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Innovation and new challenges in the world: proposals to redesign food supply and production chains to resist geopolitical and climate disruptions in a forward-looking way

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Abstract

The objective of this research was to develop some proposals to strengthen the resilience of food supply chains to guarantee, as far as possible, food security for all nations. Based on a synthesis methodology that combined philosophical reflection with a prospective vision of reality, a set of documentary sources of high scientific and academic value were processed, which led to the conclusion that addressing the current vulnerabilities of supply chains requires a combination of technological innovation, appropriate strategies on the part of the countries of the

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global south and effective international policies. Soon, collaboration between nations and productive sectors will be key to building resilient food systems capable of withstanding climatic and geopolitical shocks.

Keywords: supply chains, food production, food geopolitics, prospective analysis, climate change.

Innovación y nuevos retos en el mundo: propuestas para rediseñar las cadenas de suministro y producción de alimentos a fin de resistir las perturbaciones geopolíticas y climáticas con visión de futuro

Resumen

El objetivo de la presente investigación fue desarrollar algunas propuestas que fortalezcan la resiliencia de las cadenas de suministro de alimentos, con el ánimo de garantizar, en lo posible, la seguridad alimentaria para todas las naciones. Desde una metodología de síntesis que combino la reflexión filosófica con la visión prospectiva de la realidad, se procesaron un conjunto de fuentes documentales de alto valor científico y académico, las cuales permitieron concluir que, abordar las vulnerabilidades actuales de las cadenas de suministro requiere una combinación de innovación tecnológica, estrategias adecuadas por parte de los países del sur global y políticas internacionales efectivas. En el futuro próximo, la colaboración entre naciones y sectores productivos será clave para construir sistemas alimentarios resilientes capaces de resistir perturbaciones climáticas y geopolíticas.

Palabras clave: cadenas de suministro, producción de alimentos, geopolítica de la alimentación, análisis prospectivo, cambio climático.

Introducción

Scientific and interdisciplinary research on innovation and new challenges in the world of food supply chains and production seeks to offer valid solutions to face geopolitical and climatic shocks. In this order of ideas, the general objective of this article was to develop some proposals that strengthen the resilience of these chains, always guaranteeing food security for all nations. The fundamental

questions that emerge from this objective are: What are the main vulnerabilities of current supply chains? How can technological innovations improve resilience to geopolitical shocks? What strategies should countries in the global south adopt to ensure their access to food? What role do international policies play in the stability of these supply chains?

Food supply chains typically face significant challenges due to geopolitical disruptions of various kinds. The war in Ukraine, for example, has disrupted the flow of essential grains, affecting countries dependent on these imports. According to an analysis by the site specialized in geopolitical and strategic issues AON (2022), since its inception in February 2022, the Russian invasion of Ukraine has profoundly impacted global food security, exacerbating the crisis in nations that were already facing food insecurity (AON, 2022). This situation of high humanitarian danger highlights how conflicts between nation states can drastically alter the availability of basic products, putting millions of people in different regions of the world at risk, in fact, Ukraine and Russia:

> The region's contribution to the global food, agriculture and beverage industry is massive. Combined, the two countries are responsible for nearly one-third of the world's wheat exports. Numerous countries - many in the Middle East and Africa- are hugely dependent on that wheat. The threat of famine now seems very real for many of them. (AON, 2022, párr. 3)

Alongside the issue of the food crisis, climate change adds another layer of complexity to international supply chains. In the words of Diamond (2007), historically speaking, mutations in weather patterns and extreme events such as global warming are reducing agricultural production and increasing operating costs, which, under certain geopolitical conditions, can generate the collapse of

entire civilizations as has already happened in the past. A study authored by Oriekhoe, Adisa, and Ilugbusi (2024), indicates that climate change is transforming the dynamics of food production and distribution, creating significant economic uncertainties. This complex reality not only affects the quality and quantity of food, but also increases the risk for producers and consumers globally.

As will be seen in the following pages, innovating in the field of public policies framed in redesigning supply chains implies, among other things, adopting digital technologies and sustainable practices that improve efficiency and transparency. The implementation of technologies such as the Internet of Things (IoT) and blockchain can optimize, in the opinion of Panigrahi, Singh and Muduli (2024), the tracking and traceability of food products. Entering the 21st century, digital technologies are key to building more resilient and sustainable supply chains. So, these innovations, on the one hand, help mitigate objective risks and, on the other, allow for better adaptation to changing market conditions.

The rationale for this research lies in the urgent need to ensure sustainable food sovereignty for all nations. Without any doubt, it can be said that food insecurity is a critical problem that disproportionately affects countries in the global south, where many vulnerable communities already face high levels of poverty. As Fillol (2019) mentions, in his philosophical reflections on Food Security as a sustainable factor of international peace and security, the availability and accessibility of nutritious food are essential for sustainable development. Therefore, ensuring stable supply chains is essential to achieve these objectives associated with governance and governance.

It is the reported criterion of the authors of this research that, by philosophically addressing the redesign of these chains, it seeks not only to mitigate the immediate negative effects of geopolitical and climatic disturbances, but also to promote inclusive economic development, as a material basis for the enjoyment and enjoyment of human rights. To this end, scientific research should focus on how public policies at different levels of action (local, national, and international) can support local producers and improve their ability to adapt to sudden changes in the global environment. This is especially relevant for countries with vulnerable economies that rely heavily on international trade (Panigrahi, et al., 2024).

As can be inferred from what has been said so far, this study aims to provide a comprehensive, albeit general, framework for redesigning food supply chains in the face of contemporary challenges. Through technological innovation and effective collaboration between nations, it is possible to build a more resilient food system that not only resists future shocks, but also promotes equity and sustainability at the global level, in accordance with the SDGs, much more so when the so-called 2030 Agenda:

> ... it is a plan of action for people, planet, and prosperity. It also aims to strengthen universal peace within a broader concept of freedom. We recognize that the eradication of poverty in all its forms and dimensions, including extreme poverty, is the greatest challenge facing the world and is a prerequisite for sustainable development. (United Nations General Assembly, 2018, p. 1)

Otherwise, this article is divided into 5 sections, namely: in the first, a bibliographic balance is made of the main sources that provided the general theoretical concepts for the development of the research; in the second section, the

methodological procedures are exposed; In the third, which functions as an analysis and discussion of results, four general proposals are developed as inputs for the debate on this complex issue. Finally, the conclusions and recommendations of the research and the index of references cited in alphabetical order are presented.

1. Theoretical bases and review of the specialized literature on the subject

This section provides a theoretical review of the most outstanding high-impact scientific articles published in the last five years, in English and Spanish, on the following thematic categories that are present from the title of the article:

- Innovation and new challenges in food safety.
- Proposals to redesign food supply and production chains.
- Food security in the face of forward-looking geopolitical and climate shocks.

A theoretical review of the recent literature on innovation and new challenges in food security reveals a wide range of approaches and methodologies. In general, the studies analyzed by us (Gonzalvo, 2023; De las Moras, 2023; World Economic Forum and the Boston Consulting Group, 2024; The Food Tech, 2024), address the intersection between technology, sustainability, and public policy, emphasizing the need for innovations that respond to contemporary challenges. More specifically, most articles and sources focus on the application of advanced technologies, such as artificial intelligence and blockchain, to improve efficiency and traceability in supply chains. At the same time, the importance of a multidisciplinary approach involving both scientists and policy makers to address these complex problems and provide some

concrete theoretical and practical solutions for the benefit of food security is highlighted.

In terms of innovation and new challenges in food security, the studies consulted highlight that the adoption of emerging technologies is crucial to face current challenges. For example, nanotechnology and biotechnology are noted as essential for optimizing food production (Gonzalvo, 2023). With the necessary policies and clear objectives, these technologies allow to increase production and improve the nutritional quality of food. In addition, it should not be ruled out that the use of artificial intelligence can help, in prospective terms, to predict failures in production systems, which reduces waste and improves sustainability, as stated by De las Moras (2023).

Image 1. Technification process of food production

Source: The Food Tech, 2023

Another relevant aspect in the current debate on food safety is how changes in consumer habits are driving innovations in the food sector. In the so-called white paper on the Integration of Food Innovation, authored by the World

Economic Forum and the Boston Consulting Group (2024), it is stated that consumers are increasingly interested in sustainable and healthy products, which forces companies to adapt quickly to these demands. Thus, this transformation in eating habits not only implies changes in the products offered, but also in production and distribution practices, which represents a significant challenge for companies in the sector. However, there are other structural challenges that need to be weighed, as:

> **Today, global food systems are faced with a dwindling supply of arable land as they try to feed a growing global population**. On current trends, more than 90 percent of the world's soils could be degraded by 2050, reducing global food production by 10 percent2. Farmers, who are the foundation of the food system, bear the brunt of this dysfunction – of the 700 million people living in extreme poverty in the world. (World Economic Forum; Boston Consulting Group, 2024, p. 8) (emphasis added).

In the face of these very discouraging figures:

> ... The food system will need to produce more calories in 2030 versus 2020, as the world's population and per capita calorie consumption grow at a rate of 0.86% and 0.39% per year, respectively. In addition to this increase in demand, there is an increasingly intensive consumption of resources and an increase in waste... Immediate change is needed to improve this situation and prevent it from getting worse. (World Economic Forum; Boston Consulting Group, 2024, p. 8)

The realistic prospects of the global food crises that are looming soon drive the strategic need to rethink proposals to redesign food supply and production chains, in an international context where digitalization is a key factor. As has been repeated so far, the integration of technologies such as the Internet of Things (IoT) and data analytics allows for more efficient and proactive management of supply chains. According to the site specializing in cutting-edge food technologies, The

Food Tech (2024), digitalization provides real-time visibility, which is very useful when it comes to responding to market fluctuations. This technology not only improves operational efficiency, but also, and this is the important thing, contributes to better inventory management and waste reduction. More specifically, it is:

- IoT and Smart Sensors: Real-time sensors monitor storage and transportation conditions, ensuring that products maintain their quality and safety.
- AI and Machine Learning: These technologies analyze large volumes of data to predict demand and optimize inventory, thus reducing the risk of shortages or overstock.
- Blockchain: Facilitates product traceability, ensuring transparency and trust throughout the supply chain. (The Food Tech, 2024, par., 7)

In the literature consulted, it has been proposed to systematically promote greater collaboration between key actors in the supply chain. So, coordination with suppliers and other strategic partners is, in this context, the force to optimize processes and reduce costs. According to The Food Tech (2024) and the World Economic Forum and Boston Consulting Group (2024), companies that implement collaborative management systems manage to significantly improve their delivery times and customer satisfaction. This collaboration, both economic and strategic, can also facilitate the adoption of sustainable practices that benefit both business and the environment for the benefit of humanity.

Image 2. Sensors that combat food waste

Source: Bahena, 2023

In relation to food security in the face of geopolitical and climatic shocks, which is precisely the central theme of this research, the specialized literature on food geopolitics suggests that it is necessary to strengthen international cooperation networks. In the words of Borrell (2022), in general terms, global food insecurity is increasing due to geopolitical tensions and extreme weather events. For the authors of this research, this inescapable reality highlights the urgent need to develop bold policies that promote greater food self-sufficiency and resilience in the face of future crises, within the framework of what sustainable development means as a post-neoliberal and post-Marxist development model that combines growth with equity and respects the existential balance of the biosphere.

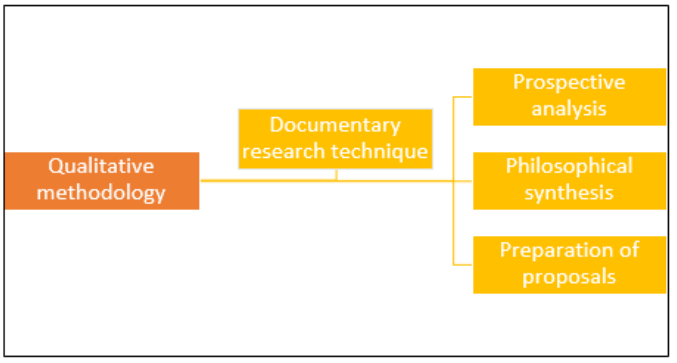
In summary, the reviewed articles offer a comprehensive vision on how to innovate in the field of food safety and, at the same time, redesign supply chains. The combination of emerging technologies, collaboration between key actors and a focus on sustainable practices are the way to face current challenges. As the

world faces growing geopolitical and climate crises, it becomes urgent to adopt a proactive and inclusive paradigm to ensure a secure and sustainable food future for all nations of the world.

2. Methodology

As already stated in the abstract, the methodological design for the topic of proposals to redesign food supply and production chains is roughly based on a synthesis methodology that combined desk research with a prospective approach. In principle, the documentary research technique made it possible to collect and analyze a set of relevant scientific and academic sources, published in high-impact journals indexed in databases such as: WOS, Scopus or Redalyc and on websites specialized in the topic that concerns us. Everything indicates that synthesis methodologies not only facilitate the identification of current trends and challenges, but also provide a solid theoretical framework for the development of practical proposals (Ureta, 2021).

Figure 1. Methodological structure of the research

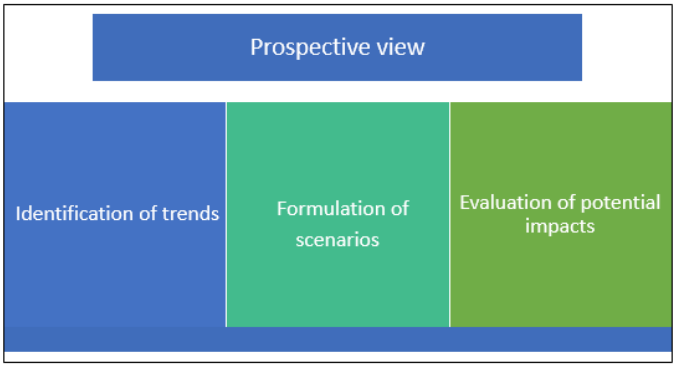


Source: prepared by the authors (2024)

In this context, prospective analysis is presented as a valid methodology to propose future scenarios that may be effective in practice. This technique allows policymakers to develop adaptive strategies that respond to geopolitical and climatic shocks, among others. According to the Universidad de la Sabana (2024), by exploring different scenarios, researchers can identify opportunities and risks associated with the redesign of food supply chains. Consequently, prospective analysis helps to anticipate changes in the environment and to formulate appropriate responses that allow future risks to be prevented. Beyond the current limitations of foresight, its likely scenarios are important to ensure that the proposals are not only innovative, but also viable in the long term, as Ruiz Douglas and Garrigó Andreu (2020) argue.

Broadly speaking, prospective analysis can be divided into three specific stages that include: 1) the identification of trends, 2) the formulation of scenarios, and 3) the evaluation of potential impacts. Through these and similar stages, concrete proposals can be developed that address both the immediate challenges and future needs of the food system. In any field of knowledge, scenario creation is the basis for understanding how different variables (qualitative and quantitative) can interact and affect food security. For these reasons, this approach allows policymakers to make informed decisions based on sound evidence.

Figure 2. Stages or Moments of Prospective Analysis



Source: prepared by the authors (2024)

For the purposes of this research, the stages of the research process ranged from the initial collection of data to the critical analysis and synthesis of results. First, a comprehensive review of the existing literature was conducted to identify the main challenges and opportunities in supply chains. Subsequently, a qualitative analysis of the collected data was carried out to draw meaningful conclusions. Finally, some concrete proposals were developed based on the findings obtained during the research process. As Berrara Morales (2010) supposes, we believe that a methodological structure consistent with the ontological nature of a research problem is essential to guarantee the validity and relevance of the conclusions.

In the words of Russell (2002), in any science or discipline, philosophical reflection is incorporated as an essential cognitive tool for understanding present and future realities, even more so in the field of redesigning food chains. As the maximum expression of critical and creative thinking, the philosophical perspective allows us to question existing assumptions and explore, in this case

study, new ways of thinking about food production and distribution. Without any doubt, philosophy can offer valuable analytical perspectives on ethics and sustainability in supply chains. In ethical terms, for Savater (1998), critical reflection is necessary to address the ethical dilemmas that arise historical realities, such as food management in general. The philosophical dimension complements the empirical analysis by providing a broader framework for assessing the social and environmental implications of food supply and production chains.

However, this research faces several limitations that should be considered by our kind readers. The limited availability of up-to-date and reliable data can make it difficult to comprehensively analyze certain aspects of the food system. Likewise, geopolitical dynamics, as Huntington (2001) states, are inherently uncertain, which complicates the formulation of accurate long-term scenarios. The inherent limitations of predictive models can affect the effectiveness of the proposals made. Therefore, it is crucial to address these constraints with a "flexible attitude" that allows for adjustments as the global context evolves.

In short, this methodological design combined documentary techniques with prospective analysis and philosophical reflection to address the complex issue of redesigning food supply chains. Through a clear methodological structure that includes defined stages and ethical considerations, it sought to generate effective proposals that contribute to the resilience of the food system to geopolitical and climatic shocks. Although there are inherent limitations to the research process, this comprehensive methodology provided a solid foundation for sustainable development in the food field.

3. Four proposals to redesign food supply and production chains to withstand forward-looking geopolitical and climate shocks

At the international level, food supply and production chains are undergoing significant transformations driven by various current trends. Firstly, digitalization has become a cross-cutting pillar for the promotion of continuous improvements, allowing companies to always optimize their operations using technologies such as artificial intelligence and the Internet of Things (IoT), among other resources (Datex, 2023). These tools make it easier to automate processes and improve inventory management, resulting in greater operational efficiency. Overall, digitalization not only improves efficiency, but also allows for a better response to market fluctuations (Datex, 2023). For these reasons, the trend towards digitalization is crucial to prepare supply chains for future challenges and opportunities.

Image 3. Industrial Process Automation in Food Chains

Source: IA Control, 2024

Another relevant trend is the growing demand for transparency and traceability in food products, which according to Sartori (2009), is connected to the democratization processes of participatory democracies in the twenty-first

century. At least in the coordinates of the global north, consumers are increasingly aware of what they consume and therefore demand detailed information about the origin and production processes of food. This legitimate social pressure has led companies to implement consistent traceability systems that not only comply with regulatory regulations, but also strengthen consumer confidence. Without information published on the specialized site SPS Commerce (2024), traceability initiatives are reshaping operations and improving efficiency throughout the supply chain. Under certain political and economic conditions, this trend can be very useful in addressing concerns about food security and sustainability in general.

In this common thread, the focus on sustainability is gaining ground in the food industry in accordance with the parameters of Sustainable Development, promoted by the United Nations (United Nations General Assembly, 2018). In this context of dizzying changes, companies are adopting more sustainable practices to reduce their environmental footprint and respond to social expectations. This includes everything from the use of eco-friendly packaging to the implementation of regenerative agricultural practices. For De las Moras (2023), companies that prioritize sustainability, on the one hand, meet consumer expectations and, on the other, obtain long-term economic benefits. This managerial shift towards more responsible business practices is key when seeking to build a resilient food system, beyond the exclusive profit motive.

It is the opinion of the authors of this work that, in an international scenario characterized by high levels of entropy, geopolitical and climatic shocks represent significant and constant threats to food supply chains in the coming decades. Conflicts such as those in the Middle East and the war in Ukraine, just to mention

a few, have shown how conflicts can drastically disrupt the flow of essential products, affecting both producers and consumers globally. According to Kisanne (2007), protracted conflicts can cause price volatility and shortages of basic products. This kind of instability at the same time geopolitical and economic highlights the urgent need for strategies that strengthen the resilience of the food system to such crises.

In addition to geopolitical disruptions, climate change remains a critical factor affecting agricultural production and food security (Gonzalvo, 2023). Extreme weather events such as droughts and floods are increasing in frequency and intensity, which negatively impacts agricultural yields, and can mark the decline of entire societies as has happened in the past (Diamond, 2007). According to Earth.Org report (2024), climate change is causing profound challenges in the agricultural sector, affecting everything from production to transportation. Because of their destructive potential, these climate disturbances require immediate public attention to develop effective solutions**.**

Image 4. Climate change

Source: Junta de Andalucía, 2024

To address these challenges, a key policy proposal is to implement stricter regulations on sustainability in supply chains. This could include tax incentives for companies that adopt responsible agricultural practices while reducing their environmental impact. Creating regulatory frameworks that promote sustainability can spur positive transformation across the food industry. As mentioned in the so-called 2030 Agenda, effective regulations are essential to ensure a sustainable future in the food sector (Organizacion de Naciones Unidas, 2022). A consistent legislative framework would not only benefit the environment, but also improve food security in general.

From an economic perspective, it is proposed to foster strategic alliances between local producers and distributors to strengthen regional supply chains. These organic collaborations that generate social capital can improve resilience by reducing external dependencies and promoting local economies. In terms of the solidarity economy model, for example, local partnerships can help mitigate risks associated with global disruptions. This approach not only supports local farmers, but also contributes to greater economic stability in times of crisis, from the grassroots of organized producers (Muñoz, Cueva, Suárez, & Gomezjurado, 2022).

In terms of technological proposals, it is suggested to invest in advanced climate monitoring systems and predictive analysis to anticipate interruptions in agricultural production. These tools can help producers quickly adapt to changing conditions and optimize their operations. For the World Economic Forum and Boston Consulting Group (2024), the implementation of advanced technologies can significantly improve the ability to respond to recurring climate crises. Therefore, technological investment is vital to ensure a steady supply of food.

Finally, within the framework of sustainable development, it is proposed to adopt agroecological models that integrate agricultural practices that respect the environment and promote biodiversity. These models help mitigate the effects of climate change and improve soil health and increase agricultural yields in the long term. Thus, agroecology offers effective solutions to face the current challenges of the food system (Earth.Org, 2024). For the achievement of sustainability, a comprehensive view is the pillar to build a sustainable future.

In philosophical synthesis, these proposals reflect an urgent need to rethink our food supply chains in an increasingly complex and uncertain world. The dialectical combination of effective policies, strong economic partnerships, technological innovation, and sustainable practices can create a resilient food system capable of coping with geopolitical and climate shocks. Ethical responsibility towards the natural environment and cultural communities must guide decisions towards a future where everyone has secure access to nutritious and sustainable food, which translates into the achievement of food sovereignty and security for all nations.

Conclusions and recommendations

When it is intended to develop some proposals that strengthen the resilience of supply chains, always guaranteeing food security for all nations. Some questions must be answered as a condition of possibility to legitimize the proposals made, such as: What are the main vulnerabilities of current supply chains? How can technological innovations improve resilience to geopolitical shocks? What strategies should countries in the global south adopt to ensure their access to food? What role do international policies play in the stability of these

supply chains? By way of conclusion, these questions are answered from the perspective of the authors of the research, which may evidence their biases and particular opinions.

Today's supply chains face a variety of vulnerabilities that make them susceptible to disruptions. Among the main vulnerabilities are the excessive dependence on certain geographical regions, which limits the diversification of suppliers and increases the risk of geopolitical crises such as wars, civil wars, political destabilization, economic crises or humanitarian crises. In addition, the lack of transparency and traceability in logistics processes makes it difficult to identify problems in real time. In this situation, inefficiency in inventory management also contributes to vulnerability, as it can lead to shortages or excess of products. Hence, Santiago (2024, para, 5) states that: "Food supply chains are increasingly fragile due to global interconnectedness and extreme weather events." These weaknesses highlight the geopolitical and geostrategic need to continually redesign chains to improve their resilience.

In this vein, technological innovations have the potential to significantly improve the resilience of supply chains to geopolitical crises. The implementation of technologies such as blockchain and artificial intelligence can increase the visibility and traceability of products, allowing for a faster response to unforeseen disruptions. These software and hardware tools can help predict supply failures and optimize logistics, thus reducing the impact of external shocks. For these reasons, the sources consulted highlight that digitalization is key to building more resilient and adaptive supply chains (Datex, 2023). If these technologies can be leveraged, companies can anticipate problems and act proactively to mitigate their effects on the industry.

For their part, countries in the global south must adopt specific strategies to ensure their access to food in an increasingly uncertain environment. In this dynamic context, it is essential to foster food self-sufficiency (food sovereignty) by supporting local agriculture and crop diversification, in line with the SDGs. It may also be useful to establish regional alliances such as the European Union or MERCOSUR to improve access to shared markets and resources. South-South cooperation is also important, as it allows for the exchange of knowledge and experiences between countries with similar challenges. According to a report by the World Economic Forum and Boston Consulting Group, (2024), cooperation between developing countries is the best option to address common food security problems. These international policy strategies can help mitigate the risks associated with external shocks in groups of countries and entire regions.

In the 21st century, international policies play a central role in the stability of food supply chains. In this scenario, cooperation between nations is the basis for establishing regulatory frameworks that facilitate trade and reduce tariff barriers. Otherwise, it is important to promote multilateral agreements that address issues such as climate change and food security globally. It is precisely for these reasons that Borrell (2022) states that effective international policies can contribute to the resilience of the global food system. And it is that by strengthening these food policies, a more stable environment can be created that benefits all the countries involved.

By way of recommendations, for researchers in the field and public policy makers, it can be very useful to adopt a multidisciplinary approach that integrates economic, social, and environmental aspects in their analyses and decisions. Fostering collaboration between the public and private sectors can lead to more

effective solutions to today's challenges. In addition, it is advisable to carry out longitudinal and interdisciplinary studies that evaluate the impact of the policies implemented on food security, in qualitative and quantitative terms, with a deductive and inductive approach. From an epistemological point of view, continuous research is vital to adapt strategies to a changing environment (Tovar-Sánchez & Rodríguez-Salazar, 2020). These recommendations can guide future efforts towards greater food resilience, both regional and global.

Possible lines of research emerging on this topic include analysis of the impact of climate change on region-specific supply chains, as well as studies on how technological innovations can be adopted by smallholder farmers in emerging economies. Alternative economic models that foster sustainability and resilience in local food systems could also be explored. Another relevant aspect would be to investigate how international policies can be reformed in international consensus to better address the specific needs of the global south in the face of geopolitical crises. In summary, these lines offer ample scope for delving into how to build a safer and more sustainable food future for all.

Finally, it should be emphasized that addressing current supply chain vulnerabilities requires a combination of technological innovation, appropriate strategies by countries in the global south, and effective international policies. Soon, collaboration between nations and productive sectors will be key to building resilient food systems capable of withstanding climate and geopolitical shocks. By implementing the proposals and recommendations made here, progress can be made towards a future where everyone has secure access to nutritious and sustainable food.

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