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RECEIVED 05 February 2025

ACCEPTED 13 March 2025

PUBLISHED 01 April 2025

CITATION

Mkumbukiy A, Loghmani-Khouzani T,
Madani K and Guenther E (2025) Agrifood
systems' resilience for sustainable food
security amid geopolitical tensions: a
systematic literature review.
Front. Sustain. Food Syst. 9:1546851.
doi: 10.3389/fsufs.2025.1546851

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Agrifood systems' resilience for sustainable food security amid geopolitical tensions: a systematic literature review

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Introduction: This study examines the resilience of the agrifood systems amid geopolitical tensions with a primary focus on the Ukraine-Russia war and its increased effects on global food security, climate change, and post-pandemic recovery. The study explores different resilience elements, scenarios, and behaviors of agrifood systems, highlighting how geopolitical conflicts disrupt resource availability and economic stability. Further, it explores the existing Resource Nexus and its influence on sustainable food and nutrition security amid geopolitical tension. Much research focuses on agrifood systems' resilience in the context of climate change and pandemics, repeatedly overlooking the impacts of geopolitical tensions and related policies enacted for sustainable food security.

Methods: Focused on geopolitical tension as an influence on food security, 76 articles were systematically reviewed to identify key resilience elements and scenarios enacted based on countries' development, discovered major vulnerability indicators, and Resource Nexus of agrifood systems.

Results: This review leads to the identification of four key resilience scenarios of the agrifood system amid geopolitical tensions: fragility reduction, robustness building, adaptive strategies, and transformative change over time. In general, the reduction of agrifood system fragility was more prevalent compared to the other three scenarios. There was a decline in the agrifood system's performance due to the existence of some policies that increased the system's instability over time. The study further identifies that the impact of enacted resilience policies on sustainable food security is not uniform. It often influences positive or negative outcomes depending on its feedback nature at different operational levels of the agrifood system. During geopolitical tensions, food, energy, and finance are the most affected sectors, followed by other interconnected resources such as land, water, food (LWF), and water, energy, and food (WEF).

Discussion: In the presence of effective policies and scenarios, the agrifood system experiences improved resilience and sustainability that contribute to the beneficial relationship between resources, and all pillars of food security.

KEYWORDS

agrifood, resilience, resilience elements, food security, geopolitical tensions, resource nexus, sustainability, Ukraine-Russia war

1 Introduction

Sustainable food security is fulfilled when the society has physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for active and healthy life (Batt, 2024; Capone et al., 2014; Ejiohuo et al., 2024; FAO, 2023; Hasan et al., 2024; Mbow et al., 2019; Mishra, 2024; Mohamed, 2017). It is highly distressed by several factors including climate change and geopolitical tensions through disrupting the operation and processes of agrifood systems (Aminetzah et al., 2022; Murphy et al., 2023). According to Fernandois and Medel (2020), geopolitical tensions are all risks posed by tensions between states that affect a peaceful course of relations, which can be composed of threats plus realizations such as riots, wars, or terrorist acts. It imposes challenges that impact sustainable food and nutrition security and continues to expand globally, affecting production, processing, and the whole supply chain of agrifood products such as grains, oilseeds, and tea in the global market (Zhou et al., 2020; Zurek et al., 2022). This situation is weakening agrifood system resilience worldwide, hindering progress toward the UN's Sustainable Development Goals (SDGs), including SDG 1 (no poverty), SDG2 (zero hunger), and SDG 12 (responsible consumption and production) (Nguyen et al., 2023; Wudil et al., 2022). Similarly, extensive consequences of degraded agrifood system resilience are expected to worsen and deepen in the coming decades (FAO, 2022). There is a pressing need for vulnerable societies to understand what, how, and when agrifood systems resilience is important for maintaining food security in the face of geopolitical tension.

The complex nature of the effects of geopolitical tensions on food security creates confused challenges to all levels of the agrifood system operation, due to the interconnected and unequal distribution of the impacts. It influences the implementation of strategies or elements that lead to different outcomes (e.g., fragility reduction, robustness building, adaptation, and overtime transformation changes) (Nieuwborg et al., 2023; Stone and Rahimifard, 2018). The effects of the geopolitical tension on agrifood systems are also stimulated by other global challenges such as climate change and human diseases. However, very little research conducted into the resilience of the agrifood systems, our understanding of what, how, and when agrifood systems resilience policies are effective in maintaining food security is only just developing.

Addressing the gap requires investigation of the previous research on the consideration of the underlying drivers, and how they affect the agrifood system's resilience. Currently, there exists a wealth of insightful perspectives from domestic and international sources regarding the impact of geopolitical tension on food security (Ben Hassen and El Bilali, 2022; Mhlanga and Ndhlovu, 2022; Trollman et al., 2023; Xu et al., 2023) with a focus on the Russia–Ukraine conflict. The conflict between Russia and Ukraine impacted global food security through market disruption of key global commodities such as grains, oilseeds, and fertilizers (Arreyndip, 2025; Bas, 2025). Export and import bans were enacted on the world's largest food and related commodities suppliers including Russia and Ukraine (Babets et al., 2024; Tsolko, 2025), leading to inflation of food prices and increased vulnerabilities

of the countries that are over-depending on the global market commodities from conflicting or other affected countries, especially developing countries. Different initiatives were introduced to reduce vulnerabilities and facilitate global food security in the most affected countries, the Black Sea Grain Initiative and the Grain From Ukraine program were expected to mitigate this global food crisis (Ivashova and Komarov, 2024; Kacperska et al., 2025; Kormych et al., 2024), but still challenges remain in securing trade routes and stabilizing agricultural production amid ongoing geopolitical conflicts (John, 2025).

While many research documents are available to provide evident trends and background of the field, most of the presented study resources are sometimes irrelevant, lack critical information, overlook targeted key policies, neglect temporal and geographical scales, and provide outdated conclusions. Nevertheless, few studies empirically assessing the link between these variables have yielded mixed results (Al-Maadid et al., 2017; Pondie et al., 2023). For instance, Zhou et al. (2020), described that food security is not negatively driven by the armed conflict only, diversified governance of agrifood systems and resources can also impact the current global food security situation. This implies that there are interactions between these long-term geopolitical conflicts and other drivers concerning food security status (Zurek et al., 2022), and it is necessary to conduct empirical research on the food system's resilience, considering both resilience policy behaviors and existing key resources.

This study employed a systematic literature review (SLR) to examine the influence of the various agrifood systems' resilience elements on sustainable food security in the context of geopolitical tensions. The SLR is a replicable and transparent research method (Harper et al., 2021), which reduces bias in addressing the challenge dynamics and is ultimately intended to improve the reliability and accuracy of conclusions. By understanding the influence of the implemented resilience elements and other food dynamics on the resilience of agrifood systems, policymakers, and practitioners can develop strategies to mitigate the risks posed by geopolitical tensions and build more sustainable food security. Eventually, this study contributes to the existing body of knowledge on the resilience and resource nexus in food systems.

2 Methodology

This paper follows the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) which provides six steps as shown in Figure 1.

2.1 Study context identification

This stage focused on the identification of the general research idea and the objectives. The study context was identified through the existing ongoing global situation on geopolitical tension and food security. It discovered the resilience elements and policies enacted by vulnerable countries to enhance their food security and the resilience of different agrifood systems. The study used a systematic literature review extracting information from studies

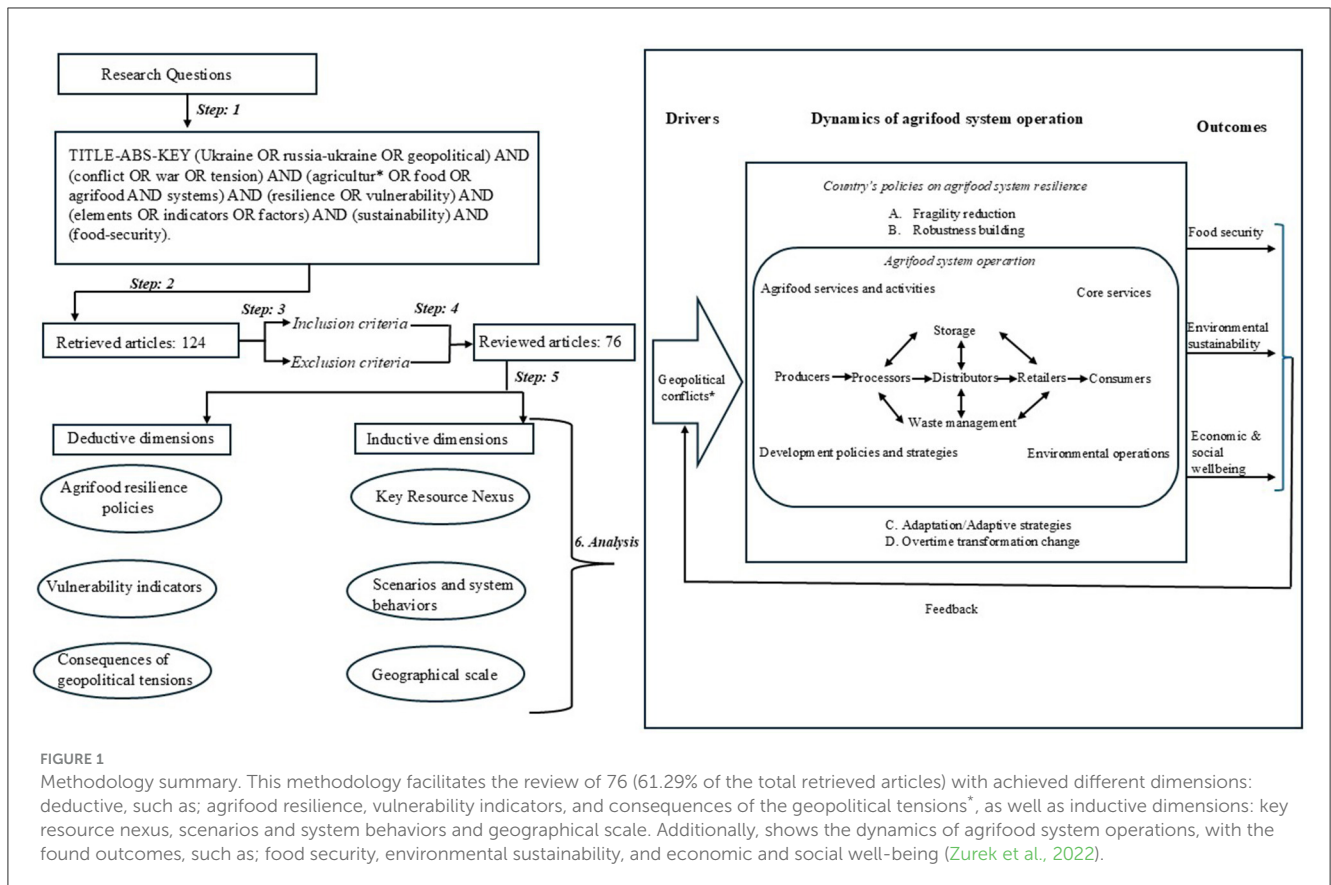


FIGURE 1

Methodology summary. This methodology facilitates the review of 76 (61.29% of the total retrieved articles) with achieved different dimensions: deductive, such as; agrifood resilience, vulnerability indicators, and consequences of the geopolitical tensions*, as well as inductive dimensions: key resource nexus, scenarios and system behaviors and geographical scale. Additionally, shows the dynamics of agrifood system operations, with the found outcomes, such as; food security, environmental sustainability, and economic and social well-being (Zurek et al., 2022).

about tensions, food security, and others related to the topic published from 2013–2023. understanding of the study’s context from the identified challenge facilitates three research questions which are; (i.) *What are the major vulnerability indicators of the agrifood system that distress global food security in the era of geopolitical tension?* (ii.) *What are the key agrifood system resilience elements and how do they differ between developed and developing countries amidst geopolitical tensions?* (iii.) *How do geopolitical conflicts influence agrifood resilience and resource interlinkages?* Most scholars define the Agrifood system’s resilience as the ability to tolerate experienced shocks and disasters and adapt to changes while maintaining its core functions (Miles and Hoy, 2023; Murphy et al., 2023).

In the context of existing conflicts, the agrifood system resilience is influenced by the diversification of the food sources and markets of the commodities, the cooperation between key stakeholders improves resilience by ensuring the continued functioning of the food supply chain (UNEP et al., 2023). These factors improve adaptability to changing situations (FAO, 2021) and reduce the vulnerability of the agrifood system to the effects of geopolitical tensions (Hobbs, 2021). Referring to Figure 1, illustrated different identified internal and external factors that affect the agrifood system’s resilience mechanisms. However, the major internal drivers include agricultural practices, technology adoption, and governance structures, while external drivers encompass factors such as climate change, economic policies, pandemics, and other related geopolitical tensions. In the era of geopolitical tension, most countries introduce different policies to

facilitate the performance of the agrifood systems. Implemented policies for fragility reduction, robustness-building, adaptation, and change in overtime transformation were considered in most cases.

Furthermore, the performance of the agrifood system involves a feedback system between drivers and outcomes that leads to a decision-making process, it enables the system’s components to adjust and adapt to changing conditions. Therefore, it is necessary to employ resilience policies at the national and global scale to ensure the efficient operation of the agrifood system and attain satisfactory results that can address the existing challenges.

2.2 Study materials search

The searches of documents were conducted in Scopus, extracting data from 2013 to 2023. The search strategy shown in Table 1 includes the keywords that form target papers focusing on agrifood system resilience and vulnerability elements or indicators or factors for the sustainability of food security during geopolitical tension, especially the Russia-Ukraine armed conflict. Furthermore, the Scopus search retrieved 124 reports related to the search terms, including publications in different languages. The search result was limited to publications in English due to our language skills. Then, followed by the screening, duplicate removal, and reports inclusion and exclusion criteria on title and abstract publications that provide insights into the relationship

TABLE 1 Document review process.

Date	Search string	Database	Documents
August 2023	TITLE-ABS-KEY (Ukraine OR russia-ukraine OR geopolitical) AND (conflict OR war OR tension) AND (agricultur* OR food OR agrifood AND systems) AND (resilience OR vulnerability) AND (elements OR indicators OR factors) AND (sustainability) AND (food-security).	Scopus	124

between agriculture and food systems resilience and food security in the context of geopolitical tension. The criteria involve lack of clarity, language, duplicate documents, and lack of other eligibility criteria as shown in Figure 2. In this study, the PRISMA meta-analysis was employed to determine the resilience of the agrifood system amid geopolitical conflicts, it is among the most suitable methodology to ensure inclusiveness, transparency, and independence in analyzing existing research articles. By following a given structured framework to obtain suitable documents for reviewing, the study can generate realistic perceptions from the findings on the existing impacts of geopolitical conflicts on agrifood systems, ultimately supporting informed policy and sustainability strategies. The screening was narrowed to include only those available publications that addressed the resilience of agrifood systems for sustainable food security during the Russia-Ukraine conflicts. After all, 76 documents were approved for the study review.

2.3 Data extraction and content analysis

2.3.1 Resilience elements and scenarios

Data extraction and content analysis were conducted to disclose enacted agrifood system policies and elements for resilience and grouped them into different scenarios. The content analysis of the retrieved documents was performed using MAXQDA which identifies resilience elements and other useful information mentioned in each scientific publication. This is a qualitative data analysis tool that facilitates the organization, coding, and analysis of different data from mixed-method research (Kirsten et al., 2025). It analyses various types of qualitative information, including text, audio, video, images, and survey responses. The study follows system-thinking steps to discover key resilience scenarios and elements of the agrifood system by reviewing approved documents. Thereafter, each scenario is composed of various enacted resilience elements or policies effective in mitigating risks and building the resilience of the agrifood system. To assess the resilience of the agrifood system amid geopolitical conflicts, the study developed different Resilience scenarios from the combination of study findings as shown in Table 2. These scenarios were designed to capture different pathways through which agrifood systems can respond to and recover from external shocks. Three resilience categorization studies provided guidance and references. First, Nieuwborg et al. (2023) described different categories of resilience in the aviation industry during the COVID-19 pandemic. The

major discovered types are fragility, robustness, adaptation, and transformation. Another framework from Hillmann and Guenther (2021) suggests categories for organizational resilience: resilience behavior, resources and capabilities, response, and organizational growth. Finally, the framework (Stone and Rahimifard, 2018) proposes redundancy, robustness, adaptability, and flexibility as the main categories of resilience in agrifood resources. The resilience categorization frameworks from these three different research studies and sectors were considered as the roadmap to show the broadest range of resilience scenarios

Four scenarios were derived from the three study frameworks consulted. The study adopted four resilience scenarios for the agrifood system in the context of geopolitical tension, guided by the following principles: fragility reduction, robustness building adaptation, and changes in overtime transformation as shown in Table 3.

These scenarios were based on the intentions of different countries they want to achieve after implementing different policies to address the effects of geopolitical conflicts on the global market trend of the agrifood key commodities for food security.

2.3.2 Geopolitical tension consequences analysis

This study employed a PESTEL breakdown on the consequences of geopolitical tensions in the agrifood system. It stands for Political, Economic, Social, Technological, Environmental, and Legal factors. Moreover, this framework provides a wide range and regular approach to studying the different external factors that influence agrifood system resilience amid geopolitical conflicts. Given that agrifood systems are governed by multiple archetypes represented by political, economic, social, technological, environmental, and legal dimensions, PESTEL allows for a holistic evaluation of how these factors interact and contribute to vulnerabilities or resilience policies, strategies, and plans. This study explored major vulnerability indicators of agrifood systems that affect food security in geopolitical tension. These indicators were associated with the four identified pillars of food security which are availability, accessibility, stability, and utilization (FAO, 2022).

2.3.3 Resource nexus concept

All Resource Nexus systems were qualitatively developed to model and explore interactions across and between sectors. Four research studies were used to generate the Matrix that described and evaluated the direct and indirect resource nexus effects in response to geopolitical tension. The first study by Brouwer et al. (2024) provided a background on the Resource Nexus concept. Moreover, it described the Resource Nexus as the interlinkages and interdependencies between the environmental resources. Besides, the study mapped different environmental resources in a Resource Nexus approach, where Water, Biota, Climate, Space, Material, and Soil were identified as key resources. In addition, Food, Sea, Waste, Energy, and Land were identified as other important resources derived from these key environmental resources. Apart from that, Hoff (2011) developed a resource nexus model to help find the optimal combinations of WEF (Water-Energy-Food) nexus system policy options and parameters that lead to the system's best

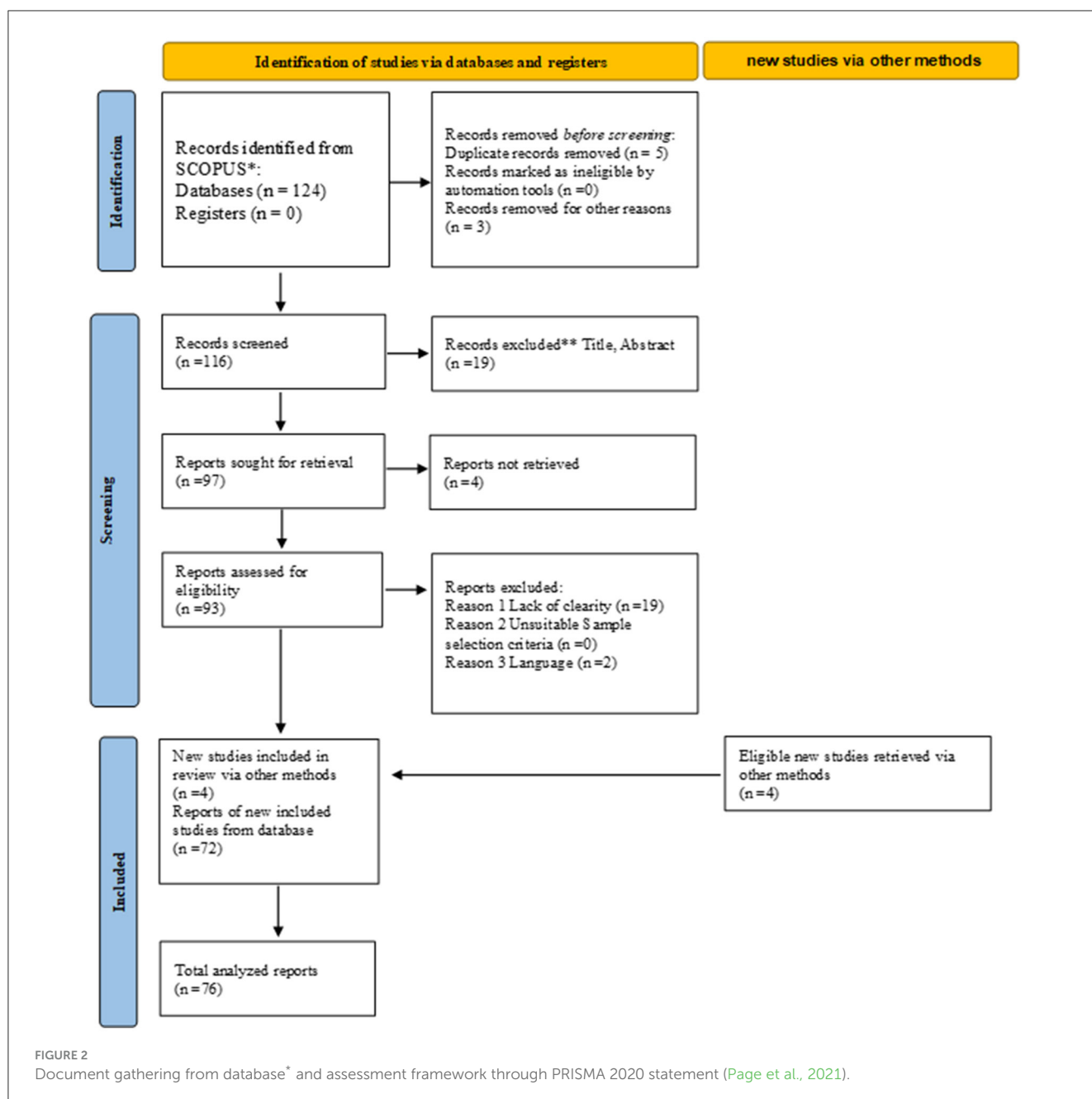


TABLE 2 Development of study's resilience scenarios from previous studies.

Targeted theme	Resilience aspects/scenarios				References
Organizational resilience	Resilience behavior, resources, and capabilities		Response	Organizational growth	Hillmann and Guenther, 2021
Agri-food resources resilience	Redundancy	Robust	Adaptive	Flexibility	Stone and Rahimifard, 2018
Aviation industry amid COVID-19 pandemic	Fragility	Robustness	Adaptation	Transformation	Nieuwborg et al., 2023
Agri-food system amid geopolitical tension	Fragility Reduction	Robustness Building	Adaptation/Adaptive Strategies	Overtime transformation Changes	Study's system thinking

TABLE 3 Agrifood system resilience elements categorization check and boundaries.

Resilience scenario	Elements categorization check	Boundaries
Fragility reduction	Does the proposed resilience policy or element address immediate risks?	<ul style="list-style-type: none"> - Reduce current vulnerabilities to prevent system collapse. - Address short-term food security and supply chain risks. - Involves reactive policies or interventions rather than proactive adjustments. - Either mentioned or discussed in the reviewed reports as a fragility reduction element.
Robustness building	Does it reinforce the immediate stability and productivity of the agrifood system?	<ul style="list-style-type: none"> - Maintain current productivity and stability during a crisis. - Focuses on hard infrastructures technological solutions and inputs. - Prevent immediate disruptions but does not involve long-term system shifts - Either mentioned or discussed in the reviewed reports to build the robustness of the system.
Adaptative strategies	Does it implicate flexible, short-to-medium-term adjustments of the agrifood system?	<ul style="list-style-type: none"> - Focuses on flexibility and learning-based responses to evolving crises. - Involves short-term to medium-term adjustments that help cope with uncertainties - Encourage diversification and innovation to adapt to new conditions. - Either mentioned or discussed in the reviewed reports contributing to the adaptive system.
Overtime transformational changes	Does the implemented policy or element drive the long-term structural transformation of the agrifood system?	<ul style="list-style-type: none"> - Focuses on structural reforms and paradigm shifts in the agrifood systems. - Involves long-term policy changes, institutional reforms, and social restructuring. - Aims at building a resilient, sustainable, and equitable agrifood system. - Either mentioned or discussed in the reviewed reports as transformative changes element.

performance. Other scholars describe a framework for integrating the quantitative WEF nexus simulation model with an optimization tool, which gives policymakers the ability to negotiate the best policy options based on the WEF nexus simulator (Karnib, 2017). Then Karthe et al. (2021) provided Resource Nexus’s understanding of the sustainable recovery of tourism amid COVID-19 where they highlighted that Resource Nexus can serve as a paradigm for promoting tourist sustainability. Moreover, instead of focusing on a single dimension, the study examines environmental resources holistically, considering possible synergies and trade-offs between different sustainable development goals (SDGs) as indicated in Table 4. Other insights acquired from Khairulbahri (2022), using the system archetypes the study proposes a qualitative analysis of the nexus dynamics in the Pekalongan coastal area, Indonesia. This study helped us integrate specific resilience elements into the renowned and less recognized nexus elements of the agrifood system during geopolitical tension. The resource nexus modeling ideas from these four different research studies were considered as guidance to show the general concept of resilience and resource nexus in agrifood systems. The study adopted and described the four most mentioned resource nexus resilience scenarios in the agrifood system in the context of geopolitical tension.

2.4 Results presentation

This study developed different data presentations based on a proposed research question. Results were presented based on the identified major consequences of geopolitical tensions on agrifood systems following the PESTEL breakdown arrangement. Also, through a literature review, the study identified the major agrifood system vulnerability indicators that affect global food security in the era of geopolitical conflicts. Moreover, it explores the possible interrelation of the agrifood system’s resilient elements and resources. Finally, it presents different implemented agrifood systems resilience elements based on context-sensitive perspectives with a specific focus on; the occurrence of the resilience elements based on the specific scenarios and country development.

TABLE 4 Sustainable development goals and their meanings.

Sustainable development goals (SDGs)
SDG1: End poverty
SDG2: End hunger, achieve food security
SDG3: Ensure healthy lives and promote wellbeing for all at all age
SDG4: Ensure inclusive and equitable quality education
SDG5: Achieve gender equality and empower all women and girls
SDG6: Ensure availability and sustainable management of water
SDG7: Ensure access to affordable, reliable, sustainable, and modern energy
SDG8: Promote sustained, inclusive, and sustainable economic growth
SDG9: Build resilient infrastructure, promote inclusive and sustainable industrialization
SDG10: Reduce inequality within and among countries
SDG11: Make cities and human settlements inclusive, safe, resilient, and sustainable
SDG12: Ensure sustainable consumption and production patterns
SDG13: Take urgent action to combat climate change and its impacts
SDG14: Conserve and sustainably use the oceans, seas, and marine resources
SDG15: Protect, restore, and promote sustainable use of terrestrial ecosystems
SDG16: Promote peaceful and inclusive societies for sustainable development
SDG17: Strengthen the means of implementation and revitalize the global partnership

Source: United Nations (2024).

3 Results

3.1 Summary list of resilience elements from the review

The selected 76 papers were retrieved from 39 different sources, including articles, books, reviews, and conference papers. It covered documents published from 2013 to 2023. The largest number

of documents was published on topics such as *Sustainable Food Systems* (8) *Sustainability* (8), *Food Security* (4), *Agriculture and Resources Economics* (3), and other sources related to policies on *Marine, Land use, Nature, and Resources*(2), and 1 document from the environment, *Global Change, and Circular Economy*. The reviewed publications include papers that shed light on agrifood systems resilience categorization, food, health, and environment security in the context of geopolitical tensions, especially in African and Middle Eastern countries. The sustainable food systems governance on interdisciplinary viewpoints, and highlights sustainability and supply chain management. Publications cover four continents (America, Europe, Asia, and Africa), with more articles from America. Dominant Corresponding Author's Countries are USA (29), Australia (22), UK (22), China (18), Ukraine (13), Germany (10), and other <10 from South Africa, India, and Italy.

A summary of the resilience elements discovered in our review is presented in [Table 5](#). From the systematic literature reviews, we extracted thirty-three (33) resilience elements that were implemented in agrifood systems during the era of Russia-Ukraine geopolitical conflict. The resilience elements refer to coping strategies or policies that individuals or systems use to manage crises, difficulties, and urgency ([Rutter, 2012](#)). There were four resilience scenarios or aspects or categories adopted from the studies of [Hillmann and Guenther \(2021\)](#), [Stone and Rahimifard \(2018\)](#), and [Nieuwborg et al. \(2023\)](#) in which the elements were grouped: fragility reduction, robustness building, adaptation or adaptive strategies, and overtime transformational change.

3.2 Geopolitical tension consequences influencing agrifood systems change: a PESTEL breakdown

The study has identified various outcomes influenced by geopolitical conflicts that affect the resilience of the agrifood system. The key influencing factors reflect the PESTEL approach, which includes Political, Economic, Societal, Environmental, and Legal/Regulatory consequences referring to [Figure 3](#). The study revealed that geopolitical conflicts between parties significantly impact the agri-food system. It has identified 24 specific consequences ([Figure 3](#)) affecting it. Considering its nature and particular sector of influence, these consequences are fitted into a specific PESTEL category. The economic category is the most dominant, comprising 41% of all identified consequences, including instability of agrifood systems, which is affected by trade disruptions and market shocks, which were the most observed factors, causing food fraud and difficulties in investment flows. However, 31% of the observed consequences are related to societal aspects like food insecurity, and humanitarian-related disasters. Moreover, 16% of the environmental consequences include the devastation of the environmental infrastructures, natural resources, and biodiversity. The political, technological, and legal/regulatory categories were less affected by 7, 3, and 2% respectively. Factors such as the destruction of foreign relations, diplomatic strategies, government policies, and international partnerships drastically impact the agrifood system.

3.3 Major agrifood system vulnerability indicators and global food security in the era of geopolitical conflicts

During geopolitical conflicts, agrifood systems were experiencing challenges in managing sustainable food security. Based on the total number of word occurrences in the evaluated studies, Food availability was mentioned as the most vulnerable aspect of the system. It is affected by two major factors, including the country's reliance on global commodities importation (grains and energy products) from conflicting parties which was mentioned 28 times. Also, the dependence of global economic development on the trade of grains and energy products from the conflicting countries was mentioned 24 times. Apart from that, the increased trend of income consumers spending mentioned on food 19 times as among food security vulnerability indicators, it was highly associated with reduced food utilization, especially in developing countries. Besides, the influence of economic and political instabilities of countries was mentioned 16 times as the vulnerability indicator for food accessibility. Finally, referring to [Figure 4](#) food instability was detected as the least affected pillar of food security.

3.4 Implementing resilience elements in agrifood systems: context-sensitive perspectives

3.4.1 Resilience elements based on specific scenarios

One of the studies revealed that 33 different elements significantly influence the resilience of the agrifood systems during geopolitical tensions ([Figure 5](#) and [Table 5](#)). These elements were systematically aligned into four categories/scenarios, including fragility reduction, robustness building, adaptation/adaptive strategies, and overtime transformation changes. These scenarios were then reflected as the outcomes of implementing certain policies over a specific period.

Furthermore, the scenario that proposed to reduce the fragility of the agrifood systems was identified as the most dominant and commonly experienced by 45% in the era of geopolitical conflicts. It is composed of 15 resilience elements, comprising the implementation of export and export restrictions to some countries to protect and govern the sustainability of the local producers, to cope with increased tariffs and quotas in other countries leveraging processed food products. Then followed by 24% of adaptive strategies were dominated by elements that focused on modifying the agrifood system and making it resilient to the consequences of geopolitical tensions. It is made of various elements like food testing, traceability, and statistical reporting, also implementations of research and technologies innovation, regional farmers/producers' cooperation, capacity building, crop substitution, as well as subsidies, intensive modernization, and mechanization. Whereas 15% of the overtime transformation changes scenario is composed of 5 resilience elements including agrifood systems governance and policy reforms, Conflict Resolution, Social safety net/access to resources,

TABLE 5 Summary list of resilience elements from the review.

Resilience scenario	Elements/Strategies	Occurrence	Category	Descriptions	References
Fragility reduction	Trade Restrictions	72	Economic	To protect domestic consumers and global food security from the effects of tensions between countries i.e. Russia-Ukraine conflict, most countries such as the European Union, the United States, and their allies-imposed trade restrictions such as import and export bans on Russia.	Hellegers, 2022
	Economic sanctions	61	Economic	The International Food Policy Research Institute recommends that both the sanctions on Russia and export restrictions to protect domestic consumers be designed to protect global food security and that consequences for third parties be assessed.	Hellegers, 2022
	Over-reliance global commodities	18	Economic	Very few African countries produce fertilizers in a minimally significant amount, they mostly depend on imports for this commodity, thus making local prices very respondent to variations in international prices.	Rogna, 2023
	Tariffs and Quotas	17	Economic	To reduce the fragility of their food systems and maintain food availability, some countries introduced tariffs and quotas, and others are categorically against tariffs, considering them an obstacle for local agricultural producers on the way to fulfilling international obligations.	Rudyk et al., 2023
	Storage and stockpiling	16	Societal	To counter food insecurity, the establishment of an independent global buffer stock to create a food reserve has been proposed, but there are numerous obstacles to practical implementation, especially in the identification of appropriate price triggers.	Trollman et al., 2023
	Market diversification	13	Economic	To minimize the global impact of the food crisis, it is important to diversify the domestic and international markets of the highly demanded food crops.	Neik et al., 2023
	Change food pattern/food assistance	12	Societal	As food prices rise, households shift their diets toward staple grains that become more dominant, while consumption of more micronutrient-dense animal-source foods, fruits, and vegetables declines. This is likely to result in child stunting, which can often lead to lifelong costs to the child and the economy.	Dyson et al., 2023
	Domestic and Regional Markets	10	Economic	As a result, some countries like Turkey are expected to mitigate the food crisis through a range of measures focusing on domestic markets, e.g., increasing domestic production, export bans, and aid to vulnerable groups, including the large population of Syrian migrants.	Al-Saidi, 2023
	Flexible Supply chain and Collaboration	10	Economic	The government's interest in private entities' supply chains increased by creating a risk management culture through a contractual agreement between a public agency and a private sector entity to market trend information, skills and assets, risks, and rewards to deliver services or facilities to the public.	Tukamuhabwa et al., 2017
	Leveraging Processed food products	8	Technological	When food prices rise, people reduce their consumption of more expensive nutritious foods, such as fruits, vegetables, meat, and dairy. And they maintain calorie consumption by buying more processed foods or cheap staple foods.	Xu et al., 2023
	Diverse Local food agricultural production	6	Environmental	Most of the developing countries are trying to produce various products as an alternative to reduce reliance on specific products and suppliers.	Tukamuhabwa et al., 2017
	Cross-border lending	6	Economic	The financial capacity of countries to protect themselves against such global threats as the war in Ukraine remains rather limited, thus, making them highly vulnerable and borrowing from other foreign countries.	Pryiatelchuk and Novak, 2022
Diverse food sources/dependence on imported global commodities.	4	Environmental	To minimize the global impact of the food crisis, it is important to diversify the import/export sources of food crops.	Karoliina et al., 2023; Neik et al., 2023	

(Continued)

TABLE 5 (Continued)

Resilience scenario	Elements/Strategies	Occurrence	Category	Descriptions	References
	Early warning systems/risk management	2	Technological	Governments develop and put in action preparedness plans (e.g., including critical data sharing among different ministries) for food safety incidents and natural disasters.	Galanakis, 2023
	International Companies negotiations	1	Political	Most of the food companies in Ukraine are now in the third round of negotiations with suppliers and retailers for the fourth wave of price increases which will further affect consumer behavior on food expenditures.	Mukhtar, 2023
Robustness building	Food/inputs price management (Negotiation)/subsidies	18	Political	Food subsidies are one of the policies that are considered to protect consumers from rising food prices, especially when there is insufficient local production and food must be supplemented by imports with fluctuating prices.	Gebeltoová et al., 2023
	Decreasing food waste	9	Social/Environmental	Efforts to reduce food waste along the value chains from retailers to private homes could thus reduce short-term pressures on global markets.	Pörtner et al., 2022
	Increase the use of synthetic agro-inputs	5	Environmental	Countries develop an application plan that optimizes synthetic agricultural input use.	Halecki and Bedla, 2022
	Controlling local currency value	3	Economic	To conserve and attract foreign currency, countries like Egypt continued devaluing their currency after the outbreak of the Russia-Ukraine war while increasing the interest rate.	Abay et al., 2023
	Resource mobilization	2	Economic	The mobilization of strategic stocks was prioritized by most of the countries as an important tool for countries to buffer spikes in commodity prices.	Berkhout et al., 2022
Adaptation/Adaptive strategies	Intensive Modernization and Mechanization	31	Technological	To minimize the negative consequences of Russia's military invasion of Ukraine and restore the Ukrainian economy's agricultural sector after the war, it is necessary to introduce innovations and modernize agricultural production.	Skydan et al., 2023
	Crop switching/substitution	13	Environmental	During the Ukraine conflict countries like the United States switched from cultivating crops that depended on the external market to crops such as corn that have more value in the domestic market.	
	Research, Innovation and Policy communication	13	Technological/Political	Collaborative networks between farmers, private and government research institutions, agronomists, researchers, and industry professionals in breeding programs drive knowledge and technology transfer through active dialogues and participatory research.	Neik et al., 2023
	Capacity building	11	Social	Knowledge and skills, both about food (or FSP) and "democratic" skills such as collaboration and tolerance, are essential prerequisites for food democracy	Pungas, 2023
	Food demands stability	10	Social	As their populations grow, several African and MENA nations are dependent on imported grains like wheat to meet their food and fertilizer needs. But if the conflict continues, there will be shortages in the supply of these goods, driving up the cost of food	Chepeliev et al., 2023
	Food testing and and traceability, statistical reporting	6	Legal	Further development in traceability and testing facilities is essential to eliminate the risk of contamination because of food fraud	Chepeliev et al., 2023
	Modern Market	4	Technological	Organized an online farmers' market on a popular online platform for groceries and other agricultural products to expand the reach of local farms	Tortajada and Lim, 2021
	Farmers' Cooperative and associations	3	Social	Farmers began to unite, and the public union "Agro-producers of Occupied Territories" was created, one of the main tasks of which was to speed up work on demining agricultural lands.	Skydan et al., 2023

(Continued)

TABLE 5 (Continued)

Resilience scenario	Elements/Strategies	Occurrence	Category	Descriptions	References
Overtime Transformational Change	Agrifood systems governance and Policy reforms/food democracy	26	Political	To cope with the global food crisis, governments and international organizations should actively act. Each country needs to reassess the risks and difficulties of its national food security from multiple dimensions of food security and restructure and improve its food system so that it remains resilient in the long run and ensures food security in the face of rising climatic, conflict-related, and economic risks.	Xu et al., 2023
	Social safety net/access to resources	19	Social	A large amount of humanitarian aid from domestic and international sources is collected and processed to be sent to countries in need like Ukraine, as well as distributed domestically.	Kovács et al., 2022
	Sustainable agriculture	13	Environmental	Diversification of agricultural practices, such as intercropping spatially or temporally, mixed farming with crop and livestock, adding organic material or beneficial microbes in the soil, and reduced tillage has contributed to biodiversity conservation, improved soil fertility, enhanced nutrient cycling, and water regulation, and improved pest control, decreasing the environmental burden without compromising crop yield.	Neik et al., 2023
	Conflict resolution	9	Legal	Promoting democracy, dialogue, and trust building should also be considered key to avoiding armed conflict and food security.	Nguyen et al., 2023
	Domestic renewable energy production	4	Environmental	Countries focus on improving energy sufficiency through implementing renewable energy infrastructures for domestic energy production. This was important because dependence on electricity was continuing to increase in society.	Karolina et al., 2023

This table shows four main resilience scenarios which are: fragility reduction, robustness building, adaptive strategies, and overtime transformational change. Additionally, each scenario is made up of several elements strategies, or policies implemented to improve the resilience of the agrifood systems amid geopolitical conflicts.

sustainable agriculture, and domestic renewable energy production. Finally, 15% of the robustness-building scenario which includes countries controlling local currency value, decreasing food waste, resource mobilization, increased use of synthetic agricultural inputs, and others focused on price management of food and agro-inputs products.

The study found trade restriction through export and import bans of the global commodities were the most frequently identified strategies with a frequency of 72. Followed by the implementation of economic sanctions against some countries, which was 61. On the other hand, the least frequently applied strategies were international companies' pricing and trade negotiation, resource mobilization, and the implementation of early warning and risk management strategies, which were identified only 1, 2, and 2, respectively.

3.4.2 Agrifood system resilience elements amid geopolitical tension for developed and developing countries

Based on the total number of resilience elements found in each scenario, the study found that compared to other resilience scenarios 15 resilience elements were employed to foster the reduction of the agri-food system's fragility (Figure 6). The study identifies that developing and developed countries prioritize measures that ensure food security. Furthermore, with a focus on specific resilience elements in each scenario, in the fragility reduction scenario, developing countries are highly executing tariffs and quotas, as well as increased foreign lending, whereas developed countries implemented policies that focus more on economic sanctions and diversifying food sources. Moreover, the study reveals that 80% to 90% of developing countries focus on initiatives such as diversification of local agricultural production, and domestic storage, respectively, while only 20 to 10% of developed countries have implemented these measures. Furthermore, developing countries have focused more on resource mobilization ideas to build the robustness of the system. The study found that about 80–90% of developed countries focused on building the robustness of the agrifood system through the reduction of food waste, increased use of synthetic agricultural inputs, and price management of crucial agrifood commodities.

Furthermore, to enhance over time transformation changes developed countries tend to focus on investing more in renewable energy and improving the governance and policy reforms within the agrifood systems. Conversely, during times of geopolitical tension, developing countries tend to prioritize social safety nets and sustainable agriculture initiatives to bring about gradual transformational changes within the agri-food system (Figure 6). On the other hand, the adaptation scenario consists of 8 resilience elements where developed countries play a dominant role in implementing food testing, traceability, and record-keeping (Figure 6). This influences regional cooperation between stakeholders, capacity building, and a shift from the production of one crop to another. Nonetheless, most of the developing countries propose adaptive strategies such as modern markets, intensive modernization, and mechanization strategies. They also implement initiatives that stabilize food demand to strengthen their adaptation.

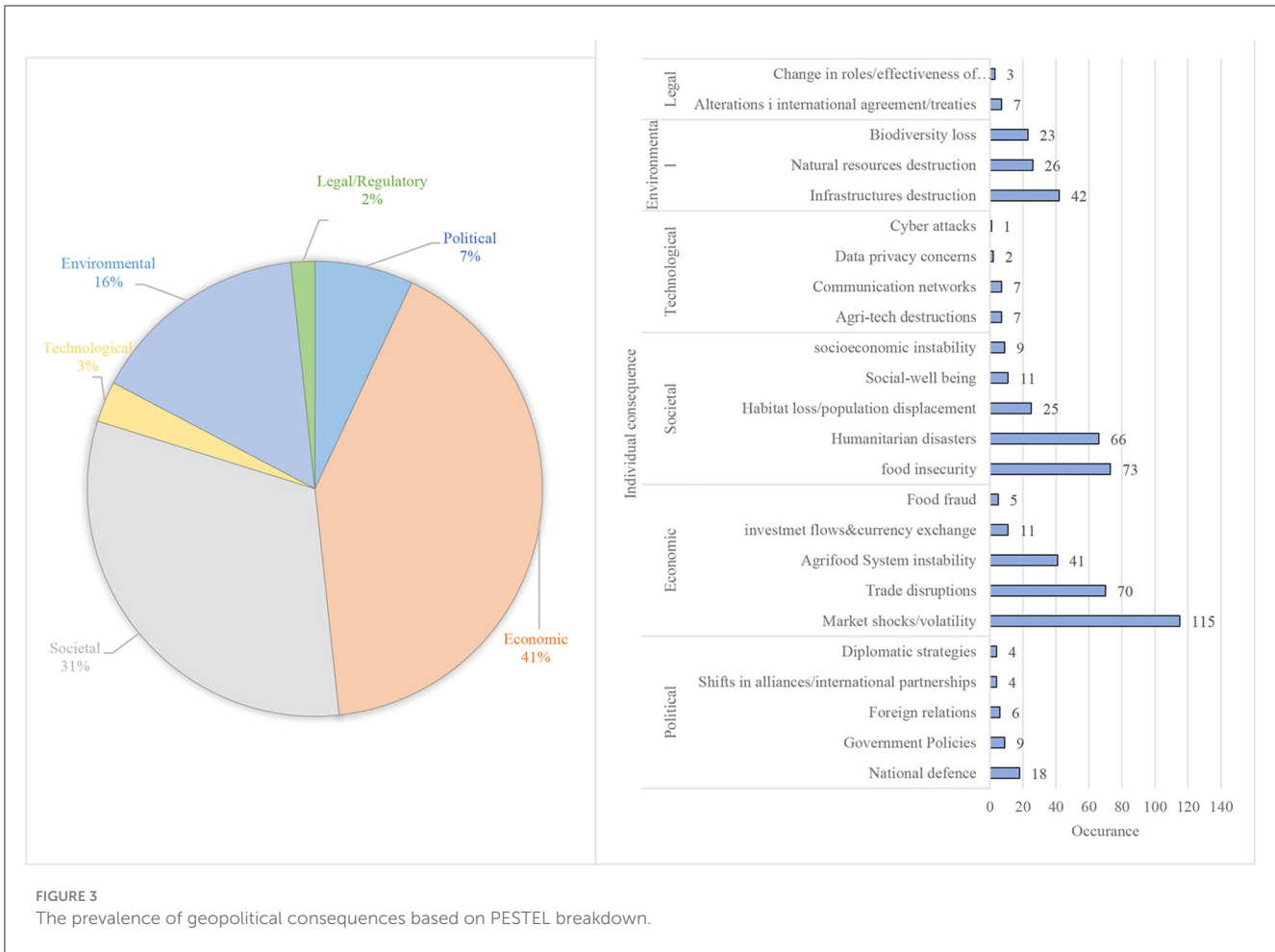


FIGURE 3
The prevalence of geopolitical consequences based on PESTEL breakdown.

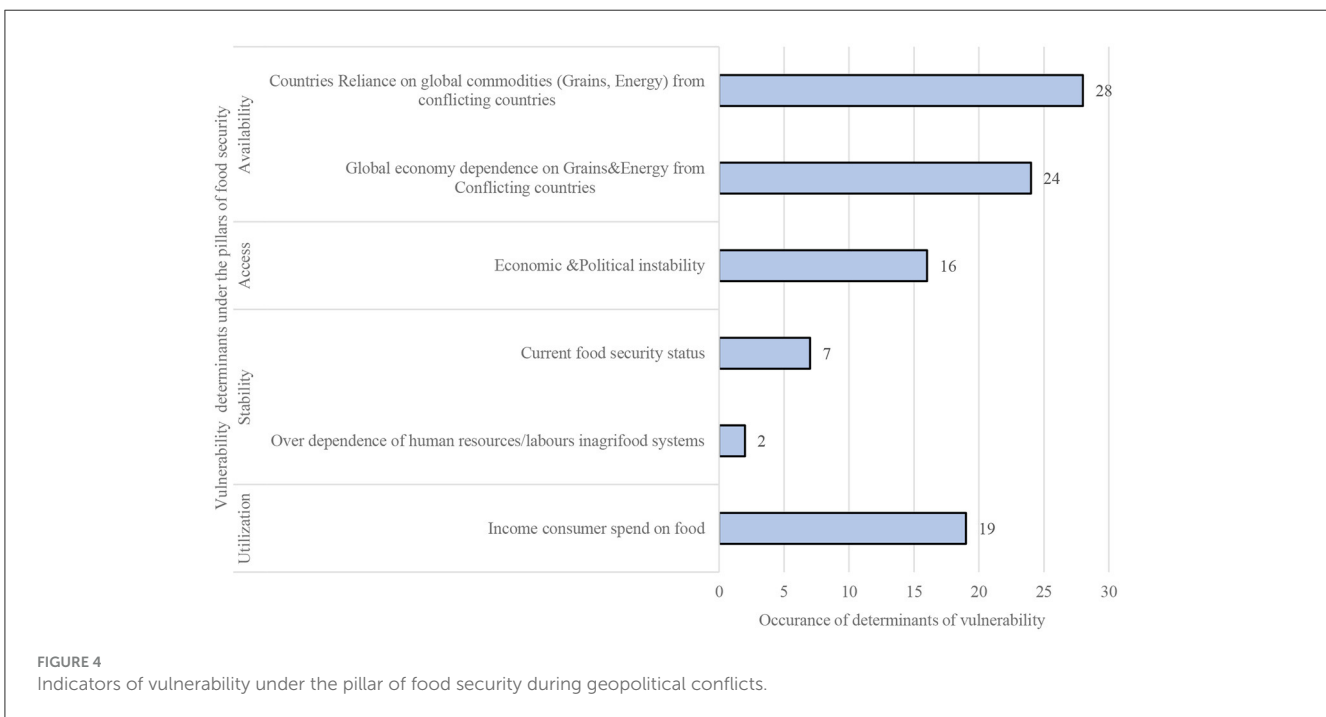


FIGURE 4
Indicators of vulnerability under the pillar of food security during geopolitical conflicts.

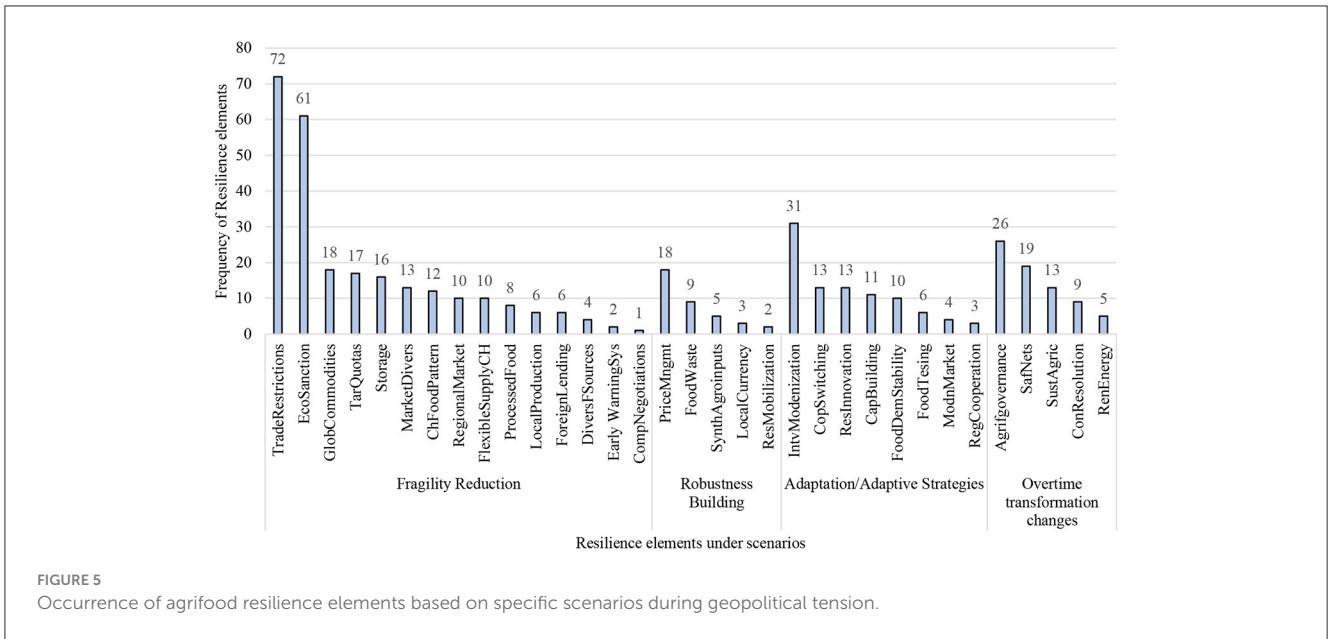


FIGURE 5 Occurrence of agrifood resilience elements based on specific scenarios during geopolitical tension.

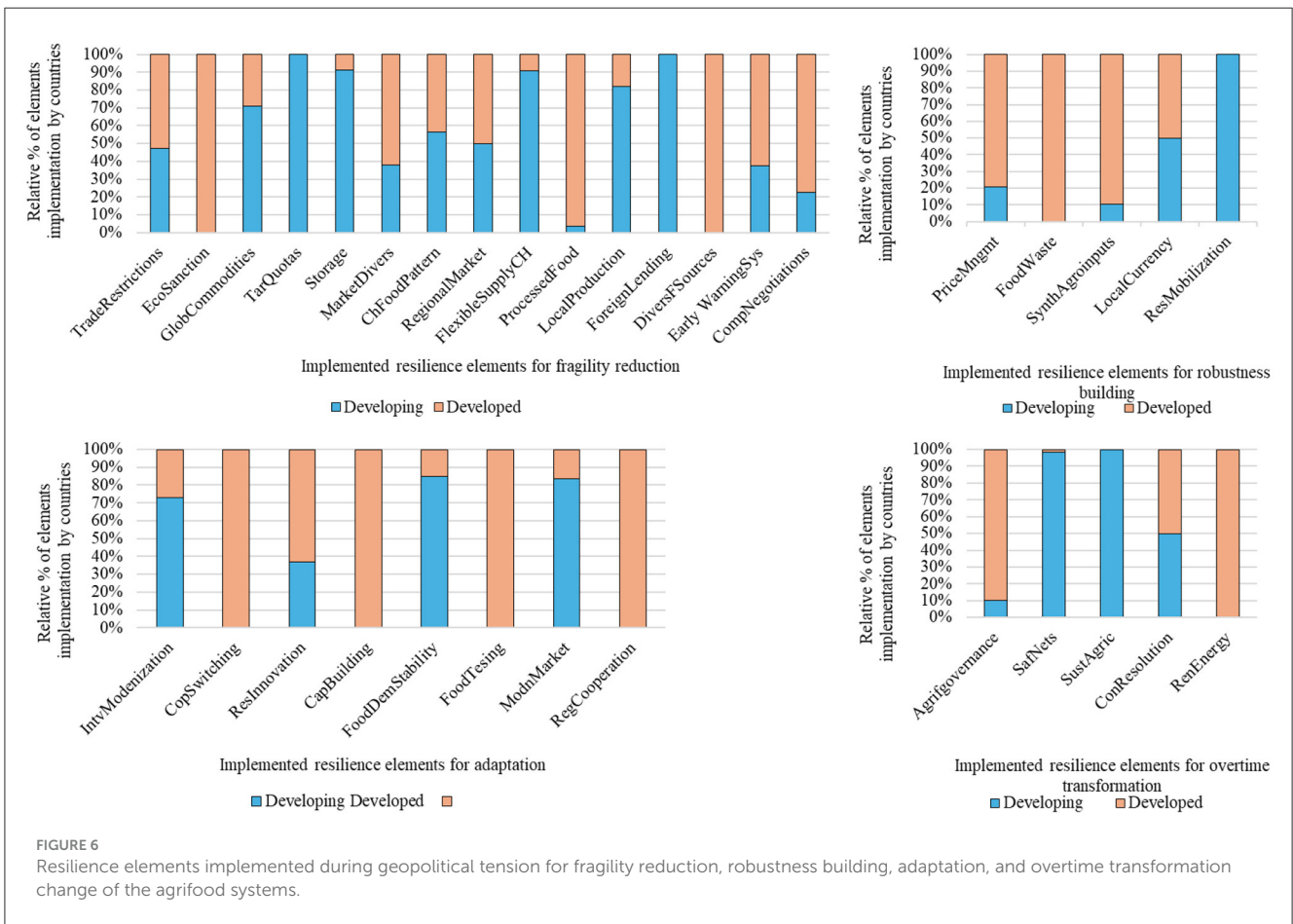
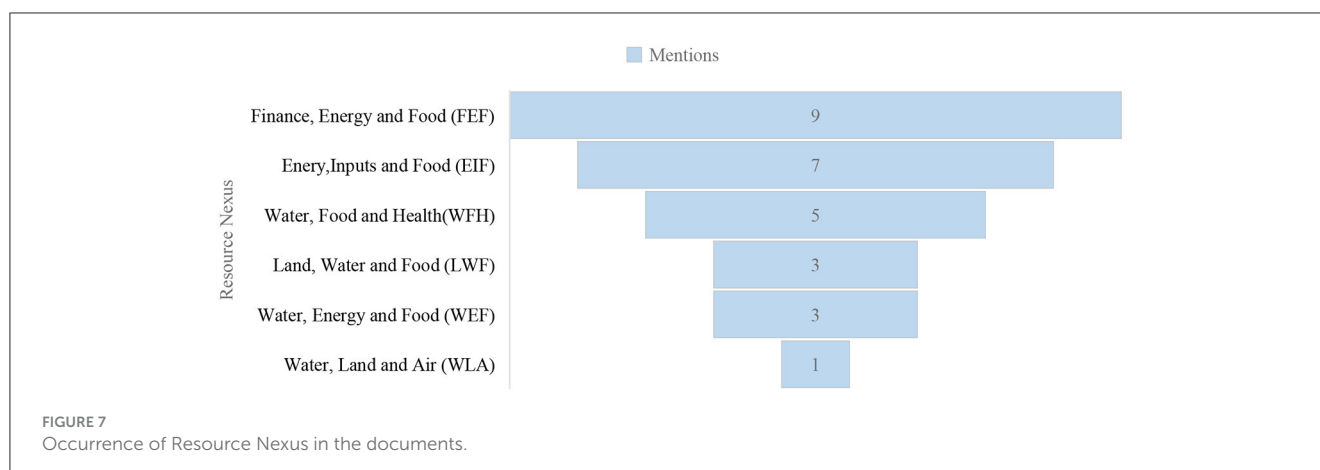


FIGURE 6 Resilience elements implemented during geopolitical tension for fragility reduction, robustness building, adaptation, and overtime transformation change of the agrifood systems.



3.5 Exploring the agrifood system resilience elements, and resource nexus in the context of geopolitical conflicts

The Resource Nexus and its related terms in the geopolitical tensions occurred 28 times. The Finance-Energy and Food Nexus (FEF) appeared as a dominant and most mentioned Resource Nexus in 9 statements. The Agroinputs, Energy, and Food sub-nexus (AEF) followed them, which occurred 7 times. Moreover, the study explored Water, Food, and Health interlinkage (WFH) stated 5 times. However, Land, water, and food (LWF), and Water, Energy, and Food (WEF) occurred 3 times while the least stated Resource Nexus was Water, Land, and Air (WLA) by 1 (Figure 7). Based on study findings, economic consequences are directly linked with FEF Nexus that financial crisis, sanctions, and increased transportation influence the agri-food systems' fragility as shown in Figures 8, 9. These factors were found to be interconnected in the study. Additionally, the primary FEF Nexus directly influences various other sub-nexuses.

4 Discussion

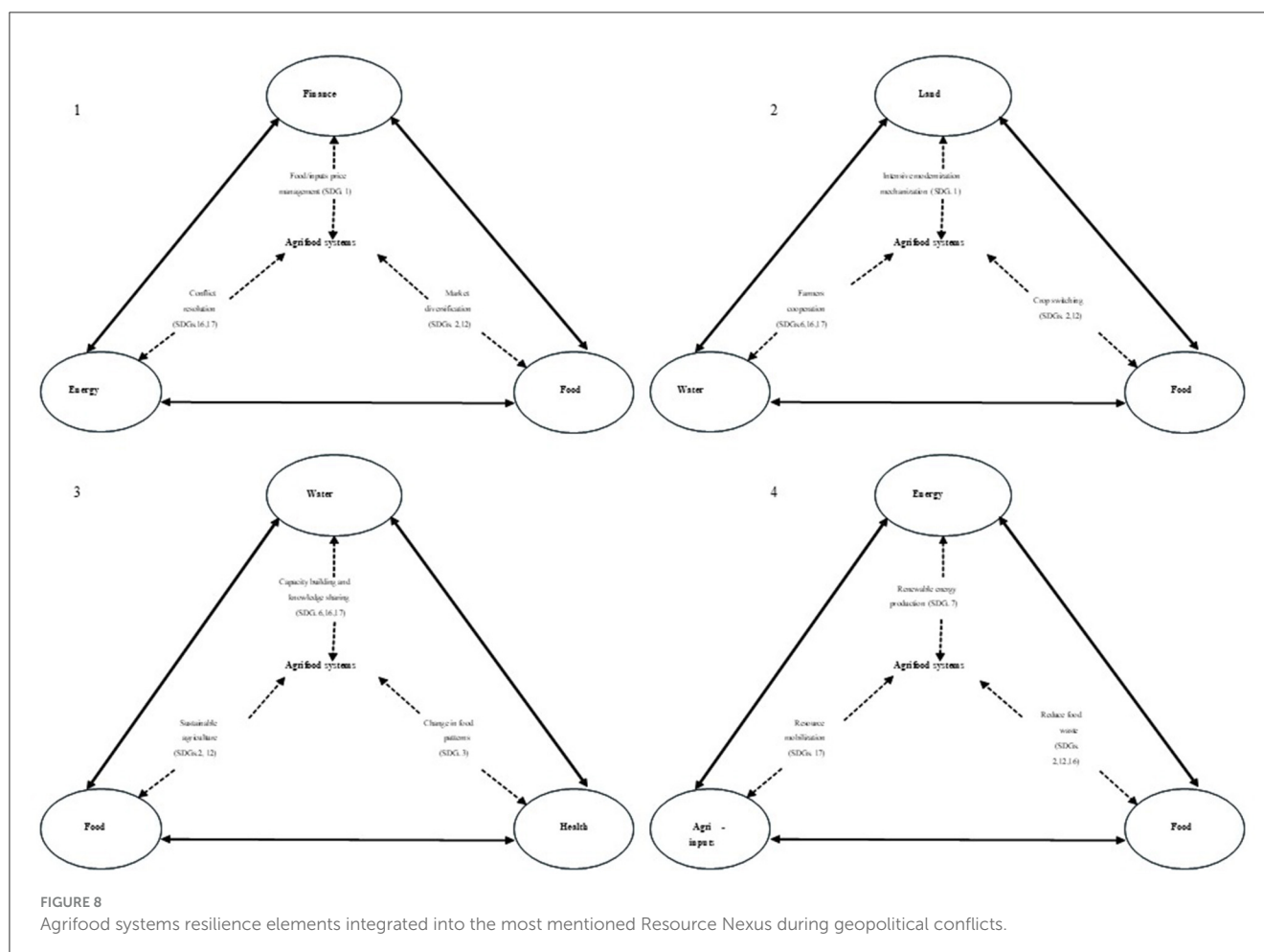
4.1 Addressing major agrifood system vulnerability indicators to enhance global food security in the era of geopolitical conflicts

The agrifood system faces distinct challenges due to geopolitical conflicts, as emphasized by this study. To make well-informed policies and be prepared for crises, it is crucial to acknowledge and comprehend indicators of food security vulnerability. This was proven through the study's systematic thinking approach. Still, the research systematically identifies how the four pillars of food security were directly affected by various socioeconomic influences that led to the vulnerability of the global agri-food system. Geopolitical conflicts disrupt agricultural production and distribution, leading to challenges in food availability, accessibility, stability, and utilization (FAO, 2022; von Cramon-Taubadel, 2022), making it difficult for stakeholders to plan and invest in agriculture for sustainable development of the agrifood system (OECD/FAO,

2023; UNEP et al., 2023). Moreover, societies in developing countries are often more vulnerable to food insecurity because they have less disposable income and are more likely to live in areas that are prone to conflict and natural disasters (UNEP et al., 2023; UNICEF, 2023). Empirically, food crises were highly experienced from 2020 to 2023, whereby wheat, energy, and fertilizer were highly scarce in the global market due to trade restrictions imposed by different countries (Vos et al., 2023). Most of the low-income countries depend on wheat, fertilizer, and oil products from Russia and Ukraine, which makes them more susceptible to hunger, undernourishment, and food insecurity due to imposed trade restrictions and sanctions.

Food utilization in the least developing countries has previously been observed as a major threatened pillar of food security for the social wellbeing and functioning of food systems (Gebel and Gundert, 2023; Morrissey et al., 2020; Nichols et al., 2013). Recently, in most of the developing countries, food availability was unexpectedly threatened by the economic consequences of geopolitical tension. However, vulnerability indicators for food availability were directly associated with the enacted economic sanctions and trade disruptions that enhanced the decrease of sufficient quantity of quality food to the global market (FAO, 2023; OECD/FAO, 2023; UNCTAD, 2023). An increase in reliance on imports and global economic dependence on global commodities from conflicting countries have heightened food availability challenges. According to (Priyatelchuk and Novak, 2022), food availability becomes increasingly limited by reduced imports, and food access is restrained by higher prices, lack of inputs, and the destruction of productive assets and infrastructure. Similarly, unnecessarily higher prices disrupt the global market and worsen the situation in sub-Saharan Africa, which is the most vulnerable (Ouko and Odiwuor, 2023). Several countries at the beginning of the geopolitical tension with the emerging financial, imposed export bans on some of the food items to address rising domestic food shortages. For example, India has banned wheat exports which has a significant impact on neighboring and vulnerable nations. Economically and politically powerful countries enforce export limits for their self-interest, prices rise, worsening food poverty (Dyson et al., 2023; FAO, 2022).

Likewise, geopolitical tensions pose additional effects to food accessibility and stability, due to the unpredictable economic and



political situation of the conflicting and non-conflicting countries. For instance, economic instability influences job losses and poverty (Gebel and Gundert, 2023; Morrissey et al., 2020; Nichols et al., 2013; Pryiatelchuk and Novak, 2022), which can make it difficult for susceptible society to afford food. Moreover, economic sanctions disrupt the food supply chain through increased costs of production and transportation due to increased prices of the agrifood commodities in the global market.

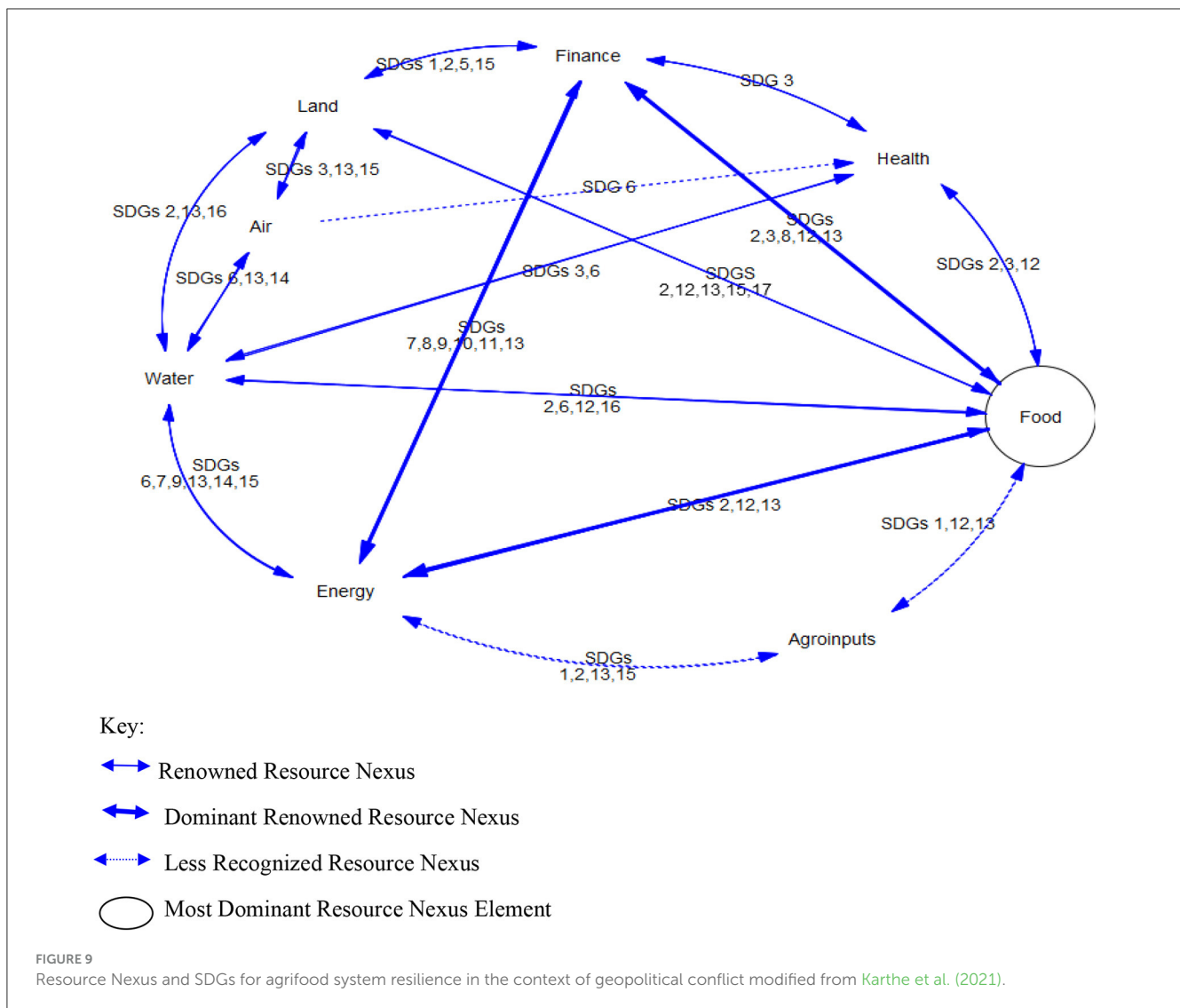
Furthermore, food utilization challenges have been linked with the consumer's purchasing power, rising food prices make people spend all their income on food, leading to social unrest. Compared between countries, consumers from richer countries spend a much smaller fraction of their income on food than those from poor countries (Hellegers, 2022). However, the amount of income spent on food is influenced by many factors, such as the cost of food and services, and preferences (Karonen and Niemelä, 2022; Muhammad et al., 2017).

Conclusively, the relationship between vulnerability indicators of the agrifood systems amid geopolitical tensions with the four pillars of food security is significant, because geopolitical tensions impact involve food insecurity, which also harms human health, economic development, and social stability (Ben Hassen and El Bilali, 2022; International Monetary Fund, 2022; Kemmerling et al., 2022). It is important to increase awareness of the possible

impact of geopolitical tensions on food security to make applicable adaptive initiatives.

4.2 Agrifood system resilience: a comparative analysis of developed and developing countries in the context of geopolitical conflicts

In the context of geopolitical conflicts, the resilience of agrifood systems varies significantly between developed and developing countries influenced by economic status, institutional framework, and trade dependencies. Developed countries implemented policies enabling them to mitigate food risks while recovering more efficiently from geopolitical shocks. Conversely, developing countries face greater vulnerability due to over-dependence on key agrifood commodities such as wheat, oilseeds, and fertilizers from the global market, making them more susceptible to disruptions in food production and distribution. The study's comparative analysis aims to identify the dominant resilience scenarios and the major elements implemented between developed and developing countries' responses to geopolitical conflicts. Also, to examine the effectiveness of each implemented



resilience policy in influencing the stability of the agrifood system, and highlight policy gaps that can inform global food security strategies.

However, the impact of the implemented resilience elements on sustainable food security varies according to the characteristics of certain specific resilience scenarios. The nature of the elements or policies determines the scenario’s behavior, enhancing the positive or negative growth of the agrifood system.

There was no statistical evidence, only the empirically significant effect of agrifood resilience elements on the sustainability of food security amid geopolitical tensions. The resilience elements that influence the effective performance of the agrifood system were found in different scenarios such as fragility reduction, robustness building, adaptation or adaptive strategies, and overtime transformation changes. In general, the fragility scenario showed negative behavior and increased food instability over time amid geopolitical tension.

In this study, the fragility reduction scenario was more dominant than other scenarios. This was due to the large number of policies or elements implemented to reduce the fragility

of the agrifood system during geopolitical tension. Somewhat surprisingly, some of the elements related to the fragility scenario appeared, although (not significant) non-beneficial to the agrifood system progress than robustness, adaptation, and transformation-related scenarios. To reduce the fragility of the agrifood system amid geopolitical conflicts, developed countries primarily focus on economic sanctions and diversification of food sources, meanwhile developing countries rely more on tariffs quotas and foreign lending. Furthermore, resilience elements such as economic sanctions, export restrictions, tariffs, and quotas were determined to distress more developing countries in safeguarding their growers, consumers, and markets (WTO, 2022). These elements raise food crises which increase the vulnerability of most of the developing countries due to a rise in the price of food and fuel. Various scholars correspond with the study findings, Araujo-Enciso and Fellmann (2020) highlight the long-term vulnerability of smallholder farmers and poor consumers to poverty traps, even when short-term price fluctuations are manageable. Imposing economic sanctions on Russia causes adverse effects on the economy of most developing countries that import agricultural commodities from Russia (Jagtap

et al., 2022; Mukhtar, 2023; Neik et al., 2023; Nguyen et al., 2023). Conversely, some studies differ from the study findings in that some of the implemented policies such as economic sanctions and export restrictions were enforced to protect susceptible domestic consumers from food insecurity (Abay et al., 2023; FAO, 2021; Hellegers, 2022; Sheahan and Barrett, 2017). Moreover, to avoid negative behavior from the implemented policies, Policymakers stabilized food markets and food security through focusing on short-term initiatives, consequently in the end these initiatives may not solve the intended problems with agrifood systems.

The study reveals that the robustness-building scenario was less implemented in both developed and developing countries. It was dominated by resilience elements that strive to increase the local currency values, reduce food waste, increase the use of synthetic agricultural inputs, commodities price management, and resource mobilization for sustainable food security. In this scenario, the developed economies rely on reducing food waste while developing economies focus on resource mobilization. Robustness differs from fragility because it has a sort of absorptive capacity to shocks. Implementing robustness-building mechanisms can result in suboptimal outcomes for the food system. Hence, several developed and developing countries have refrained from implementing it. In the adaptive strategies: developed economies rely on crop switching and regional cooperation, meanwhile developing economies rely on stabilizing food demand. Generally, the study findings highlight how sometimes erroneous it is to count only upon some scenarios as worthwhile to agrifood system resilience amid geopolitical tensions. This suggests that policymakers, governments, and stakeholders should prioritize the collective implementation of acknowledged measures to reinforce the resilience of agrifood systems in times of geopolitical tensions.

4.3 Exploring agrifood system resilience and resource nexus amid geopolitical conflicts

This study discovers different types of Resource Nexus and its Subsets that are directly or indirectly influenced by geopolitical tensions. The most mentioned resource nexus is Food, Energy, and Finance (FEF). Various scholars described that the geopolitical tensions supercharging a three-dimensional crisis of food, energy, and finance with devastating impacts on the world's most vulnerable people, countries, and economies balancing the three core needs is an uphill task that requires joint efforts of the international community (Guterres, 2022; Ouko and Odiwuor, 2023). The other identified nexus are Agroinputs-Energy-Food (AEF), Water-Health-Food (WHF), and Land-Water-Food (LWF). This situation happens to increase the growing importance of understanding the nexus between water, energy, food, and land in academic research (Khairulbahri, 2022).

This study showed that the disturbed nexus of food, finance, energy, water, land, health, and agricultural inputs (fertilizers and agrochemicals) might have far-reaching effects on the resilience of the agrifood system, owing to increased global interest. Influences such as increased food costs, lower resource availability, investment uncertainty, food insecurity, and other socioeconomic issues were

considered among the experienced consequences. These factors collectively make the agrifood system's resilience susceptible to different global shocks that endanger global food security.

Moreover, the synergies of two more resilience elements tend to stimulate the efficiency of any Resource Nexus and enhance the resilience of the agrifood system. It indicates that a disturbance in a single resource and its related policy can increase adverse effects across all levels of the agrifood system (Folke et al., 2002; Khairulbahri, 2022). Human Rights (2022); Kitenge (2023) and Onyeaka et al. (2022) portrayed that hunger and severe food insecurity in Eastern Africa are worsening due to the negative influence of the Russia-Ukraine conflict on food, energy (oil and gas), and fertilizer prices. Furthermore, in different nexuses, the resilience elements needed to achieve the same resource may vary. For instance, the FEF Nexus, achieving SDGs 2 and 12 requires enhancing food resources through market diversification. This also influences the function of other elements like commodity price management (Finance) and conflict resolution (Energy). In other Resource Nexus such as AEF, WHF, and LWF, achieving food security necessitates implementing different elements other than that from the FEF nexus. For example, reducing food waste, promoting sustainable agriculture, and crop switching are essential. Moreover, disturbances to the food supply chain caused by geopolitical conflicts affect the efficiency of various resource nexuses and make food production more expensive (OECD/FAO, 2023). Nevertheless, to sustain food security in the era of geopolitical tensions, the key resilience elements that should be considered are those that improve resource nexus efficiency, through strengthening market diversification, investing in agricultural innovation, promoting sustainable land management, empowering smallholder farmers, enhancing cross-sectoral coordination, etc.

In conclusion, change in Resource Nexus efficiency has an obvious influence on food security, public health, and economic stability (Ben Hassen and El Bilali, 2022). It is relevant for policymakers, researchers, and stakeholders to focus on the resilience of the agrifood system through sustainable management of the available resources that will finally achieve maximum efficiency.

4.4 Bridging the gaps: agrifood system's vulnerability indicators, resilience differences, and resource nexus solutions amid geopolitical conflicts

This study found that the resilience of agrifood systems amid geopolitical tension, in both developed and developing countries, is deeply dependent on the addressed six major vulnerability indicators that facilitate the effectiveness of the four pillars of food security (availability, accessibility, stability, and utilization), through the application of worthwhile resilience policies, and the consistent resource nexus. Major vulnerability indicators, including the overreliance of countries on global commodities from conflicting nations, economic and political instability, and the proportion of consumer income spent on food, have significantly aggravated food insecurity in developing countries

compared to developed countries where they have strong economic and institutional capacity. The experienced vulnerabilities affect susceptible agrifood systems and Resource Nexus, which are more exposed to global shocks.

Moreover, the study identified that the food-energy-water (FEW) and land-water-food (LWF) nexuses under the support of finance, and community health factors are crucial in enhancing agrifood resilience. The existence of geopolitical conflicts between major producing countries of the key global commodities hinders the efficiency of these resource nexuses, intensifying food insecurity by limiting the availability and accessibility of important agricultural inputs, such as fertilizers, and irrigation resources (Bas, 2025; Quitzow et al., 2025; Rudloff et al., 2024), which in turn distresses the agrifood system's productivity and elevates food crisis in vulnerable countries. Furthermore, the extent to which the resource nexus overlaps or should be integrated for effective operation and sustainability of the agrifood system is a key consideration in policy design and implementation. However, employing different resilience policies to facilitate robustness, adaptive, and transformative agrifood systems amid geopolitical conflicts will significantly impact attaining resource nexus efficiency and food security (Aungkulanon et al., 2024; Nadia et al., 2024). For instance, during geopolitical conflicts, countries enact policies such as food and inputs price management, resource mobilization, and implementing sustainable agricultural practices (Stanberry and Fletcher-Paul, 2024) to facilitate an effective adjustment of the devastated resources. Consequently, some of the policies disclosed positive promising results under sustainable resource management and ensured the resilience of the agrifood system, while others exhibited worse reactions. A holistic approach that promotes regional cooperation and sustainable resource management can enhance Resource Nexus efficiency and strengthen resilience capacity in both developed and developing economies in the context of geopolitical conflicts.

Conclusively, the study responds to the proposed three research questions, where it highlights that the connection between identified agrifood system's major global vulnerability indicators, enacted resilience elements, and prioritized Resource Nexus determines how agrifood systems respond to the consequences of geopolitical shocks to enhance resilient agrifood system for sustainable global food security. A well-designed agrifood system's resilience context that integrates findings from the research questions dimensions can better inform policies, strategies, and plans to sustain global food security and mitigate the long-term consequences of an existing geopolitical conflict. Addressing these challenges through adaptive governance, cross-sectoral collaboration, and strategic resource allocation will be essential for strengthening agrifood system resilience in an increasingly uncertain geopolitical landscape.

5 Conclusion

This study proposed based on the increased interest in exploring the resilience behaviors of the agrifood system, observing the interlinkage between resources, and their influences on sustainable food and nutrition security amid geopolitical tension. The findings declared that compared to developed countries,

most developing countries employed policies focused on reducing the fragility risks of agrifood systems. Moreover, the reduction of agrifood system fragility is more prevalent compared to the other three scenarios, there was a decline in the performance of the agrifood system due to the existence of some elements that increased the system's instability over time. However, the impact of the implemented resilience elements on sustainable food security varies following the characteristics of certain specific resilience scenarios. The nature of the elements or policies determines the scenario's behavior, enhancing positive or negative growth of the agrifood system. Based on their specific outcomes, resilience elements have been designated into four unique scenarios, namely fragility reduction, robustness building, adaptive strategies, and overtime transformation changes. We found that the impact of agrifood system resilience elements on sustainable food security is not uniform and varies depending on the specific scenario; it can influence either valuable or devastating impacts across all levels of the agrifood system.

Furthermore, this study shows that the impact of agrifood resilience concepts on food security is not uniform and varies depending on the specific agri-food resilience scenarios recognized at each level of the agri-food system. It identifies food availability as the most important pillar of food security in times of crisis in the region, due to the increasing dependence on imports and the dependence of international trade on goods from conflicting countries. At the same time, the most common resource relationship during the crisis in the region was food, energy, and finance (FEF), while other relationships included land, water, food (LWF), and water, energy, and food (WEF). Generally, this means the main factors to consider are those that contribute to the relationship between resources, food availability, accessibility, sustainability security, and use. At a time of increasing geopolitical tensions, this research demonstrates the need to reflect on increased knowledge and interest in the resilience of agri-food systems and Resource Nexus.

This study is limited to specific geopolitical tension and armed conflicts between countries and was only conducted in the agrifood sector. However, despite this limitation, this study makes an important contribution because it provides a thorough analysis of the present understanding regarding the resilience of agrifood systems and the impact of geopolitical tensions. This research paper contributes to the existing body of knowledge on the resilience and resource nexus in food systems. Future research should focus on determining the characteristics and behavior of the identified resilience scenario under the influence of existing Resource Nexus efficiency.

6 Limitations of the study

Although the review covers a wide geographical range, the dominance of articles from Western and Chinese perceptions may introduce a geographical bias, potentially limiting the applicability of findings to regions with lower representation in the dataset (e.g., Africa and South America). There is a need for future research to address this gap by incorporating more diverse regional perspectives.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AM: Conceptualization, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Funding acquisition, Investigation, Software, Validation. TL-K: Investigation, Resources, Software, Visualization, Writing – review & editing, Methodology, Validation. KM: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing. EG: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research was jointly funded by the Saxon State Ministry of Energy, Climate Protection, Environment and Agriculture (Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft, SMEKUL), and the United Nations University-Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES). The Technische Universität Dresden (TU Dresden) provided financial support for the open access fee associated with this publication.

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Acknowledgments

The authors of this review would like to thank Dr. Offoro Didas Kimaro, Ramoudane Orou Sannou, and Simon Chidodo for their valuable contributions. The constructive comments of all four reviewers, Editor Prof. Dr. Catherine Keske, and the Technische Universität Dresden (TU Dresden) support for open-access publication are greatly appreciated.

Conflict of interest

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