and technology, improving infrastructure and supporting smallholder farmers are also key components (Relief, 2020). Improving access to nutritious food is another crucial aspect. This can involve initiatives to enhance food distribution networks, ensure equitable access to markets and promote nutrition education and awareness. Efforts to reduce food waste and losses throughout the supply chain, from production to consumption, are also essential in maximizing food availability and reducing food insecurity.

Furthermore, this component emphasizes the importance of building resilience in the face of multifaceted threats. It involves developing risk management and contingency plans to address climate-related shocks, economic instability and other challenges (UN, 2023). Diversifying sources of food and income, promoting social safety nets and strengthening local food systems are strategies that enhance resilience and ensure the availability of food in times of crisis. The component of food security in a changing world recognizes the need for collaboration and coordination among stakeholders, including governments, international organizations, farmer" associations and civil society. By working together, sharing knowledge and leveraging resources, stakeholders can develop integrated approaches that address the root causes of food insecurity and foster sustainable solutions.

Ultimately, the global resilience framework seeks to ensure that communities around the world have access to sufficient, nutritious and affordable food, even in the face of a changing world. By developing strategies that strengthen agricultural systems, improve access to food and enhance resilience, the framework aims to contribute to a more food-secure future where the well-being and livelihoods of individuals and communities are protected.

Case Studies and Examples of Food Security in a Changing World

Case study 1: Ethiopia's climate resilient agriculture (FAO, 2023a) Ethiopia, a country highly vulnerable to climate change impacts, has been implementing strategies to strengthen its agricultural systems and improve food security. The Climate-Resilient Green Economy (CRGE) strategy, initiated by the Ethiopian government, focuses on sustainable agricultural practices, such as conservation agriculture, agroforestry and improved irrigation methods. These practices enhance resilience to climate change, improve soil fertility and increase crop productivity. By promoting climate-smart agriculture and investing in smallholder farmers'' capacity building, Ethiopia aims to improve food security and reduce vulnerability to climate-related shocks.

The Climate-Resilient Green Economy (CRGE) strategy in Ethiopia has yielded substantial outcomes in bolstering agricultural resilience and ensuring food security. Through the adoption of conservation agriculture, agroforestry and advanced irrigation methods, the country has witnessed a marked increase in crop productivity. This surge in agricultural output has not only enhanced food security for vulnerable communities but has also led to improved livelihoods for smallholder farmers.

Additionally, the integration of agroforestry has contributed to environmental conservation by restoring

biodiversity and mitigating the impact of climate change. Furthermore, the implementation of water-saving technologies has optimized water use efficiency, critical for safeguarding harvests in drought-prone regions. Capacity-building initiatives have empowered farmers with essential knowledge and skills for climate-smart agriculture, catalyzing a broader transformation in agricultural practices nationwide. These specific outcomes exemplify the tangible benefits of Ethiopia's CRGE strategy, setting a commendable precedent for sustainable agricultural development in the face of a changing climate.

Case study 2: Brazil's zero hunger program (Inter, 2012). Brazil's zero hunger program, launched in 2003, is a comprehensive initiative that addresses food security and poverty reduction. It combines social protection measures with initiatives to promote sustainable agriculture, family farming and rural development. The program includes components such as income transfer programs, school feeding programs and support for small-scale farmers. By integrating social and agricultural policies, Brazil has made significant progress in reducing hunger, improving nutrition and enhancing the resilience of vulnerable populations to food insecurity.

Brazil's zero hunger program, launched in 2003, stands as a remarkable success story in the realm of food security and poverty reduction. This multifaceted initiative, which intertwines social protection measures with efforts to bolster sustainable agriculture, family farming and rural development, has yielded profound impacts. Through income transfer programs, school feeding initiatives and robust support for small-scale farmers, Brazil has witnessed a substantial reduction in hunger and malnutrition. The program's holistic approach, combining social and agricultural policies, has not only elevated food security but has also significantly enhanced the resilience of vulnerable populations against the specter of food insecurity. This integrated approach serves as a beacon of how coordinated efforts can yield transformative outcomes in the fight against hunger and poverty (Inter, 2012).

Case study 3: The World Food Program's Purchase for Progress (P4P) initiative (WFP, 2023). The World Food Progra''s P4P initiative aims to strengthen agricultural supply chains and support smallholder farmers in low-income countries. The initiative facilitates market access for small-scale producers, provides training on improved agricultural techniques and links farmers to buyers. By enhancing the capacity and market participation of smallholder farmers, the P4P initiative contributes to improving food security and building resilience in the face of multiple threats.

The world food program's Purchase for Progress (P4P) initiative has emerged as a potent force in fortifying agricultural supply chains and uplifting smallholder farmers in low-income nations. By facilitating market access for these producers, delivering crucial training on enhanced agricultural techniques and establishing vital connections between farmers and buyers, the initiative has wrought transformative impacts. By bolstering the capacity and market participation of smallholder farmers, P4P not only drives significant strides in food security but also lays a sturdy foundation of resilience against a spectrum of threats. This integrated approach not only empowers individual farmers but also exemplifies a scalable model for sustainable agricultural development with far-reaching impacts on global food security.

Case study 4: Urban agriculture in Nairobi, Kenya (Omondi *et al.*, 2017) In response to urban food insecurity and limited access to nutritious food, initiatives promoting urban agriculture have emerged in Nairobi, Kenya. Organizations like Urban Harvest and the Nairobi City County agriculture sector development support programs that promote rooftop gardens, community gardens and urban farming practices. These initiatives not only enhance local food production but also provide employment opportunities, improve nutrition and strengthen community resilience to food insecurity in urban areas.

The initiatives promoting urban agriculture in Nairobi, Kenya, spearheaded by organizations like Urban Harvest and the Nairobi City County agriculture sector development support program, have yielded multifaceted impacts (IADB, 2023). In addressing urban food insecurity and the challenge of accessing nutritious food, these programs have ushered in a transformation. Through the establishment of rooftop gardens, community green spaces and the cultivation of urban farms, these initiatives have not only significantly augmented local food production but have also engendered vital employment opportunities. Simultaneously, they have contributed to an improvement in the overall nutrition landscape of urban communities. Beyond this, the promotion of urban agriculture has forged a deeper sense of community resilience, effectively combating food insecurity within urban areas. This holistic approach serves as a powerful model for sustainable urban development, offering tangible solutions to complex challenges related to food security in urban environments.

These case studies and examples demonstrate the diverse strategies and initiatives being implemented to address food security in a changing world. By strengthening agricultural systems, improving access to nutritious food and enhancing resilience to multifaceted threats, countries and organizations are working towards a more sustainable and secure food future. These efforts involve a combination of climate-resilient agriculture, social protection measures, market access and community-based initiatives to ensure food security for all.

Future Recommendations

Inclusive community networks play a crucial role in building global resiliency by promoting collaboration, participation and inclusivity at the local level. While significant progress has been made in this area, there are still research gaps and opportunities for further advancements. The state-of-the-art in inclusive community networks involves the establishment of platforms and initiatives that facilitate knowledge sharing, capacity building and the co-creation of resilience strategies. These networks empower policymakers, practitioners and community members to actively engage in shaping resilience agendas and implementing effective solutions (Unesco, 2022). However, several research gaps need to be addressed. Firstly, there is a need for more comprehensive studies on the effectiveness of inclusive community networks in building resilience. While there is evidence of positive outcomes, more rigorous evaluations are required to understand the specific mechanisms and factors that contribute to their success.

Additionally, research should explore the social dynamics and power structures within these networks to ensure that marginalized voices are adequately represented and decision-making processes are truly inclusive. Furthermore, there is a need to enhance the scalability and replicability of inclusive community networks. Many successful initiatives are often localized and struggle to expand their impact beyond a specific context. Research should focus on identifying strategies to overcome barriers and facilitate the replication of successful models in different communities and regions.

The future of inclusive community networks lies in harnessing the potential of science, technology, research and innovation. Advances in digital technologies, such as online platforms, data analytics and artificial intelligence, can significantly enhance the effectiveness and reach of these networks. For example, digital platforms can facilitate real-time knowledge sharing, virtual collaboration and participatory decision-making processes, enabling broader engagement.

Research should also explore the potential of innovative approaches, such as citizen science and community-based monitoring, in strengthening inclusive community networks. Engaging local communities in data collection, analysis and interpretation can provide valuable insights and empower them to address resilience challenges effectively. To achieve the goal of robust and inclusive community networks, several recommendations can be made. Firstly, it is crucial to invest in capacity building and knowledge transfer to strengthen the skills and capabilities of community members, particularly those from marginalized groups. This includes providing training on resilience planning, sustainable practices and effective communication and collaboration. Secondly, fostering interdisciplinary research collaborations is essential to address the complexity of resilience challenges. Collaboration between social scientists, environmental scientists, technologists and community stakeholders can lead to holistic and context-specific solutions that consider both social and ecological aspects of resilience. Lastly, there is a need for strong policy support and institutional frameworks that prioritize and facilitate the establishment and sustainability of inclusive community networks. Governments and international organizations should provide funding, regulatory support and policy incentives to encourage the development and scaling up of these networks.

In conclusion, inclusive community networks have the potential to drive global resiliency by fostering collaboration, inclusivity and participation. However, research gaps exist in understanding their effectiveness, scalability and replicability. The future of inclusive community networks lies in leveraging science, technology, research and innovation to enhance their reach and impact.

Investments in capacity building, interdisciplinary collaborations and supportive policies are crucial for achieving resilient and inclusive communities worldwide.

Knowledge sharing and mapping play a crucial role in building global resiliency by facilitating the exchange of information, best practices and lessons learned. The state-of-the-art in this field involves the use of various platforms, networks and tools to enable the dissemination and accessibility of knowledge (Yaqub and Alsabban, 2023). These efforts have contributed to enhancing global resilience by empowering stakeholders to make informed decisions and take effective actions. However, there are still research gaps and areas for improvement in knowledge sharing and mapping for global resiliency. One key challenge is the lack of standardized methodologies and frameworks for knowledge sharing and mapping. Different organizations and sectors often use diverse approaches, making it difficult to integrate and synthesize information effectively. Developing common standards and guidelines would enhance interoperability and consistency, enabling a more comprehensive understanding of resilience-related knowledge.

Another research gap lies in addressing the digital divide and ensuring equitable access to knowledge-sharing platforms. While digital technologies offer opportunities for widespread knowledge dissemination, not all communities and regions have equal access to the Internet and digital resources. Bridging this divide requires targeted efforts to provide access to information and build digital literacy skills, particularly in marginalized and remote communities. Furthermore, research should focus on enhancing the quality and relevance of shared knowledge. This includes improving the identification and validation of best practices, ensuring the accuracy and reliability of the information

and promoting the incorporation of local and indigenous knowledge. Emphasizing participatory approaches and engaging diverse stakeholders in the knowledge-sharing process can enhance the applicability and effectiveness of shared knowledge.

The future of knowledge sharing and mapping lies in leveraging science, technology, research and innovation to overcome these challenges. Advancements in artificial intelligence, machine learning and data analytics offer opportunities to automate knowledge extraction, categorization and synthesis. These technologies can assist in identifying patterns, trends and gaps in resilience-related knowledge, enabling more targeted and efficient knowledge-sharing efforts. Additionally, science and research play a vital role in generating new knowledge and evidence on resilience strategies and approaches. Investing in interdisciplinary research collaborations and conducting rigorous studies can provide valuable insights into the effectiveness of different resilience interventions. Science also plays a crucial role in assessing the impact of knowledge-sharing and mapping efforts on building global resilience, allowing for evidence-based improvements.

Technology and innovation can contribute to the future of knowledge sharing and mapping by developing user-friendly platforms, interactive tools and data visualization techniques. These advancements can enhance the accessibility, usability and engagement of stakeholders in the knowledge-sharing process. Embracing open data principles and promoting data interoperability can further facilitate the sharing and integration of diverse knowledge sources. In conclusion, while significant progress has been made in knowledge sharing and mapping for building global resiliency, there are research gaps and opportunities for improvement. The future of this field lies in leveraging science, technology, research and innovation to enhance the quality, accessibility and relevance of shared knowledge. Recommendations include standardizing methodologies, addressing the digital divide, improving knowledge quality and promoting interdisciplinary research collaborations. By harnessing the power of knowledge sharing and mapping, we can strengthen global resilience and effectively address the challenges of an uncertain and changing world.

Climate change and migration are interconnected phenomena that pose significant challenges to global resiliency. The state-of-the-art research in this field highlights the complex relationship between climate change and human migration, particularly in regions such as Senegal, Moldova and Bangladesh (Wilson Center, 2023b). Studies have shown that climate stressors, including extreme weather events, sea level rise and changing precipitation patterns, can lead to displacement and migration as communities struggle to cope with

environmental degradation and loss of livelihoods. However, several research gaps need to be addressed to build global resiliency in the context of climate change and migration. Firstly, there is a need for a deeper understanding of the causal pathways and drivers of climate-induced migration. This includes investigating the socioeconomic, political and cultural factors that influence migration decisions and examining the differential impacts of climate change on various population groups, such as women, children and marginalized communities. Secondly, more research is required to explore the potential synergies between climate change adaptation, disaster risk reduction and migration policies (IPCC, 2014). This involves identifying effective strategies and interventions that can enhance the resilience of both migrant communities and the areas they migrate to. Understanding the social, economic and environmental implications of migration can inform policy development and ensure that migration is managed in a way that supports sustainable development and resilience. Furthermore, research should focus on the long-term implications of climate-induced migration, including the potential for conflicts and tensions in receiving areas, the loss of cultural heritage and the need for social cohesion and integration. Understanding these dynamics is crucial for developing comprehensive policies and interventions that address the challenges and harness the opportunities associated with climate-induced migration.

The future of climate change and migration lies in adopting a holistic and interdisciplinary approach that integrates science, technology, research and innovation. Science plays a key role in providing evidence-based insights into the impacts of climate change, the drivers of migration and the effectiveness of adaptation and resilience strategies. This includes studying climate models, conducting vulnerability assessments and analyzing migration patterns and trends. Technology and innovation can contribute by developing advanced tools for monitoring and predicting climate change impacts, facilitating early warning systems and supporting the dissemination of information to vulnerable communities. Remote sensing, geospatial analysis and mobile applications can aid in understanding climate-related risks and informing decision-making processes. Research collaboration between academia, policymakers and local communities is essential for addressing the research gaps and implementing effective solutions. This includes engaging local stakeholders in participatory research, incorporating indigenous knowledge and code-signing resilience strategies that are contextually relevant and community-driven.

In conclusion, while significant progress has been made in understanding the relationship between climate change and migration, there are research gaps and opportunities for improvement. The future of this field lies in adopting a multidisciplinary approach, leveraging science, technology, research and innovation to address

these gaps and develop comprehensive policies and strategies. Recommendations include conducting further research on causal pathways and drivers, exploring synergies between adaptation and migration, examining long-term implications and promoting interdisciplinary collaboration. By doing so, we can enhance global resiliency and support the well-being of communities affected by climate-induced migration.

Critical minerals resilience is a vital component in building global resiliency, considering the increasing demand for these minerals driven by the transition to renewable energy and the digital economy. The state-of-the-art research in this field focuses on understanding the environmental, social and governance risks associated with the extraction, processing and supply chain of critical minerals (IEA, 2023). It involves assessing the vulnerabilities and identifying strategies to ensure a resilient and sustainable supply of these minerals. One area of research gap is the need for comprehensive and up-to-date data on critical mineral reserves, production and consumption. Accurate and reliable information is essential for identifying potential supply chain disruptions, understanding market dynamics and informing policy decisions. Improved data collection and sharing mechanisms are required to address this gap and enhance the transparency and efficiency of critical minerals supply chains. Another research gap lies in developing technologies and processes for responsible and sustainable extraction and processing of critical minerals. Current practices often pose significant environmental and social challenges, including habitat destruction, water pollution and labor rights abuses. Advancements in science, technology and research can play a crucial role in developing innovative and cleaner extraction techniques, as well as promoting circular economy principles for recycling and reusing critical minerals.

Furthermore, research should focus on developing strategies to reduce the reliance on specific critical minerals and diversify the supply chain. Identifying alternatives or substitutes for critical minerals can mitigate the risks associated with their scarcity or geopolitical dependencies. This requires interdisciplinary research collaborations and innovation in materials science, engineering and product design.

The future of critical minerals resilience lies in fostering international cooperation and dialogue among stakeholders from different sectors and regions. Cross-regional and cross-sectoral stakeholder dialogues can help build consensus on policies and standards that promote responsible sourcing, supply chain transparency and social and environmental sustainability. International cooperation also enables knowledge sharing, technology transfer and capacity building, facilitating the adoption of best practices globally. Science, technology, research and innovation play a crucial role in achieving critical minerals resilience. Scientific research can provide

insights into the environmental impacts and risks associated with critical mineral extraction and processing. It can also contribute to the development of advanced technologies for sustainable mineral exploration, efficient extraction and recycling. Additionally, research can support the assessment of social impacts and governance issues, such as human rights, labor conditions and community engagement. Innovation in materials science, process optimization and product design can help reduce the demand for critical minerals or improve their efficiency in various applications. This includes developing new materials with similar or enhanced properties, designing products with longer lifecycles and increased recyclability and implementing digital solutions to optimize supply chain management. To achieve critical minerals resilience, it is crucial to invest in research and development, support collaborative initiatives and promote responsible business practices. Governments, industry players and research institutions should collaborate to establish research programs, funding mechanisms and knowledge-sharing platforms that support innovation and advance sustainable practices in the critical minerals sector.

In conclusion, while progress has been made in understanding and addressing the challenges of critical minerals resilience, there are research gaps that need to be addressed. The future of this field lies in promoting responsible sourcing and supply chain practices, developing sustainable extraction and processing technologies and diversifying the use of critical minerals. Science, technology, research and innovation are vital in achieving these goals and recommendations include improving data availability, developing sustainable extraction techniques, reducing reliance on specific minerals, fostering international cooperation and investing in research and development. By doing so, we can enhance critical minerals resilience and ensure a more sustainable and resilient future for global supply chains.

Environmental change and security is a critical field of research that explores the interconnections between environmental change, health, population dynamics, conflicts and foreign policy. The state-of-the-art research in this area has shed light on the complex relationships and feedback loops between environmental degradation, human security and social stability (Entwisle, 2021). It highlights how environmental stressors, such as climate change, deforestation and resource scarcity, can exacerbate conflicts, displacement and vulnerabilities in communities. One significant research gap is the need for a deeper understanding of the causal pathways and mechanisms through which environmental change influences security dynamics. This includes studying the socio-economic and political factors that mediate the relationship between environmental stressors and conflicts, as well as exploring the role of environmental

degradation in exacerbating inequalities and vulnerabilities. Improved empirical research and modeling techniques can provide valuable insights into these complex interactions.

Another research gap lies in understanding the differential impacts of environmental change on different populations, including marginalized groups, women and indigenous communities. Recognizing and addressing the unique vulnerabilities and adaptive capacities of these groups is crucial for building inclusive and equitable resilience strategies. Research should focus on assessing the gendered and intersectional dimensions of environmental change and security to inform policies and interventions that promote social justice and human rights. Furthermore, there is a need for research that explores the potential for transformative actions and innovative solutions to address environmental change and security challenges. This includes studying the effectiveness of nature-based solutions, sustainable resource management approaches and climate adaptation strategies in reducing conflicts and enhancing resilience.

Interdisciplinary research collaborations and the integration of traditional knowledge systems can contribute to developing context-specific and culturally appropriate responses.

The future of environmental change and security lies in adopting a holistic and integrated approach that combines scientific research, technology, policy development and community engagement. Science can provide evidence-based assessments of environmental change, predict future scenarios and evaluate the effectiveness of interventions. Technology and innovation can support early warning systems, remote sensing and data analysis to monitor and manage environmental risks. Research can contribute by developing tools and frameworks for assessing environmental security risks, conducting vulnerability assessments and informing policy and decision-making processes. This includes the integration of environmental considerations into conflict prevention, peacebuilding and development initiatives. Collaboration between researchers, policymakers and local communities is essential to ensure that knowledge is effectively translated into actionable policies and practices.

In conclusion, while progress has been made in understanding the interconnections between environmental change and security, there are research gaps that need to be addressed to build global resiliency. The future of this field lies in advancing our understanding of causal pathways, addressing inequalities and vulnerabilities, exploring transformative actions and integrating scientific research with technology, policy and community engagement. Recommendations include interdisciplinary collaborations, consideration of gender and social dimensions, exploration of innovative solutions

and the translation of research into policy and practice. By doing so, we can enhance environmental change and security, promoting sustainable development and building a more resilient and peaceful world.

Food security in a changing world is a pressing global concern, exacerbated by various factors such as climate change, inflation, the COVID-19 pandemic and geopolitical tensions.

The state-of-the-art research in this field focuses on understanding the complex interactions between these factors and their impacts on agricultural systems, food production and access to nutritious food (FAO, 2023b). It emphasizes the need for resilient and sustainable solutions to ensure food security for all. One research gap is the need for comprehensive data and monitoring systems to assess the current state of food security, identify vulnerable populations and track the impacts of various stressors. This includes monitoring crop yields, climate patterns, market dynamics and nutritional indicators. Improved data collection, remote sensing technologies and data analysis can contribute to more accurate assessments and informed decision-making. Another research gap lies in understanding the social, economic and political drivers of food insecurity, particularly in the context of changing climates and global trade dynamics. This includes studying the impacts of land-use changes, agricultural practices and food value chains on food availability, affordability and nutrition. Socio-economic research can help identify barriers to access and address inequalities in food distribution and consumption.

Furthermore, research should focus on developing and promoting sustainable agricultural practices that enhance productivity, resilience and environmental stewardship. This includes exploring innovative farming techniques, such as precision agriculture, agroforestry and organic farming, which can reduce resource inputs, minimize environmental impacts and increase the adaptive capacity of farmers (Nicolétis, 2019; Smit and Wandel, 2006).

Interdisciplinary research collaborations can facilitate the development and dissemination of sustainable agricultural practices. The future of food security in a changing world lies in adopting a holistic and integrated approach that encompasses the entire food system. This includes addressing not only production and distribution but also the nutritional quality, safety and cultural aspects of food. Recommendations include promoting diversified and resilient agricultural systems, investing in climate-smart technologies and infrastructure, strengthening social safety nets and empowering local communities.

Science, technology, research and innovation play a crucial role in achieving food security in a changing world. Scientific research can contribute to improving crop varieties, developing climate-resilient crops and

optimizing agricultural practices. Technology, such as precision farming tools, remote sensing and data analytics, can support decision-making and resource management. Research can help identify and address the impacts of climate change on agricultural productivity, develop strategies for climate adaptation and mitigation and assess the potential of emerging technologies, such as vertical farming and aquaponics. Innovation in food processing, storage and distribution can help reduce postharvest losses, improve food safety and extend shelf life. Research can also contribute to understanding consumer behaviors and preferences, facilitating the development of nutritious and culturally appropriate food products. Additionally, collaboration between researchers, policymakers and local communities is crucial to ensure that scientific knowledge is translated into effective policies and interventions.

Technology, particularly the advent of precision agriculture and remote sensing, has emerged as a linchpin in bolstering food security and resilience. Precision agriculture employs advanced technologies like GPS, IoT devices and drones to optimize farming practices, enabling farmers to make data-driven decisions regarding planting, irrigation and resource allocation. This not only maximizes yields but also minimizes resource wastage. Additionally, remote sensing technologies, often deployed via satellites or drones, provide a bird's-eye view of agricultural landscapes, offering critical insights into crop health, water usage and pest management. By harnessing these technologies, farmers can proactively address challenges, anticipate environmental changes and implement targeted interventions. This convergence of agriculture and technology not only amplifies food production but also fortifies the sector against disruptions, contributing significantly to global food security and resilience.

In conclusion, while progress has been made in understanding the challenges of food security in a changing world, there are research gaps that need to be addressed. The future of this field lies in adopting a comprehensive approach, addressing data gaps, understanding the drivers of food insecurity, promoting sustainable agricultural practices and empowering local communities. Recommendations include interdisciplinary collaborations, investment in climate-smart technologies, strengthening social safety nets and incorporating local knowledge and cultural perspectives. By leveraging science, technology, research and innovation, we can achieve food security, reduce inequalities and build a resilient and sustainable global food system.

Conclusion

Building global resiliency is a critical imperative in the face of escalating challenges such as climate change,

resource scarcity and geopolitical tensions. To effectively achieve this goal, the following recommendations are crucial: First, it is essential to strengthen collaboration and partnerships on a global scale. Governments, organizations, researchers and local communities must actively engage in joint efforts to address global challenges. Platforms for knowledge sharing, best practice exchange and cooperative initiatives should be established to foster international cooperation. Investing in education and capacity building is paramount. Education and awareness programs should be designed to enhance the understanding of global resiliency challenges at all levels. Integrating sustainability and resilience concepts into educational curricula and providing training programs for professionals in relevant fields will build the necessary capacity (Folke *et al*., 2010).

Sustainable development must be prioritized in all decision-making processes. The principles of sustainability should be integrated into development planning, focusing on responsible resource management, renewable energy adoption, responsible consumption and production and nature-based solutions. Balancing economic growth with environmental protection and social equity is essential for long-term resilience (Meadows *et al*., 1972). Data and information systems need to be enhanced to support evidence-based decision-making. To achieve enhanced data and information systems for evidence-based decision-making, leveraging emerging technologies like Artificial Intelligence (AI) and implementing comprehensive data governance frameworks can streamline data collection, analysis and dissemination, while ongoing initiatives like open data platforms and data Collaboratives foster accessibility and transparency in information sharing. Robust monitoring systems should track key indicators of global resiliency, such as climate patterns, resource availability and social vulnerability. Investment in innovative technologies and data-driven approaches will enhance early warning systems and risk assessment capabilities. Addressing inequality and social vulnerability is crucial. Inclusive and equitable approaches must be adopted to tackle the root causes of vulnerability. Marginalized groups, women and indigenous communities should have equal access to resources and opportunities and their active participation in decision-making processes should be ensured. Social justice and human rights perspectives should be integrated into resilience-building efforts.

Fostering innovation and technological advancements is vital. Science, technology, research and innovation play a significant role in addressing global challenges. Emerging technologies such as blockchain for transparent supply chains, advanced genomics for personalized healthcare and AI-driven climate modeling for precise adaptation strategies are promising avenues to tackle global challenges and drive resilient investment in

research and development that should explore emerging technologies, sustainable solutions and transformative approaches to building resilience.

Innovation ecosystems that encourage collaboration, entrepreneurship and knowledge and technology transfer should be fostered. Strengthening interdisciplinary collaboration: To enhance the effectiveness of global resiliency efforts, it is imperative to foster robust interdisciplinary collaboration. This entails establishing dedicated platforms for regular dialogues and knowledge-sharing sessions between researchers, policymakers, local communities and practitioners. These forums should encourage the exchange of expertise, insights and best practices from diverse fields such as environmental science, social sciences, technology and policy development. Additionally, incentivizing joint research projects and co-authored publications can further solidify these collaborations. By ensuring that stakeholders with varying expertise work in tandem, a more comprehensive and contextually relevant approach to global resiliency can be developed.

Implementing integrated resilience strategies: A holistic approach remains paramount in the pursuit of global resiliency. This involves seamlessly integrating scientific advancements, technological innovations, cutting-edge research findings and inclusive policy development. Initiatives should be designed to encompass a wide spectrum of dimensions, including environmental sustainability, social equity and economic viability. Encourage the formation of multi-disciplinary task forces that encompass experts from diverse fields to co-create and implement strategies. Furthermore, local communities should be empowered through capacity-building programs and participatory decision-making processes. By merging the strengths of science, technology, research and policy with the wisdom of local communities, a resilient framework can be constructed that not only addresses immediate challenges but also fortifies societies for an uncertain future.

However, several challenges need to be overcome to effectively build global resiliency. These include the lack of political will and fragmented international cooperation, resource constraints, the need for behavioral and cultural change, technological and knowledge gaps and overcoming short-term thinking. To surmount these challenges, strong leadership, political commitment and international cooperation are essential. An interdisciplinary and collaborative approach that brings together science, technology, research and innovation is crucial. Strengthening partnerships among governments, organizations, academia and civil society will facilitate effective knowledge sharing, capacity building and resource mobilization. By embracing these recommendations and overcoming the challenges, the world can pave the way for a more resilient future. Global resiliency will enable us to navigate the complex and interconnected challenges we face, ensuring a sustainable and secure future for all.

Acknowledgment

Funding Information

Author's Contributions

Clifford Jaylen Louime: Conceptualized the idea presented in this study. Developed the theoretical framework. Developed the theoretical framework. Verified the case studies and encouraged collaborative investigation. Supervised the overall research findings. Engaged in discussions with the co-author to shape the final manuscript.

Keith Cecil Simmonds: Conducted research and authored several case studies documented in the manuscript. Provided critical review and constructive feedback on the manuscript.

Both authors collaborated to refine and contribute to the final version of the manuscript.

Ethics

We want to affirm our unwavering commitment to upholding ethical standards in our research and publication process. Throughout this study, we have diligently followed ethical guidelines, including obtaining informed consent, ensuring research integrity and safeguarding data confidentiality. We remain vigilant to any potential ethical issues that may arise post-publication and pledge to address them promptly, transparently and by ethical principles to maintain the integrity of our research.

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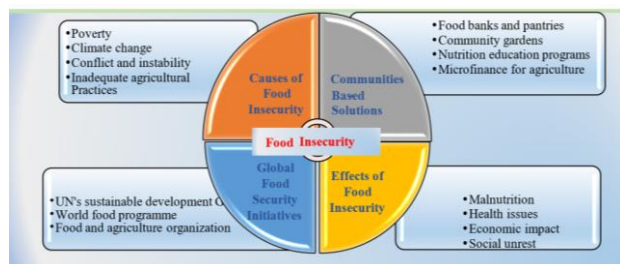
Supplementary Figures:

Fig. 1: This knowledge map provides a structured overview of the concept of food insecurity, outlining its causes, effects, global initiatives and community-based solutions. Each sub-topic provides a clear understanding of the different aspects associate
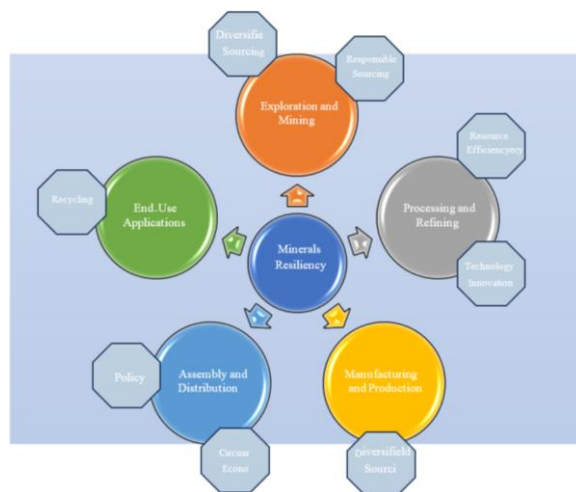

Fig. 2: This diagram provides a visual representation of the critical minerals supply chain and highlights key points where resilience-building measures can be implemented to enhance the sustainability and stability of the supply chain
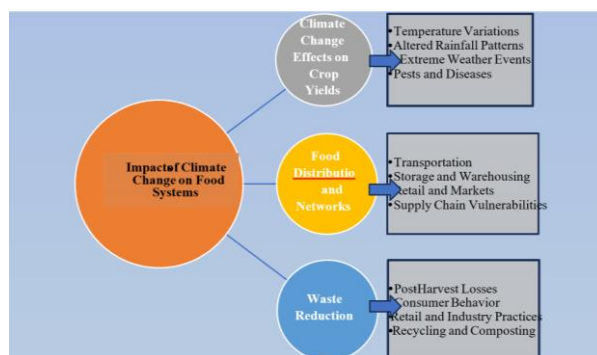

Fig. 3: This diagram illustrates how climate-related events affect food distribution