Food Security in Argentina in the event of an Abrupt Sunlight Reduction Scenario (ASRS)

A STRATEGIC PROPOSAL

April
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Foreword

The enactment of Law 27,287 on the creation of the Sistema Nacional para la Gestión Integral del Riesgo y la Protección Civil (SINAGIR), and the complementary regulations, constitute a milestone in terms of optimizing mechanisms for prevention and response to adverse events, inasmuch an articulated scope of work of the different levels of government is defined with a multi-agency, interdisciplinary, and federal approach in the Argentine Republic.

This is the framework that, aligned with the priorities and goals of the Sendai Framework, promoted the development of the first National Plan for Disaster Risk Reduction (Plan Nacional de Reducción del Riesgo de Desastres - PNRRD) 2018-2023, whose purpose was based on integrating and strengthening actions aimed at the disaster risk reduction (DRR), crisis management, and recovery through the technical work of the respective commissions.

At present, 19 technical commissions, many of them coordinated by representatives of the Red de Organismos Científico Técnicos para la Gestión del Riesgo de Desastres (Red GIRCyT) are active and dedicated to the elaboration of the new PNRRD 2024-2030, which, in addition, incorporates the proposals received from the community through the consultative process carried out at the end of 2022 and which included the participation of both civil society organizations and the private sector.

Given that the threat of "Abrupt Sunlight Reduction Scenarios" (ASRS), developed in this report, is not contemplated in the scope of the national plan, I invite the organization "Riesgos Catastróficos Globales" to register in the Registro de Asociaciones para la Gestión Integral del Riesgo (RAGIR) and thus join SINAGIR's Advisory Council of Civil Society Organizations.

We are following a course that implies building the road as we go. We do so with the conviction that the paradigm shift and consolidation of a state policy on disaster risk reduction must be carried out within the framework of integral and transversal management.

That is why we congratulate the different actors who have been involved in the effort of the strategic proposal for "Food Security in Argentina in the event of an Abrupt Sunlight Reduction Scenario (ASRS)", thank them for their fruitful work and hope that the recommendations resulting from this guide can serve as input for the new national plan 2024-2030.

Silvia La Ruffa
Secretary of Federal Articulation of Security
Executive secretary of SINAGIR
june 2023

Executive Summary

Abrupt Sunlight Reduction Scenarios (ASRS) result from events that eject particulate matter into the upper atmosphere, reflecting and absorbing sunlight that would otherwise reach the Earth's surface. This decrease in sunlight causes a drop in global temperatures and rates of precipitation, with devastating consequences for agriculture. Potential causes of an ASRS include large volcanic eruptions, nuclear war, or asteroid impact (ALLFED, 2022). The impact of such events is likely to last for several years or even a decade, with global implications for agriculture and food security.

Some researchers estimate that in such a scenario (e.g. severe nuclear winter), around 75% of the world's population could starve to death within two years of the event (Xia et al., 2022). Specifically, if the atmosphere collected 150 million tons of soot, there would be a 15-80% decrease in sunlight for a period of weeks to months, as well as a 7-15ºC decrease in temperature and 20-70% reduction in rainfall globally which would continue to impact the Earth for up to ten or more years. This would cause a drop in caloric production of between 80% and 90%.

Some regions of the world seem to be better positioned to survive an ASRS; among them are island countries such as New Zealand and Australia (Boyd & Wilson, 2022), as well as some continental countries such as Argentina, Uruguay, and Paraguay (Xia et al., 2022). As a network of professionals dedicated to the prevention of global catastrophes, Riesgos Catastróficos Globales chose to examine Argentina in this report due to its location, agricultural production capacity, and supply chain resilience, among other relevant indicators. These factors augment Argentina's capacity to respond to an ASRS and to play a crucial role in the distribution and exportation of food. **Preparation and response could mean the difference between starvation and production of sufficient, varied, and nutritious food with a surplus to export, preventing a refugee crisis.**

Considering the importance of the geographical location of Argentina, it is essential that the government actively participate in **developing contingency plans** to deal with possible threats in the region. Therefore, we recommend **creating an interdepartmental working group** to investigate the hazards of an ASRS and how to address them. For this reason, this report has been prepared based on an exhaustive bibliographical review, a mapping of actors, and a series of 11 interviews with national and international experts in the field, as well as representatives of the risk management system of the Argentine government. This document contains eight main recommendations, divided into **communication and food supply,** and the **production and redirection** of these resources in the event of an ASRS, as well as priority actions for effective implementation:

Communication and food supply

1. Formulate coordinated response plans to guarantee water supply to the population at the federal and provincial level through the *Dirección Nacional de Agua Potable y Saneamiento* (DNAPyS) (National Directorate for Drinking Water and Sanitation).
2. Formulate strategies and legal frameworks for internal food rationing and waste reduction in the event of a disaster.
3. Maintain international trade to stimulate food production and guarantee access to critical imported materials and inputs.
4. Establish a clear and centralized communication strategy by publicizing an emergency management plan.

Food production and redirection

1. Redirect food used in animal feed and biofuel production to human consumers.
2. Implement adaptations in agricultural systems to increase food production, including the relocation of crops tolerant to conditions of low temperature and low rainfall, rapid construction of simple greenhouses, and the expansion of cultivated land through the conversion of arable land not currently used for food production.
3. (Lower priority) Implement adaptations in aquaculture systems to increase food production, including reactivation of the national algae industry and strengthening the fishing sector.
4. (Lower priority) Implement high-tech adaptations to increase food production, including industrial food technologies such as the conversion of paper and biofuel facilities for producing lignocellulosic sugar and single-cell protein.

In conclusion, based on our completed work, several institutions in Argentina will be able to prepare a response plan incorporating the recommendations outlined in this report. These institutions include the *Secretaría de Articulación Federal de la Seguridad* (Federal Security Management Secretariat) the *Secretaría de Coordinación Militar en Emergencias* (Emergency Military Coordination Secretariat); the *Secretaría de Agricultura, Ganadería y Pesca* (Secretariat of Agriculture, Livestock, and Fisheries); the *Instituto Nacional de Tecnología Agropecuaria* (National Institute of Agricultural Technology); the *Oficina de Riesgo Agropecuario* (Agricultural Risk Office); and the *Oficina de Monitoreo de Emergencias Agropecuarias* (Agricultural Emergency Monitoring Office). Participation of the Ministries of Defense and Security, as well as the Civil Protection Secretariat, will be necessary as well. The challenge of coordinating these different departments is why we recommend the creation of an interdepartmental working group with named, responsible actors to develop a plan for food security in the event of an ASRS.

Index

Report structure

This report consists of eight sections. The first three sections provide situational context and describe the conceptual and methodological assumptions present throughout the document. The first of these sections is the Introduction, which includes the problem description, a basic definition of an ASRS, and the objectives that will guide the report. The Background Summary includes a brief review of the existing literature on ASRS and the models that have been used to measure the impact that these scenarios would have on climate and food production. The following sections describe the methodological aspects of prioritization between regions and the mapping of actors. In these sections, we elaborate on how we decided to focus on Argentina and these interviewed actors.

The next sections of the report focus on the concrete analysis of aspects related to the management of an ASRS in Argentina. We begin with the section on the effects of an ASRS in Argentina, which examines the potential impact of an ASRS event on feed production. Specific strategies to mitigate this impact and improve preparation are suggested in the ASRS management proposals section. After that, a graphical representation was made to illustrate which managers and experts could be involved in implementing each proposal in the country, which appears in the section called Responsible Parties. Finally, the Conclusion summarizes the report's main findings and suggests recommendations for future research and actions related to global catastrophic risks and, specifically, to ASRS.

Introduction

Global catastrophic risks (GCR) refer to risks that can affect the well-being of humanity on a global scale (Bostrom & Cirkovic, 2008). Some global catastrophic risks significantly affect the international food system, and are able to cause its collapse (Benedict et al., 2021). By the end of this century, events in this category have been forecast to have an 80% probability of occurring (Bailey et al., 2015), with a 10% probability of a near total loss of food production (Denkenberger & Pearce, 2014).

The most extreme food shock that could threaten humanity is an abrupt sunlight reduction scenario (ASRS). In an ASRS, the atmosphere would be clouded by a large amount of particulate matter, preventing the passage of sunlight. This would lead to a global "winter" and, consequently, an imminent agricultural collapse that could end the lives of billions of people (García Martínez, 2022).

At least three potential causes of an ASRS have been identified (Rivers, et al., 2022): the impact of a giant asteroid, the probability of which is estimated to be about 0.0001% per year (Bostrom & Cirkovic, 2008); the eruption of a supervolcano, with a probability of about 0.01% per year (Lin et al., 2022); and nuclear war, with a probability of about 1% per year (Baum et al., 2018). Consequences of an ASRS, such as summer temperatures in the northern hemisphere below freezing (Coupe et al., 2019), would prevent conventional agriculture and lead to a catastrophic global food shock due to a loss of agricultural production around the world. A historical example of this scenario was the eruption of the Tambora volcano in Indonesia, which triggered an international famine in 1816, the "year without a summer" (Fuentes, 2016).

Insufficient preparation, in combination with the sudden nature of the event (Pham et al., 2022) and possible compounding social conflicts and economic crises, could cause a rapid social collapse or aggravate the already alarming consequences of an ASRS (Xia et al., 2022a). Currently, global society is not prepared for such a catastrophic event, and needs to urgently assess our preparedness and implement solutions. An ASRS would require a series of radical adaptations to the food system and complementary solutions to prevent mass famine, known as resilient food solutions (Rivers, et al., 2022).

According to the Alliance to Feed the Earth in Disasters (ALLFED), the key work to prevent global famine due to lack of food production in any ASRS includes 1) research on food production methods, production increases, technology deployment, and adjustments in production based on the nutritional requirements of the population; 2) development and pilot testing of technologies and techniques leading to faster response; and 3) creation and implementation of effective disaster response plans (Rivers, et al., 2022).

Preparing a response plan in countries capable of self-sufficiency in an ASRS can be an opportunity to mitigate the international caloric deficit during this type of catastrophe. This report aims to identify the most promising Spanish-speaking regions in an ASRS and to equip political actors with up-to-date information and concrete recommendations to manage this risk effectively.

Different climate models and adaptations (Xia et al., 2022) (Rivers, et al., 2022) have highlighted that some countries in the southern hemisphere could be less affected in the event of an ASRS. The combination of these conditions with Argentina's current and potential agricultural production capacities makes it one of the most promising Spanish-speaking states regarding food production in such a scenario. Due to the absence of an ASRS risk management plan in this country, this report presents a series of recommendations that can be taken into account in preparing and responding to an ASRS in Argentina.

Background Summary

The first hypotheses about the possibility of a decrease in sunlight caused by the accumulation of volcanic ash and gases in the atmosphere arose at the beginning of the 19th century. The scientific community welcomed the first approaches to the study of an ASRS in 1982 (Martin, 1988), when the Swedish magazine AMBIO published a special issue on the environmental effects of nuclear war. In this issue, they modeled a full-scale nuclear war scenario in which 5,000 Mt of weapons were dropped on targets in North America, Europe, and Asia. AMBIO invited scientists from around the world to write articles about its environmental and atmospheric effects; this resulted in a groundbreaking article by Paul Crutzen and John Birks on the effects of air pollution.

Motivated by the findings of Crutzen and Birks, researchers from different countries used various models to calculate how the Earth's climate system would respond to such an amount of particulate matter in the atmosphere and how temperature and other climate variables would change (Robock, 2015). As climate models became more refined, some details about temperature variation changed, but no one took issue with the basic fact that light cannot efficiently pass through thick clouds of particulate matter (ibid.).

From these first investigations until today, simulations of the potential impacts from an ASRS, mainly from nuclear war, have been carried out. Some of the most relevant at present are the comparative exercises between the projections of the WACCM4 model (Whole Atmosphere Community Climate Model version 4) and the GISS ModelE (Coupe et al., 2019). As a complement to climate models, the specific impacts that such an event may have on the global food system in different war scenarios have also been measured (Xia et al., 2022). These studies assert that the average calorie production of crops could decrease from 7% to 90% depending on the war scenarios, which range from 5 Tg to 150 Tg of ash. Even the most optimistic scenario would imply a 7% decline, which would be the most significant anomaly recorded since the beginning of FAO observations of global calorie production and consumption.

Hand in hand with these estimates, in recent years, new research has emerged that would make it possible to address the impact of ASRS on the food system, identifying promising areas (Boyd & Wilson, 2022; Xia et al., 2022), investigating food resilience (Baum et al., 2018; García Martínez, 2022; García Martínez et al., 2022; Pham et al., 2022), and preparing recommendations for political agents (ALLFED, 2022). According to the experts we consulted and the current literature on the subject, government intervention is a priority to prepare for severe ASRS. On national and supranational levels, we need coordination of information and communication; financial support; government preparation and prioritization; and plans for the rationing of fuel, energy, medical attention, and food (Boyd & Wilson, 2022). According to the available literature, solutions are possible (Baum et al., 2018; García Martínez, 2022; García Martínez et al., 2022; Pham et al., 2022), but it is vital to prepare sufficiently ahead of time for an adequate response.

Methodology

Prioritization between regions

For prioritization of regions, climate and food production models in ASRS conditions from scientific studies were analyzed (Rivers, et al., 2022; Xia et al., 2022a). Considering these models, an initial estimate was made, complemented by a decision matrix (see *Appendix 1a*). In this matrix, different indicators were evaluated by country, such as:

- Supply chain resilience, taken from the World Economic Forum Global Competitiveness Index. In an ASRS, it will be vital to continue distributing food and goods despite massive disruptions.
- Political stability and government effectiveness, taken from the Worldwide Governance Indicators. Cooperation and trust in governance at the national and local levels can be important for coordinating disaster logistics (Boyd and Wilson, 2022).
- Agricultural production capacity, referring to food self-sufficiency in nuclear winter conditions. The better the situation of a country in its baseline scenario, the better its capacity to handle stress and contribute to the recovery of neighboring states..

Appendix 1b presents a detailed description of the considered indicators.

This analysis made it possible to generate a list of countries which would be in a uniquely favorable position to respond to a catastrophe of this nature, such as Argentina, Uruguay, and Chile. We focused on Argentina, as it would have greater productive capacity during an ASRS. Additionally, it is possible to highlight some potential conditions of this country, such as:

- Location: As a country in the temperate zone of the southern hemisphere, Argentina is less vulnerable to the impact of nuclear winter and probably volcanic winter as well.

- Natural resources: Argentina is rich in natural resources, including fertile agricultural land, oil and gas reserves, and mineral deposits.
- Diversified economy: Argentina's economy is relatively diversified, with solid sectors in agriculture, mining, manufacturing, and services.
- Infrastructure: Argentina has a relatively developed transport infrastructure (roads, railways, and airports) and connections with its main trading partners.
- Close proximity to major trading partners: Argentina has rail links with its six neighboring countries and good maritime links with some of them as well. Continued trade with these countries — especially Brazil, a major exporter of food and fossil fuels — could increase capacity to ensure adequate food supplies and a faster recovery for Argentina.

Actor mapping

During the process of preparing the report, a series of interviews were conducted with national and international experts, as well as with actors related to local food security. The people interviewed were selected from a database of our own elaboration (Appendix 2), weighing the technical knowledge of the experts and their influence in the Argentine political field in the case of the stakeholders.

Experts

The factors considered to identify relevant experts were:

- **Experience:** Experts with a background in food security and a demonstrated understanding of global catastrophic risks.
- **Relevance:** Experts who have published research or spoken publicly on food security from a global catastrophic risk perspective.
- **Recognition:** Experts recognized as leaders in their field, either through awards, peer-reviewed publications, or invitations to speak at conferences or events.
- **Diversity:** Experts from various geographic locations and backgrounds to ensure a diversity of perspectives.

Five international experts were interviewed. The first was Matthew Boyd, whose paper *'Island refugees for surviving nuclear winter and other abrupt sunlight-reducing catastrophes'* formed an essential basis for preparing this report. The remaining four are part of the Alliance to Feed the Earth in Disasters (ALLFED), identified as the leading global research center on food resilience in ASRS. Specifically, some of the issues discussed with members of ALLFED were modeling the Argentine context, the challenges and economic implications, and the criteria for evaluating which measures to prioritize.

Local experts were contacted to determine the possibilities of implementing various promising food solutions in Argentina. In particular, the project had the participation of academics in plant physiology, phycology, and aquaculture. The summary of the interviews can be found in Appendix 3.

Interest groups

As for the interest groups, the approach to local actors was carried out based on the understanding of the National System for Comprehensive Risk Management (SINAGIR), whose function is to integrate the actions of the different levels of government (national, provincial, and municipal) in national emergencies. In turn, they also integrate the National Emergency Alert and Monitoring System (SINAME), whose function is to monitor hydrometeorological threats and potential adverse situations in the country.

The system comprises government actors distributed across 20 sectors according to their functions: Government (the presidency), Security, Interior, Transportation, Foreign Relations, Agriculture, Environment, Science, Culture, Defense, Productive Development, Social Development, Territorial Development, Economy, Justice, Women, Public Works, Health, Work, and Tourism.

The 20 sectors are, in turn, represented by 18 ministries and 110 offices (entities, secretariats, sub-secretariats, departments, institutes, directorates, commissions, agencies, centers, public companies, and boards). Of the 18 ministries, there are 7 which would be responsible for acting in the scenario proposed in our investigation: Security, Foreign Relations, Economy (including Agriculture), Environment, Science, Defense, and Public Works.

In particular, of these ministries, we prioritized 12 of the 110 offices because they specialize in food security or direct risk management from a central level. Of these, we focus on those that have prevention, mitigation, and response functions rather than monitoring, resulting in 10 priority offices:

Ministry/sector	Entity/office	Function
Ministerio de Defensa	Secretaría de Coordinación Militar en Emergencias.	Carry out the institutional coordination and deployment of the Armed Forces, to develop tasks, activities, **preventative actions and immediate responses to emergencies and natural disasters**.
Ministerio de Seguridad	Secretaría de Articulación Federal de la Seguridad.	Assists the Minister in directing the national police effort, regarding the participation of the provincial Police Forces and in coordinating **the National System for Comprehensive Risk Management and Civil Protection.**
	Subsecretaría de Gestión del Riesgo y Protección Civil.	Articulate the functioning of the agencies of the National Government, the Provincial

Ministry/sector	Entity/office	Function
		Governments, the Autonomous City of Buenos Aires and Municipal Governments, Non-Governmental Organizations and Civil Society, to strengthen and optimize actions aimed at risk reduction, **the management of crisis and recovery.**
	Dirección Nacional de Operaciones de Protección Civil.	Assist the Undersecretariat in the development of **preparation and immediate response actions in emergency situations and/or socio-natural disasters**, coordinating the deployment of the Police and Security Forces.
	Dirección Nacional de Prevención y Reducción del Riesgo de Desastres.	Assist the Undersecretariat for Risk Management and Civil Protection in the development of **disaster risk reduction actions**, in its mitigation and in the reconstruction of the affected areas, promoting volunteer actions and community mobilization.
Ministerio de Economía	Oficina de Riesgo Agropecuario (ORA).	**Develop, analyze, and disseminate agricultural risk assessment and reduction tools** from a comprehensive perspective, helping to generate the appropriate framework for the expansion and diversification of insurance markets and coverage instruments for the agricultural and forestry sector.
	Oficina de Monitoreo de Emergencias Agropecuarias (OMEGA).	Inform institutions and the general public on the development of measures to prevent and mitigate social and productive vulnerability to droughts, fires, and floods.
	Instituto Nacional de Tecnología Industrial (INTI).	Promote the development of federal industry through innovation and technology transfer.
	Instituto Nacional de Tecnología Agropecuaria (INTA).	Contribute to the sustainable development of the agricultural, agri-food, and agro-industrial sectors, through research and expansion.

Ministry/sector	Entity/office	Function
Ministerio de Salud	Instituto Nacional de Alimentos de Argentina (ANMAT).	Manage medicines, food, and medical technology to protect the population.

Table 1. Offices of interest within the Argentine Government.

The interviews made it possible to specify the information on existing plans in the event of ASRS, priority solutions and adequate cost-benefit ratio, Argentina's risk management system, geographic, economic and social characteristics, and its food production capacities.

Effects of an ASRS in Argentina

In the event of an ASRS affecting the country, the impacts will vary depending on the magnitude of the event, measured as the concentration of particulate matter in the atmosphere. For example, inputs of between 5 and 150 Tg of particulate matter in the atmosphere would generate variations in the average temperature of between 0.5 and 15°C, respectively *(Harrison et al., 2022), (Xia et al., 2022).*

In a 150 Tg scenario, Argentina would face severe effects on the environment, including the water supply, and a significant loss in agricultural yields of up to 73%. Starting two years after the catastrophe occurred, without taking any kind of adaptive measures, this could lead to the famine deaths of more than one million Argentine citizens *(Xia et al., 2022).*

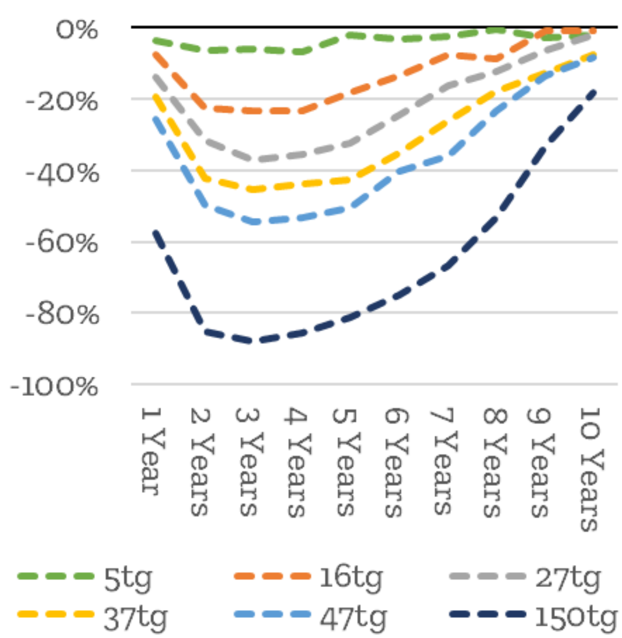

Figure 1. Decrease in global caloric production if there were no response measures, estimates over time at different magnitudes of nuclear winter (Xia et al., 2022).

These potential effects highlight the importance of creating the country's first ASRS risk management plan to mitigate fatalities as much as possible, considering the current emergency management scheme and implementing solutions and proposals that will be developed in the following sections.

Risk management in Argentina

In order to understand how a risk management plan for ASRS in Argentina could be developed, it is necessary to understand the functioning of its institutions and the plans formulated for other types of risks. These can serve as a basis for the effective formulation of new plans and allocation of responsibilities.

Currently, the institutional structure for emergency management essentially depends on Law 27,287 of 2016, which creates the National Risk Management System (SINAGIR), adopted within the framework of SENDAI 2015-2030 to which the country subscribed and which replaces the Hyogo framework. This system involves all governmental and non-governmental actors in risk management. It creates the National Council for Comprehensive Risk Management and Civil Protection as the highest level of decision-making, articulation, and coordination of national State resources (see interview with Silvia La Ruffa, *Appendix 3*).

This Council is chaired by the Chief of Staff and is connected with five other system dimensions that share the Executive Secretariat of SINAGIR as a common point. The five areas are (i) the Ministry of Security, which brings together the civil protections of the 24 subnational jurisdictions; (ii) a network of technical scientific organizations coordinated by the Ministry of Science and Technology; (iii) a registry of civil society organizations; (iv) an advisory council; and (v) another advisory council for the business sector (interviews with Claudio Schbib and Silvia La Ruffa, Appendix 3).

The National Council approved a five-year plan called the National Plan for Disaster Risk Reduction (PNRRD), which is currently valid from 2018-2023. This plan was created from a process in which the national government, provincial and local governments, civil society organizations, universities, the business sector, representatives of the legislative powers, specialists, and citizens in general participated. Further participants included such scientific-technical organizations as the National Meteorological Service, the National Water Institute, the National Institute of Seismic Forecasting, the Maritime Geological Service (which includes the Volcanic Activity Observatory), and the Office of Monitoring of Agricultural Emergencies (OMEGA), among others. SINAGIR participating institutions must operate per the PNRRD.

These actors are consulted on different previously selected thematic axes, including meteorological, geodynamic, volcanic, and technological threats, as well as earthquakes, forest fires, etc.

Based on the functions of SINAGIR in the investigation process and the interview with the National Director of Prevention and Disaster Risk Reduction, the institutions that would be in the best capacity to participate in the preparation of ASRS management plans in matters of preparation and response would be *(Appendix 5b):*

Preparation	Response
Ministry of Economy	Ministry of Defense, together with the Armed Forces
Ministry of Science, Technology, and Innovation	Ministry of Security
Secretariat of Agriculture, Livestock, and Fisheries	Ministry of Social Development
Secretariat of Technological and Scientific Coordination	Secretariat of Federal Security Coordination
Agricultural Emergency Monitoring Office (OMEGA) and Agricultural Risk Office (ORA)	Subsecretariat of Risk Management and Civil Protection
National Institution of Agricultural Technologies (INTA)	National Directorate of Civil Protection Operations
National Institute of Industrial Technologies (INTI)	Agricultural Emergencies Directorate, composed of Agricultural Emergency Monitoring Office (OMEGA) and Agricultural Risk Office (ORA)

Table 2. Main responsible parties in the case of ASRS in Argentina.

In the event of an ASRS affecting Argentina, the National Council would convene extraordinarily, and, by law, the Disaster Risk Management Committee (GIRD), integrated by representatives of SINAGIR that can follow up on the measures that contain a future risk management plan for this event and communicate in a centralized and effective manner the corresponding actions at all levels of the population. First, each municipal and provincial jurisdiction must evaluate its response capabilities and coordinate effectively with federal authorities (interviews with Silvia La Ruffa and Carlos Ospital, Appendix 3); however, a declaration of national emergency can be considered if necessary.

Secondly, logistical support is requested from the Secretariat of Military Coordination in Emergencies concerning military capabilities and the Secretariat of Federal Articulation of Security (with the Undersecretariat of Management of Risk and Civil Protection) in everything related to civilian capacities (interview with Carlos Ospital, Appendix 3).

Third, the National Commission for Agricultural Emergencies convenes, including the leading producer associations, local governments; the Agricultural Emergencies Directorate also meets, composed of the Agricultural Emergency Monitoring Office (OMEGA) and the Agricultural Risk Office (ORA). It is essential to highlight the need for coordination and improved communications between these two organizations (interview with María Estrada, Appendix 3). We would also like to highlight the importance of the National Fund for the Mitigation of Agricultural Emergencies and Disasters (FONEDA), created by Law 26,509 of 2009, whose objective is to finance the execution of the National System for the Prevention and Mitigation of Agricultural Emergencies and Disasters. Plans for continued food production in an ASRS, such as the relocation and expansion of crops, could be channeled through this fund.

Finally, it is vital to mention the role that the National Emergency Alert and Monitoring System (SINAME) would have in monitoring and updating the meteorological status before, during, and after the catastrophe. This geographic information system serves as a risk management tool by different institutions and enables the mapping and monitoring of hydrometeorological threats, as well as the ongoing exchange of information to follow up on potential adverse situations in the country (interview María Estrada, *Appendix 3*).

Considering that current risk management plans and strategies do not contemplate the occurrence of an ASRS, this report presents a series of priority proposals suggested to Argentine institutions to prepare for and respond to such a catastrophe.

Management proposals in case of ASRS

In response to the threat that an abrupt reduction in sunlight event (ASRS) represents for food security in Argentina and the world, researchers have proposed various initiatives and strategies to guarantee access to food, minimize impacts on agricultural production, and maximize the availability of food for human consumption. In this section, we detail these possible proposals, which have been amalgamated from the expert interviews (Appendix 3) and an exhaustive bibliographical review (Appendix 4).

The management proposals (see Table 3) have been grouped into two categories: Solutions for **food supply and communication** and solutions for ensuring ongoing **food production and resilience.**

Management proposals	
Food supply and communication	
Plans and strategies for water supply	Diversification of water supply sources, consumption reduction through information campaigns, and improvements in storage.
Rationing and reducing food waste	Maximize the availability of food and guarantee access to it in a controlled manner.
Maintaining international trade and guarantees for producers.	Based on the country's export quotas, international trade would be a stimulant in agriculture in terms of prices and a necessity for the importing of agricultural supplies. Guarantees must also be provided to producers, e.g. subsidies, advance purchases, and access to irrigation and other agricultural inputs.
Communication management	Provide assertive communication through the corresponding entities to reduce the panic that an event of this nature could cause, by verifying that there is a response plan in place for the country.
Food production and resilience	
Redirection of food used as raw materials in animal production and production of biofuels.	Redirect the availability of food that is currently used for raising animals and in the manufacture of biofuels. Instead, use them for human consumption, and use other plant biomass to feed animals in the dairy industry.
Agricultural system adaptations to increase food production.	The initiatives proposed according to the productive advantage of Argentina are the following: relocation and increase in crop area, implementation and increase in greenhouse area.
Aquaculture adaptations to increase food production.	The proposed initiatives include the reactivation of the algae-producing industry and the strengthening of the fishing industry.
High-tech adaptations to increase food production.	The proposed initiatives include the redirection of industrial capacities from paper and biofuel production to the production of sugar, of the food industry to obtain vegetable proteins and the generation of single-cell protein (SCP).

Table 3. Summary of proposals in case of ASRS.

1. Food supply and communication

This category includes recommendations focused on forming strategic plans as a preventive measure in various areas, such as the supply and rationing of water and food, the implementation of a clear communication strategy with all sectors of society, and developing a plan for the export of food and the import of goods and supplies.

Proposals in the first category include:

Formulation of plans and strategies to guarantee water supply.

According to Morgan Rivers (see Appendix 3, interview with Morgan Rivers), a drinking water supply plan is crucial to ensure access to clean and safe water for drinking, cooking, and maintaining sanitation, thus avoiding possible emerging public health problems. Additionally, having water supply strategies helps to avoid price gouging. In emergencies such as an ASRS, the supply of water might be limited, leading to inflated prices, which would be an obstacle to access for the most vulnerable.

Some ASRS response strategies are: 1) water supply diversification, such as the use of wells, rivers, lakes, reservoirs, and the collection and storage of rainwater, depending on the magnitude of the ASRS; 2) water consumption reduction through communication campaigns about responsible use, the implementation of saving measures in homes, and the promotion of greater efficiency in industrial and agricultural uses of water; and 3) improvement of water storage, including construction of more tanks and reservoirs in order to ensure greater availability in a crisis.

It is also important to mention that water resources are required for food production. In this sense, it will be necessary to expand the irrigation system, guarantee the level of the reservoirs, and financially support farmers who will seek to buy systems for their lands and ensure production (ALLFED, nd). This idea will be expanded upon later.

Plans for rationing and reducing food waste.

Internal food rationing in a disaster can help ensure that everyone has access to food during an ASRS, especially for the most vulnerable people. As a complement to rationing, reducing food waste is crucial to ensure that food is available for as long as possible and to as many people as possible, as supplies would be limited.

Maintain commercial openness and give guarantees to producers.

It is necessary to maintain international trade for the mutual benefit of the countries in the event of an ASRS (see Appendix 3, interviews with Dr. Denkenberger and Dr. Boyd). When there is an increase in food prices, the free flow of trade can work as a stimulant to increase production, taking into account export quotas and allowing the country to purchase inputs and materials of foreign origin, which will be essential for solution implementation.

From a commercial point of view, Argentina's main partners are Brazil, China, the USA, and Chile (National Institute of Statistics and Censuses of the Argentine Republic INDEC, Annual Report 2020). Food exports represent the largest source of income (Central Bank of the Argentine Republic BCRA, report "Commercial Balance of Goods and Services" 2020), which demonstrates the importance of maintaining trade in case of an ASRS. International cooperation would benefit the region and act as a stimulant to the economy.

Brazilian, Chinese, American, and Chilean imports, to a large extent, come from inputs for plastic production. Plastics will be necessary to expand agricultural infrastructure, as well as machinery, technologies, and other agricultural inputs essential for the deployment of food solutions contributing to ASRS mitigation.

- Consider subsidies to farmers.

  Due to difficulties in accessing the resources and inputs necessary for food production after an ASRS, farmers may face higher production costs and need to adopt new agricultural practices (see Appendix 3, interview with Michael Hinge). For this reason, offering subsidies would help alleviate the economic costs associated with food production and ensure that an adequate supply is maintained for the population. Additional measures are suggested, such as implementing incentives to reduce food waste in production processes and offering financial support for adopting new cold-tolerant crops.

- Consider the advance purchase of farmers' produce by the state.

  In an ASRS, agricultural production is seriously threatened due to changes in temperatures and rainfall, so food is one of the primary needs to be guaranteed for the population. However, just as climate and agricultural and industrial issues are affected, their markets and prices are also affected.

  Because global production will decrease, food prices will increase, and people will have less access to food (Appendix 3, interview with Michael Hinge). One of the ways to mitigate the rise in prices and provide for greater food availability consists of guaranteeing the advance purchase of farmers' produce after the occurrence of ASRS since these and the market are given the certainty of minimum conditions that are equally translated into price stability.

  The purpose is that, in an ASRS, the Ministry of Agriculture, Livestock and Fisheries can guarantee a minimum sale price for the farmers' production, which would provide them with financial security by reducing their economic risk and would grant Argentine farmers the capital necessary to invest and improve their production processes during the scenario. It would be critical for the government to ensure food affordability for everyone, particularly for the most economically disadvantaged populations, as no other actor is positioned to accomplish this.

In addition, this guarantee can be beneficial for the state as part of its preparedness plan. By procuring produce from farmers in advance, the state can ensure that food will be available to the population for the time being and at reasonable prices.

- Guarantee the access of producers to irrigation water and necessary agro-inputs.

  According to data from INTA, of the 45 million easily arable hectares in the country, only 12% have infrastructure dedicated to irrigation, so it is necessary to increase irrigation capacities in new different districts and achieve coverage close to the total number of easily arable hectares.

  As a complement, according to the Chamber of the Chemical and Petrochemical Industry (CIQyP), the consumption for 2020 of fertilizers was 5 million tons, while internal production reached 2.3 million tons, with about 50% of coverage. During an ASRS, it may be necessary to increase these local supplies to maintain sufficient supplies.

  Due to these conditions, it is necessary to strengthen the national petrochemical industry and increase importation of high volumes of these agro-inputs. In the case of *phosphate* fertilizers, commercial alliances with nearby countries such as Peru must be strengthened, and, in the case of *nitrogenous*, from Brazil and the United States.

Clear and centralized communications management strategy, in order to avoid popular panic by disseminating the emergency management plan in the event of an ASRS.

Since most of the population would be generally unaware of what to do in an ASRS, it will be necessary to have a communication strategy before and after the catastrophe. The government of Argentina can start by reporting on ASRS in the Risk Management manuals generated by SINAGIR and by disclosing response plans to the public as they are developed.

In the aftermath of a disaster, it is important that any communication is in clear and simple language in order to increase public confidence in the government and its response capabilities (see Appendix 3, interview with Morgan Rivers), as well as public cooperation with wholesalers and retailers, to avoid:

- Collective panic
- Food hoarding and price speculation
- Food waste

Within the response actions, in addition to the strategy for the general public, it will be necessary to carry out targeted dissemination programs to help farmers with new crops and inform them about the growing conditions of those crops in the following seasons, using accurate models of weather conditions in future crop years once the scale of the disaster is known (ALLFED, nd). These outreach and information programs for farmers can be structured based on the current strategies of the Argentine government for the provinces to develop adaptation skills to climate change, which were mentioned by Silvia La Ruffa (see Appendix 3).

2. Solutions in food production

In this category are the proposals associated with the production of resilient food, along with various alternatives, such as redirecting food from animal use to human use and halting the production of biofuels. Image *2* shows the need for these adaptations, since half of the current global food production is dedicated to producing animal products and biofuels.

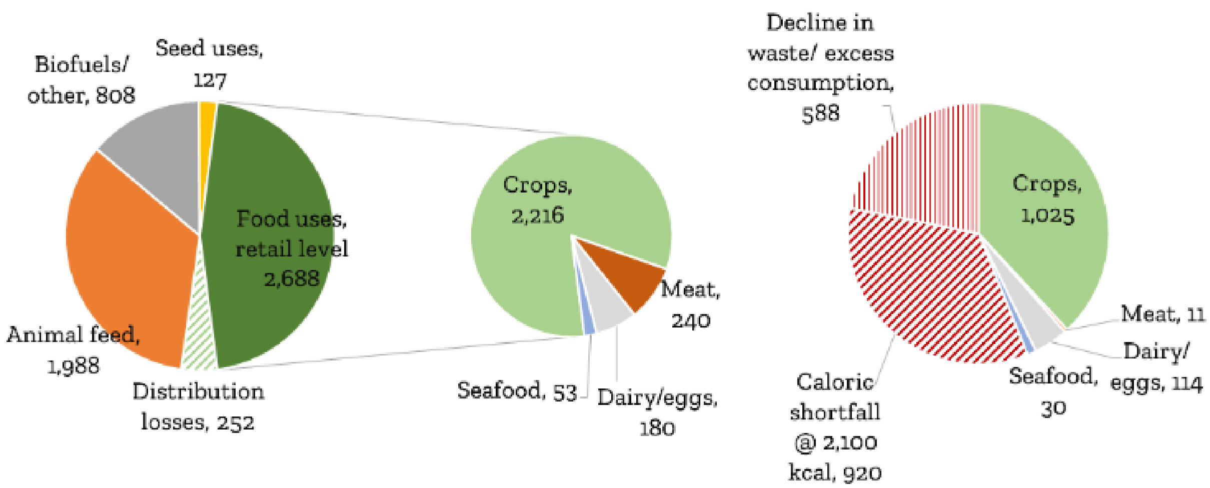

Figure 2. Global food production before (left, ~5,600 kcal/capita) and after (right, ~1,200 kcal/capita, 3rd year) severe ASRS. Without employing adaptations, 80-90% of world food production would be lost in the initial period of a nuclear winter (150 Tg), falling short of the direct needs of the population.

Redirection of food used as raw materials in animal production and production of biofuels.

- Redirection of the food used in animal feeding for human consumption, limiting animal reproduction, and increasing animal protein slaughter and conservation capacities.

This initiative seeks to maximize food availability during an ASRS. Instead of being used to feed livestock, most of these products could be diverted to feed humans directly.

In addition to redirecting food, stopping new births of breeding animals is a preventative measure to conserve limited food resources. Increasing animal slaughter capacity and conserving animal proteins could ensure that available resources are used efficiently and maintained for more extended periods. Image 3 shows how stopping animal husbandry would generate a significant amount of food quickly, by reducing the number of calories devoted to meat and biofuel production by an estimated ~15,000 kcal/capita/day. For comparison, an average person's requirement is usually cited as 2,100 kcal/day.

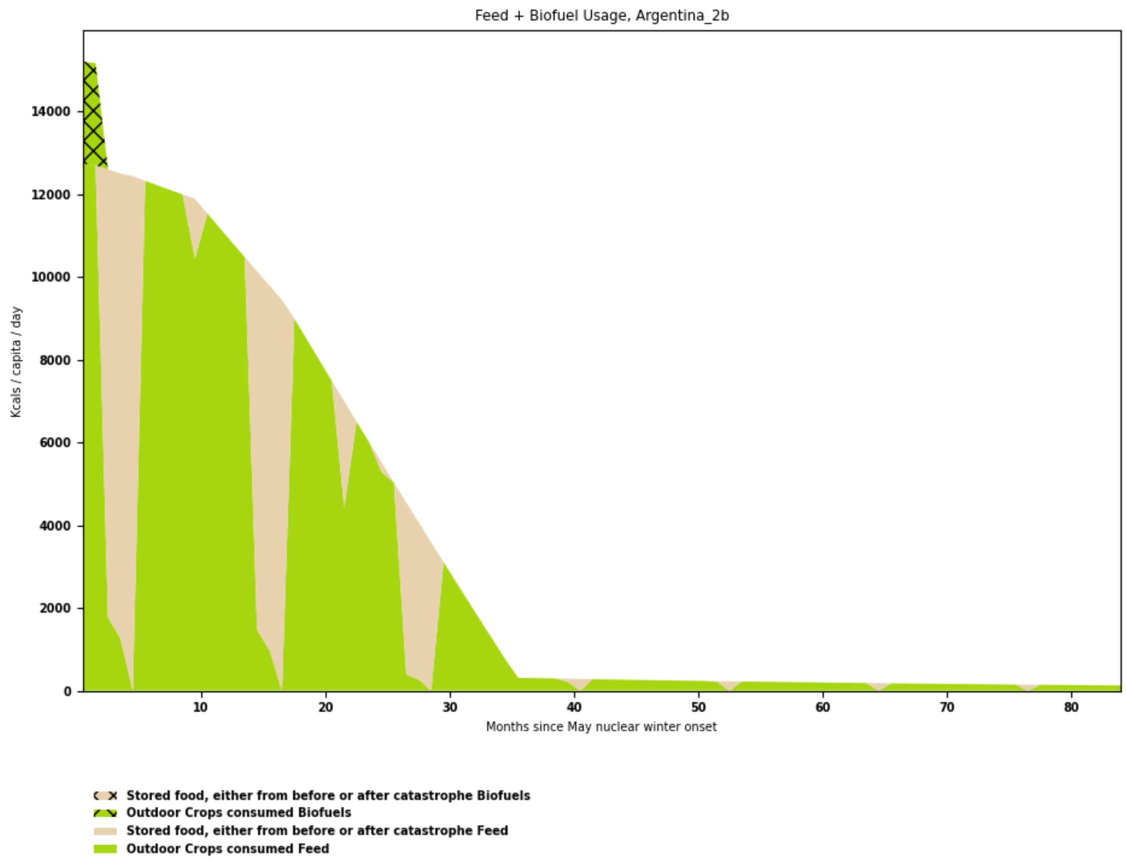

Image 3. Effect of ending animal agriculture on the reduction of food dedicated to animal consumption over time, which would then become available for human consumption.

To implement this initiative, we suggest identifying the types of food used in animal feed that could be redirected to human consumption, establishing the necessary procedures to guarantee that these foods are safe for human consumption, and creating animal population control regulations to prevent them from competing with humans for resources in a condition of decreased food production such as an ASRS.

- Strengthening the dairy production sector, using agricultural residues as animal feed.

We propose the use of vegetable biomass as a feed source for dairy cattle. This biomass can be obtained from different sources, such as food residues and crops. This reduces the reliance of livestock feed production on sunlight-dependent crops such as grasses and fodder, which are unviable in an ASRS.

To implement this initiative, dairy farmers will need technical assistance and training on how to implement a transition to diets more focused on plant biomass. In addition, it is necessary to consider quality evaluation of the food produced in this manner, and the establishment of policies to increase the use of these materials, while limiting arable land to food production intended exclusively for human consumption.

- Redirection of food used in the production of biofuels to human consumption, justified by the infeasibility of keeping this industry competitive in the face of an increase in the prices of the required raw materials (soybeans and corn).

In case of emergency, it is necessary to suspend certain activities of the biofuels industry in order to redirect raw materials such as corn and soybeans to contribute to national food security. However, sufficient fuel production must be maintained for the proper functioning of critical infrastructures, whatever their origin.

To implement this initiative, it is necessary to identify the foods used in producing biofuels that both have a large caloric value and are viable for human consumption, and also to establish a supply chain for their distribution.

Adaptations to agricultural systems to increase food production.

- Relocation of crops.

In an ASRS, the temperature drop will be particularly devastating to crops that are not cold-adapted. Taking into account the climatic changes in the regions in the face of various scenarios of reduced sunlight and the bioclimatic needs of each of the crops which contribute most to human caloric needs, it will be necessary to relocate cold-tolerant crops. Examples of cold-tolerant crops which will need to be relocated to lower latitudes include potatoes, wheat, and certain varieties of corn. Relocation would enable the maintenance of yields in areas that are currently planted with crops at higher temperatures and are not suitable under these conditions. However, further research and generation of simulation models will be necessary, complemented by experiments on the behavior of these plant varieties under ASRS conditions, such as low irradiance and low temperatures, as well as the use of greenhouses in these conditions (see Appendix 3, interview with Mariana Antonietta).

According to the available information (ALLFED, nd), the relocation must occur continuously from the beginning of an ASRS. The worst consequences of the catastrophe can manifest 2 or 3 years after its onset. It will take time to replant large cultivated areas.

- Increase in cultivation area.

Currently, according to the 2018 National Agricultural Census (INDEC Argentina, 2021), Argentina has about 154 million hectares of arable land, of which 43 million are considered easily cultivable from the point of view of infrastructure and connectivity. The remaining 112 million hectares will require further adaptations and investments for cultivation due to their use in other agricultural areas. In 2020, only about 37 million hectares were exploited in the country (CEP XXI & MAGyPN, 2020).

Due to the caloric foundation open-air crops provide, it is necessary to increase their areas from the 37 million hectares currently in production in case of an emergency, in order to supplement yield losses associated with an ASRS. This increase must cover easily usable cultivation areas equivalent to 43 million hectares. In the medium term, we recommend evaluating the feasibility of expanding the hectares that require further adaptations, which could imply clearing and deforestation, bringing into question ethics and environmental values.

- Increase in the coverage area of low-tech greenhouses.

Since temperature conditions are the main limitation for crops during an ASRS, greenhouses are a viable way to improve yields. They are quick and easy to build, and are able to improve available crop diversity. To make a significant contribution to food security in an ASRS, greenhouse deployment must be rapid, cost-effective, and on a large scale. Additionally, it is essential to have sufficient production of the materials necessary for construction, to allow for a massive deployment.

In an emergency, an exponential increase of up to 360 times the current coverage area of low-tech greenhouses is recommended during the first two years, going from 6,500 hectares currently covered (Alvarado et al., 2020a) to about 2.3 million hectares. Greenhouses must be adapted according to the conditions of the five regions of the country. Some of these adaptations include ventilation, temperature measurements, humidity controllers, precision irrigation, and other controls specific to the crops. In addition, one must take into account the technical characteristics considered in the INTA manuals, such as the inclination of the terrain, shape and slope of the roof, wind regime, and precipitation including hail (Lenscak & Iglesias, 2019).

Aquaculture adaptations to increase food production.

- Strengthening and rehabilitation of the national algae production industry (for scenarios under 50 Tg), with cultivation areas of at least 10,000 hectares.

Although the algae production industry in Argentina peaked in the 1960s and 1970s when production exceeded 30,000 tons of wet algae per year, the figures have since fallen drastically, and current production is practically zero (see Appendix 3, interview with Fernando Dellatorre). However, algae production could be a potential contributor to human caloric needs in an ASRS, and it would be necessary to rehabilitate the industry; this is recommended prior to the disaster (see Appendix 3, interview with Florian Ulrich. In addition, this would generate an economic benefit for the country in the present day. Internationally, there is commercial interest in several Patagonian algae varieties, which could boost the industry.

According to Fernando Dellatorre, Argentina has access to technical knowledge but lacks qualified personnel and equipment, especially ropes for growing the algae. Accordingly, in order to scale up the production of algae, the advice of experts in the area must be obtained, and at least the following points should be considered: the initial stock, the number of ropes available, the efficient technology for drying it, and the possibility of automating cultivation (interview with Florian Ulrich).

High-tech adaptations to increase food production.

- Redirection of industrial production capacity in areas such as paper pulp and biofuels into generating sugars from plant biomass.

This initiative is justified by the infeasibility of keeping the biofuels industry active in an emergency scenario of rising prices and scarce raw materials, such as soybeans and corn. Considering this, it seeks to take advantage of the pre-existing capacities in the Argentine industry to generate lignocellulosic sugars from vegetable biomass. This is possible through converting biofuel infrastructure to transform agricultural residues from corn production into sugars, or paper mill infrastructure to transform paper pulp into sugars.

In order to do this, we recommend evaluating the existing industrial capacities in biofuel production in Argentina to determine their potential for producing sugars from vegetable biomass. This evaluation must consider aspects such as the quality and quantity of the biomass, the efficiency of the production processes, and the capacity of the industry to adapt to the new conditions. In addition, it is necessary to encourage research and development of technologies that allow the efficient production of sugars from plant biomass.

- Apply the country's industrial capacities for food based on single-cell protein, produced from inedible raw materials.

There are currently a large number of production methods for single-cell protein (SCP), which is not limited by environmental conditions, produces a constant stream of final products without the breaks which characterize the harvest cycle, and can respond flexibly to downtime and interruptions without jeopardizing an entire crop. These can be obtained from several different feedstocks, such as natural gas, biogas, CO_2, certain kinds of paraffin, and methanol, as well as cellulosic material such as plant residues, wood, and leaves.

In the event of an ASRS emergency, these technologies could serve multiple purposes: ensuring the supply of feed needed to support fish, chicken, and pig farmers given the pressure on conventional feed; being used as food ingredients for direct human consumption to offset reductions in agricultural yields; and serve as export feed or food for severely affected regions.

- Redirect the industrial capacities of the private sector in food processing to obtain proteins of plant origin.

The private sector can significantly contribute to mitigating a potential ASRS by investing in research and developing technologies and practices that enable more resilient food production. In such a scenario, the production of meat and other animal products could be affected due to the increased price of livestock feed, which would lead to a decrease in the availability of animal protein.

In this sense, this initiative proposes that during the emergency, the food industry's capacities, facilities, and resources be redirected for the use and processing of plant-based proteins, which can be used as an alternative to animal proteins. Private industry must participate in preparing and responding to a possible ASRS; their collaboration and commitment can make the difference between a famine situation and sufficient, varied food production in the face of a global food crisis.

Results of adaptations

In order to determine the success of our proposed solutions, we have conducted estimates combining different scenarios in response to large-scale ASRS events (150 Tg). More information about the model we developed in partnership with ALLFED can be found in Appendix 6. We have identified four scenarios to assess the per capita calorie availability in the months following an ASRS, to demonstrate the impact of our suggested adaptations.

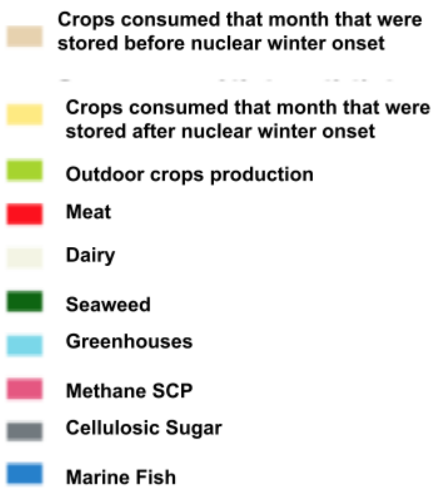

Image 4. Legend for model scenarios 1 a and b, 2 a, b, c and d.

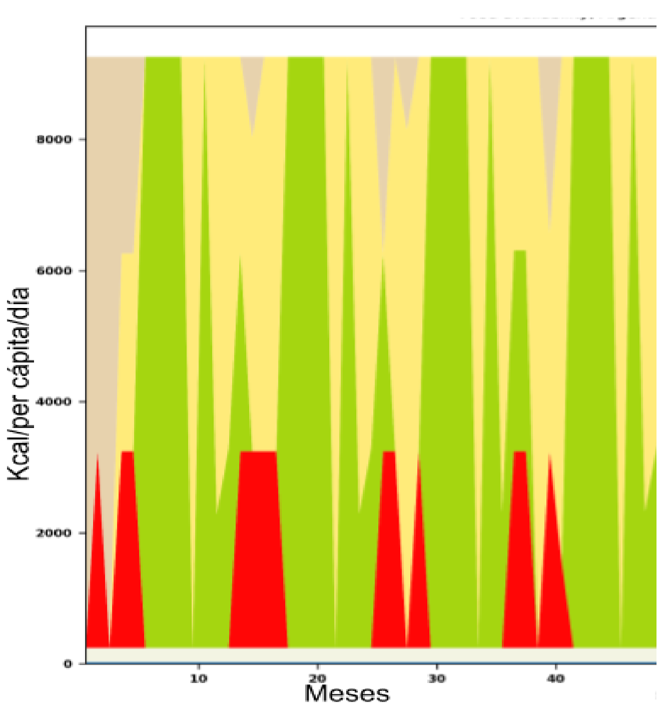

Image 5. Scenario 1a: the ***current net*** *food production in Argentina.*

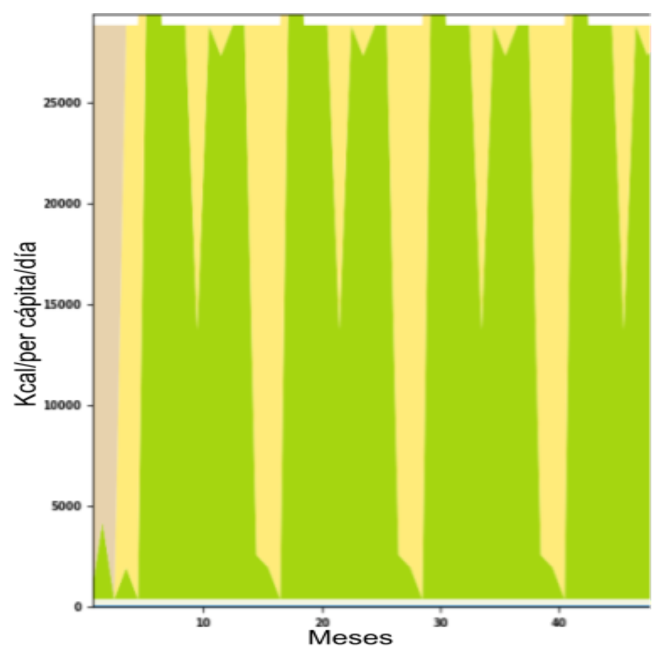

Image 6. Scenario 1b: the ***current gross*** *food production in Argentina, that is, the total amount of food that is produced, before some of this food is transformed into animal meat and biofuels.*

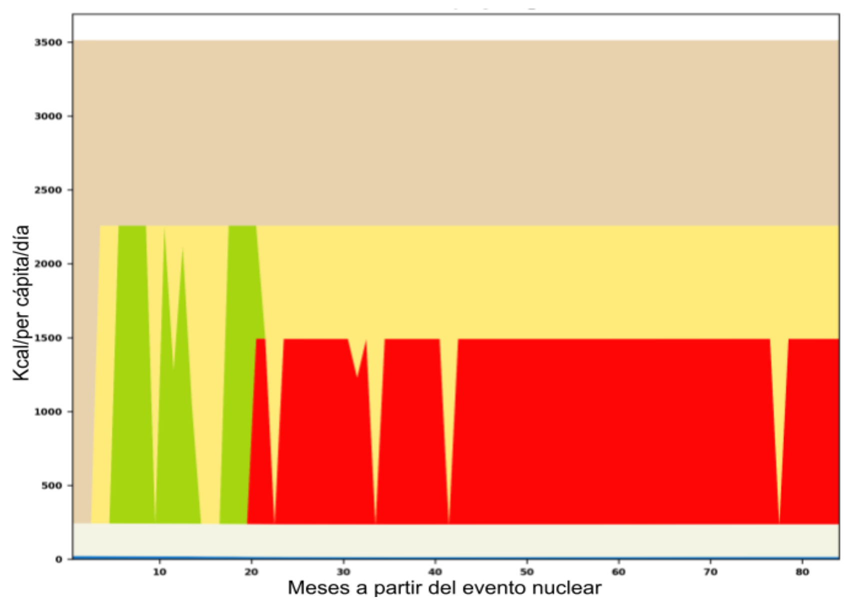

*Image 7. Scenario 2a: the current net production of Argentina in a scenario within the **climatic conditions of a severe ASRS (150 Tg), with the consequent loss of agricultural yield**, with optimal management of stored feed but no other adaptation, maintaining the **current level of production of animal meat and biofuels**.*

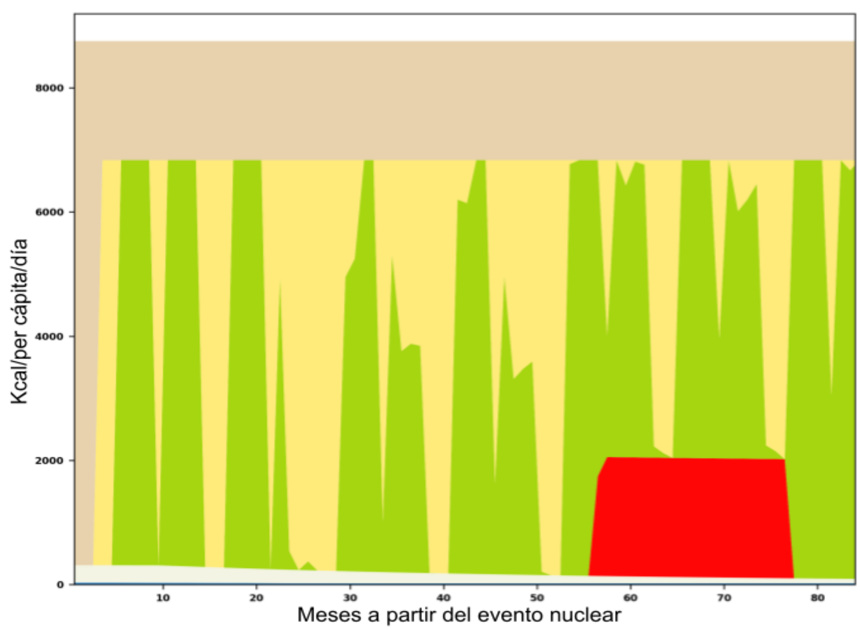

*Image 8. Scenario 2b: represents Argentina's production in ASRS if **the feed used by the livestock and biofuel industries were redirected to human consumption**. The comparison with scenario 1a shows how the ASRS has reduced crop yields to less than half in Argentina. The comparison with scenario 2a shows how reducing these industries can almost triple food availability.*

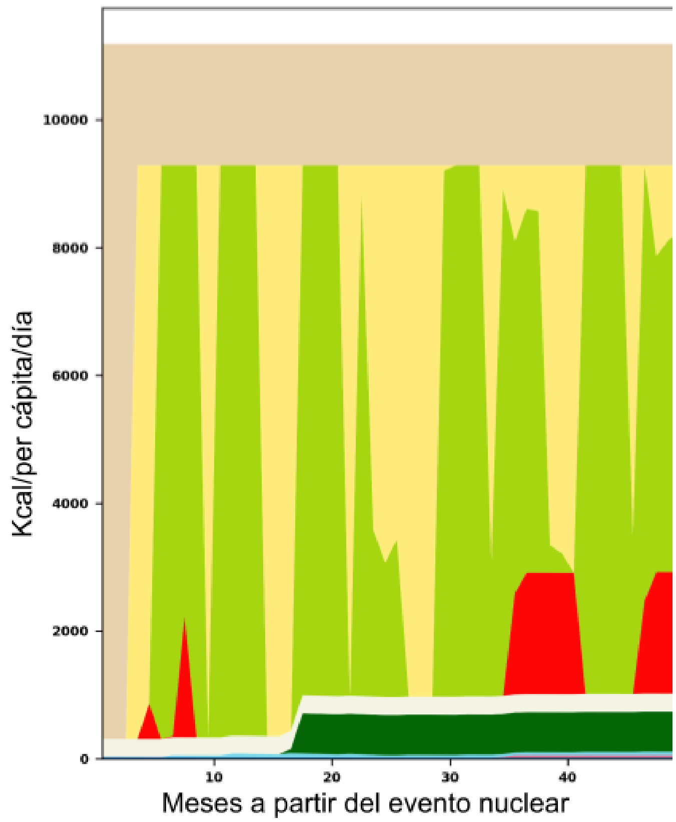

*Image 9. Scenario 2c: equivalent to scenario 2b, but with the addition of **resilient food production adaptations**, with the consequent increase in food production and availability. It shows how solutions such as crop relocation, algae production, and industrial resilient food manufacturing can significantly increase food availability.*

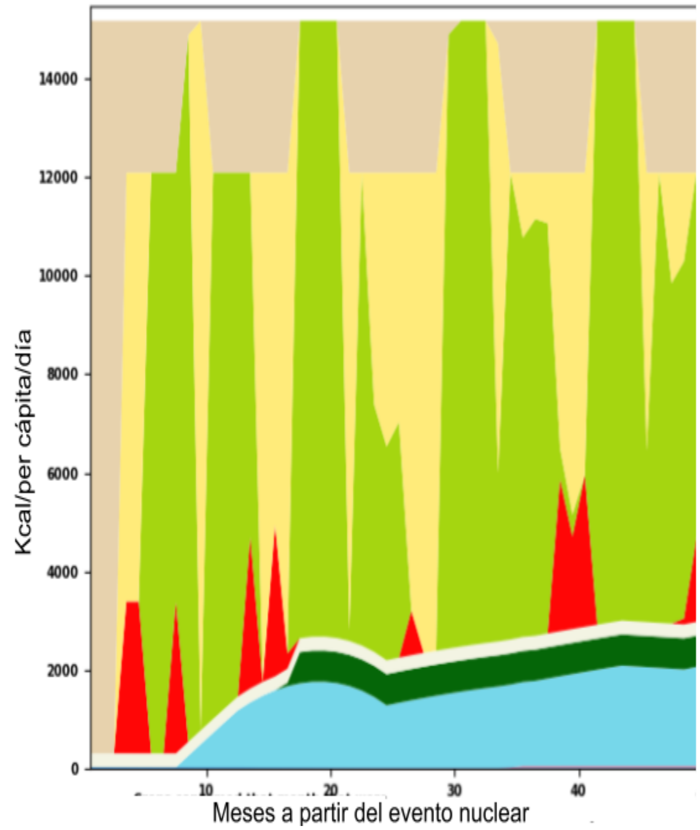

*Image 10. Scenario 2d: scenario of **more intensive adaptations** than 2c, including **significant deployment of greenhouses** (covering the entire current irrigated area)**,** and a **very significant increase in cultivated land** equivalent to planting an additional half of today's pastureland (total 72 million cultivated hectares, assumed over 3 years).*

Taking into account the results obtained from the previous scenarios, the satisfaction of the caloric needs of the Argentine population can be analyzed in percentages. In a scenario without an ASRS (scenario 1a and 1b, Images 5 and 6), gross production is more than 10 times the caloric needs of the population. In the case of an ASRS, **if adaptations are not made** in food production, gross production still satisfies 4 times the needs of the population (Image 8). However, if the production of biofuels and animal agriculture were maintained, the net production would be barely enough to cover the minimum needs of the current population (Image 7). This would **trigger higher prices and significantly increase food insecurity**. **With the adaptations displayed in scenarios 2c** (Image 9) **and 2d** (Image 10), **gross production can be raised to between 5 and 7 times the amount needed by the population**. It is also interesting to note that **without proper management of food stocks** (rationing, waste reduction, etc.), the amount produced in scenario 2a (Image 7) **would not be enough to feed the Argentine population**, according to a recent study in *Nature Food* (Xia et al., 2022b).

These values greater than 100% translate into the satisfaction of the caloric needs of the current Argentine population, and show that it is possible to feed populations larger than that of Argentina in the event of ASRS. Through surplus exports, Argentina can save up to almost 300 million people outside of its borders from famine (Image 11). This would also help to maintain trade, resulting in continued essential imports which would help maintain Argentina's critical infrastructure, as well as a reduced risk of refugee crises and local conflict.

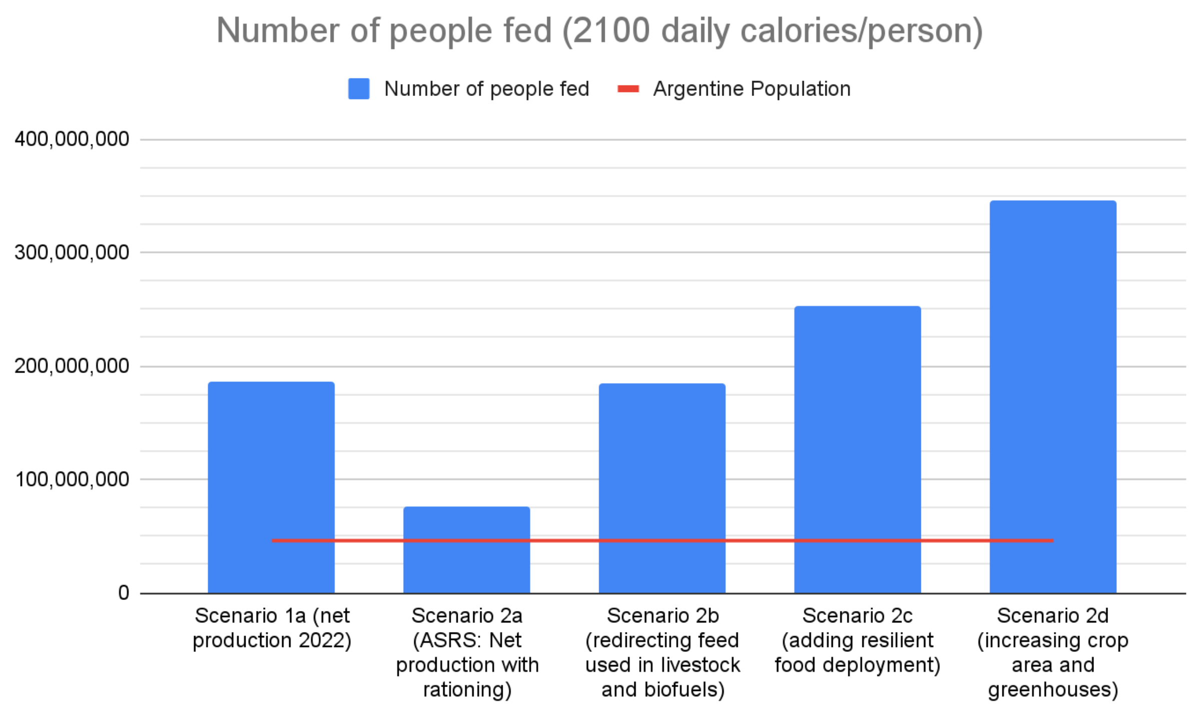

Image 11. Percentage of people fed for each modeling scenario.

The intervention that presents more significant impacts on calorie production, which is the expansion of cultivated areas, shows an estimate of how much agricultural production in Argentina could be increased at different degrees of expansion of the cultivated area during scenarios of various levels of severity (*Image 12)*. Note that a fixed drop in yield per hectare is assumed for soybeans, maize, wheat, potatoes, and oats taken from FAO statistics *(*Appendix 7*)*. However, in ASRS scenarios, yield drops would be variable. For example, cold-sensitive crops such as soybeans and corn would fare worse than crops with more significant resistance, such as potatoes, wheat, and oats. Currently, these crops represent about 31 million hectares. In the second scenario, it is expanded to the arable area of 43 million hectares, and finally, in the third, to the total cultivation and grazing area greater than 108 million hectares (Ritchie & Roser, 2013); taking into account the decrease in production before different magnitudes of

ASRS events between 5 and 150 Tg from the supplementary information of (*Xia et al., 2022b)* for the worst moment of the scenario towards the second year.

From the above, we can calculate the total caloric contribution of each crop of interest, and therefore the equivalence in kcal per capita, taking into account the redirection of food used for animal feed and production of biofuels for human consumption and a requirement of no less than 2100 Kcal per day per person for the population of the country.

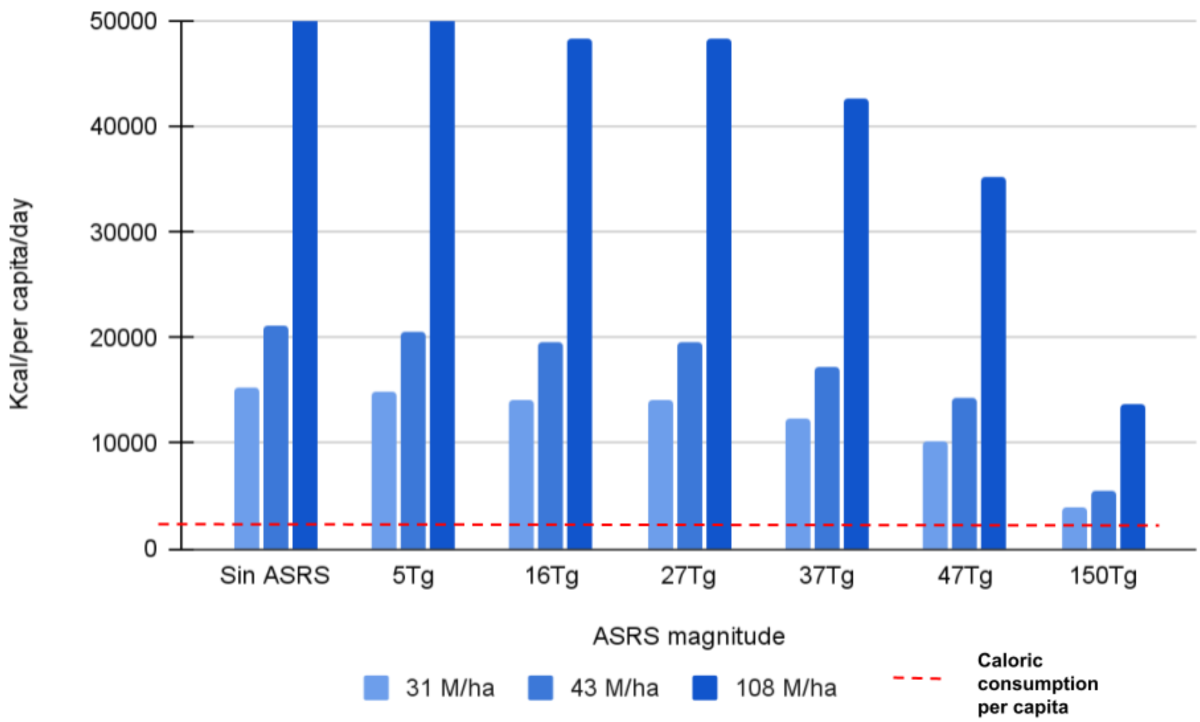

Image 12. Kcal per capita as a function of the increase in the cultivation area in Arg before different magnitudes of ASRS. The red dotted line represents the caloric consumption per capita equivalent to 2100 Kcal per day.

By taking into account the coverage of the caloric requirements of the Argentine population, it is possible to estimate the surpluses in production that can be used for international trade and generate a significant impact in the face of the crisis generated in an ASRS. In the most optimistic case, using the area of 108 million hectares would generate enough caloric production to feed between 6 and 22 times the population of the country (depending on the severity of the scenario), whereas in a more conservative scenario using only the easily arable hectares (43 million) this would feed between 2 and 8 times the population *(Image 13)*.

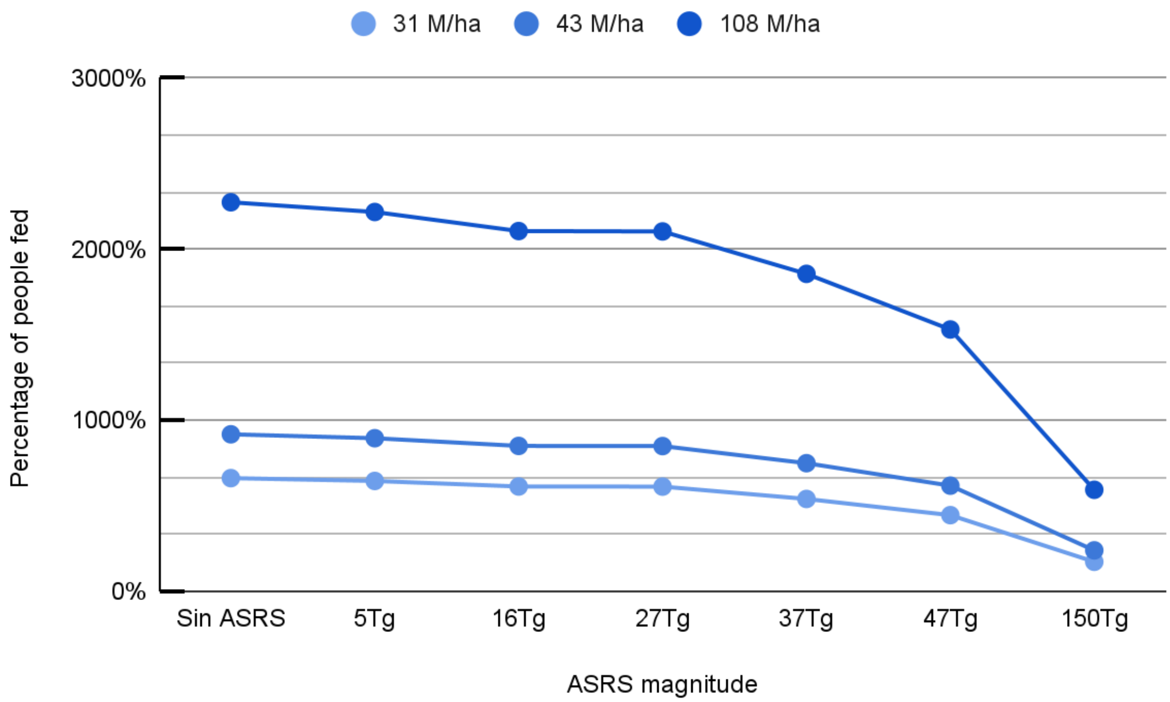

Image 13. Percentage of people fed in relation to the Argentine population taking into account the expansion of cultivation areas before different magnitudes of ASRS.

Responsible Parties

To implement our supply and communication proposals, we used our mapping of actors and their interviews to identify leading institutions for each proposal (see Image 14). The complete list of initiatives and actors, including international and national experts and various interest groups, are expanded on in greater detail in Appendix 5a.

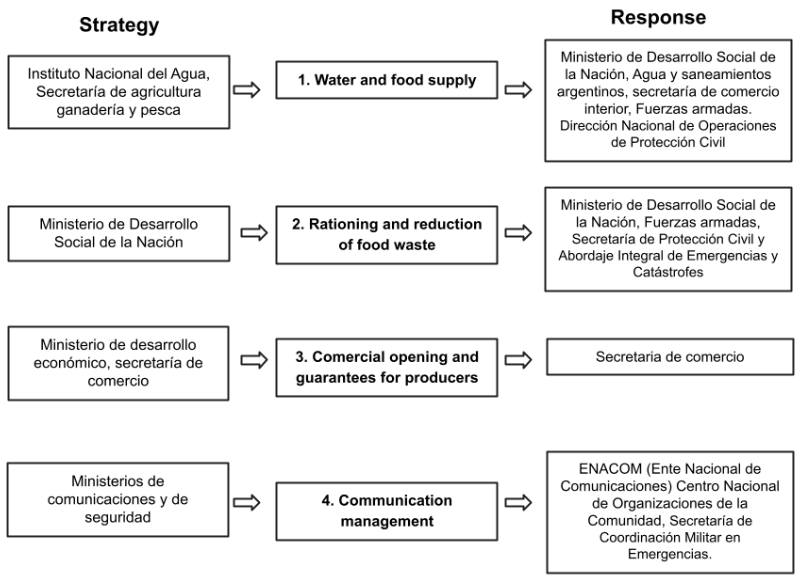

Image 14. Main entities during the planning and response of category 1 proposals in the field of Food Supply and communication.

To implement our solutions in food production, we used our mapping of actors and their interviews to identify leading institutions for each proposal (see Image 15). The complete list of initiatives and actors, including international and national experts and various interest groups, are expanded on in greater detail in Appendix 5a.

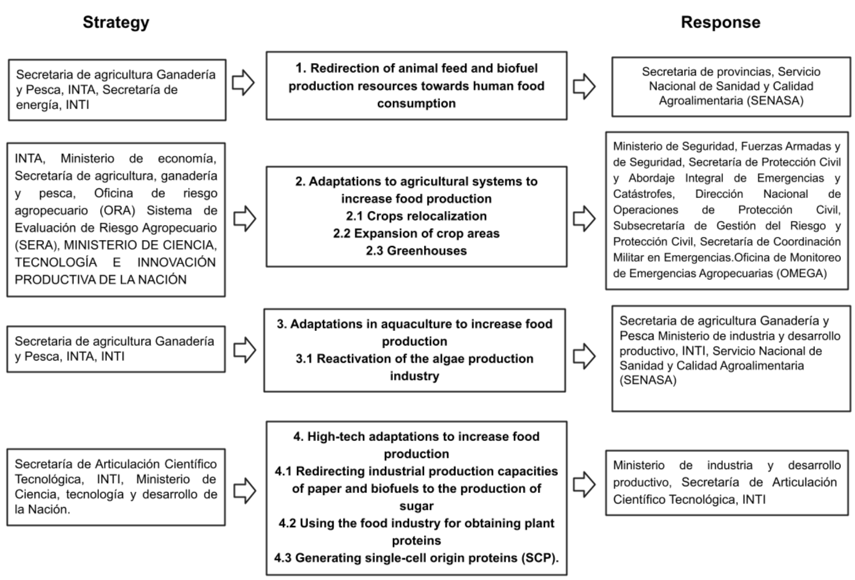

Image 15. Main entities during the planning and response of section two of proposals regarding food production solutions.

Conclusion

Abrupt sunlight reduction scenarios (ASRS) pose a significant threat to global agriculture and food security. In such an event, food productio n would decline and starvation rates would increase around the world, with a possible mortality rate of up to 75%. However, some countries like Argentina would benefit from a **favorable geographical location that could allow them to play a crucial role** in the production and distribution of food during an ASRS.

For this reason, it is important that the Argentine government actively participates in preparing **contingency plans** to deal with possible threats of this type in the region, and take preventive measures to guarantee the production and distribution of food during food crises such as an ASRS. We suggest the Argentine government and Argentine producers implement a series of response strategies which would minimize the impact that such a catastrophe may have on food production and maximize the availability of food for human consumption, thus avoiding humanitarian and migratory crises in the region.

In addition to contingency measures, it is essential to encourage **research and development** of resilient agricultural technologies and practices that allow adaptation to a potential ASRS. Collaboration between the public and private sectors is also crucial to achieving these advances and guaranteeing food security in a crisis. These initiatives must be considered a priority at the local, national, and global level to guarantee the population's right to food and reduce the impact of a potential ASRS on international food security.

As an intermediate step to build resilience in the country's food system and be better prepared for an ASRS, we suggest creating an interdepartmental working group involving different government institutions and relevant actors in Argentine food security. These are the people most prepared to investigate and deal with a situation like an ASRS. The formation of this interdisciplinary working group would enable an integrated and broader view of the problem with the participation of experts from different areas, such as scientists, representatives of the food industry, and political agents, among others. In addition, involving different actors would foster dialogue and collaboration between them, which could contribute to the generation of even more effective solutions.

Finally, the importance of a collaborative and multilateral approach is highlighted to address global catastrophic risks such as extreme food shocks and guarantee food security and access worldwide. In this sense, the preparation and execution of contingency plans must be a shared task between governments, the private sector, and civil society to ensure the resilience of food production and distribution.

Authorship of the report

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Thanks

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René Segura Latorre contributed to the editing of the document.
Isabel Johnson and Melissa Quintana Pineda contributed to the proofreading of the English version of the document.

Appendix

Appendix 1a Assessment of Latin American countries to respond to an ASRS - Decision Matrix

country/factor	Absolute level of production capacity without adaptations (150 Tg, only local consumption) [measured in people fed, normalized]	Level relative to the local population of production capacity without adaptations (150 Tg)	Absolute difference with and without adaptations [measured in local fed persons, normalized]	Political stability	government effectiveness	Supply Chain Resiliency	Final value
Factor weight	40%	20%	10%	5%	5%	20%	100%
Argentina	1.00	1	0.00	-0.11	-0.36	0.46	0.67
Uruguay	0.07	1	0.00	1.05	0.84	0.51	0.43
Chili	0.26	0.6	0.12	0.06	0.63	0.68	0.40
Panama	0.09	1	0.00	0.29	0.16	0.67	0.39
Costa Rica	0.11	1	0.00	0.87	0.26	0.44	0.39
Mexico	0.28	0.1	1.00	-0.64	-0.31	0.58	0.30
Paraguayan	0.15	1	0.00	0	-0.62	0.37	0.30
Colombia	0.22	0.2	0.49	-0.91	-0.01	0.44	0.22
Guatemala	0.22	0.6	0.00	-0.39	-0.75	0.48	0.25
Ecuador	0.08	0.2	0.22	-0.27	-0.21	0.65	0.20
Peru	0.15	0.2	0.32	-0.41	-0.26	0.44	0.19
bolivian	0.05	0.2	0.15	-0.32	-0.73	0.43	0.11
Nicaragua	0.03	0.2	0.00	-0.47	-0.85	0.50	0.09
Venezuela	0.12	0.2	0.18	-1.53	-1.85	0.36	0.01

Appendix 1b Explanation of indicators included in the decision matrix

Resilience dimension	Metrics	Justification
Absolute level of production capacity without adaptations (150 Tg, only local consumption) [measured in people fed]	Food self-sufficiency under nuclear winter conditions measured in people fed (150 Tg). Food System Adaptation and Maintaining Trade Greatly Mitigate Global Famine in Abrupt Sunlight Reduction Scenarios	This indicator relates the number of population and food self-sufficiency by country in an ASRS to measure the number of people fed. Additionally, more people are likely to be more resilient. For example, a very large unprepared population could be at increased risk of civil war if it becomes too unequal and divided (Boyd and Wilson, 2022).
Relative level of production capacity without adaptations (150 Tg)	Food self-sufficiency in nuclear winter conditions without adaptations (150 Tg). Food System Adaptation and Maintaining Trade Greatly Mitigate Global Famine in Abrupt Sunlight Reduction Scenarios	The better the situation of a country without having to respond to the disaster, the better chances it has for a part of its population to survive. A high value also favors those countries that could produce more than they need to feed the rest of the region.
Absolute difference with and without adaptations [measured in local fed people]	Difference in caloric consumption in nuclear winter with and without adaptations. Food System Adaptation and Maintaining Trade Greatly Mitigate Global Famine in Abrupt Sunlight Reduction Scenarios	This indicator assesses the potential per country of the feasible adaptations identified by ALLFED to mitigate famine in an ASRS. Resilient foods were selected for their potential to scale quickly, be affordable, and provide sufficient calories, fat, and protein.
Political stability	World Bank - Worldwide Governance Indicators. Political stability index (1996 - 2021)	The Political Stability Index measures perceptions of the likelihood that the government will be destabilized or overthrown through unconstitutional or violent means, including politically motivated violence and terrorism. It was considered as coordination and trust in governance at the national or local level can be important for coordinating disaster logistics.
government effectiveness	World Bank - Worldwide Governance Indicators. Government effectiveness index (1996 - 2021)	The government effectiveness index captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.

Resilience dimension	Metrics	Justification
Supply Chain Resiliency	World Bank Development Indicators (World Economic Forum Global Competitiveness Index) (World Economic Forum, 2019)	It is considered, given that in an ASRS it will be necessary to continue with the distribution of food and goods.

Appendix 2 Resources and Contacts

Interest groups

Name	Category	Web page	Relevance	Contact information
Secretaria de Agricultura Ganadería y Pesca (MAGyP)	Government	https://www.argentina.gob.ar/agricultura	high	informacion@magyp.gob.ar
Instituto Nacional de Tecnología Agropecuaria (INTA)	Government	https://www.argentina.gob.ar/inta	high	Centro de investigación de Recursos Naturales: (011) 3754 8400 int 8621
Sistema Nacional para la Gestión Integral del Riesgo (SINAGIR)	Government	https://www.argentina.gob.ar/sinagir	high	secretariaejecutiva.sinagir@minseg.gob.ar
Agencia de Planificación	Government	https://www.argentina.gob.ar/apla	high	Lic. Sonia A. Kabala, contacto@apla.gob.ar
Dirección Nacional de Operaciones de Protección Civil	Government	https://www.argentina.gob.ar/seguridad/gestion-del-riesgo-y-proteccion-civil/operaciones	high	Esteban Chalá
Dirección Nacional de Prevención y Reducción del Riesgo de Desastres	Government	https://www.argentina.gob.ar/seguridad/gestion-del-riesgo-y-proteccion-civil/prevencion	high	Claudio Schbib
Instituto Nacional de Tecnología Industrial (INTI)	Government	https://www.argentina.gob.ar/inti	high	Sandra Mayol, consultas@inti.gob.ar

Name	Category	Web page	Relevance	Contact information
Oficina de riesgo agropecuario (ORA) - Sistema de Evaluación de Riesgo Agropecuario (SERA)	Government	http://www.ora.gob.ar/	high	Lic. Adriana Basualdo - abasual@magyp.gob.ar
Oficina de Monitoreo de Emergencias Agropecuarias (OMEGA)	Government	https://www.magyp.gob.ar/sitio/areas/d_eda/omega/	high	Maria de Estrada
Dirección Nacional de Emergencias y desastres Agropecuarios	Government	https://www.argentina.gob.ar/agricultura/emergencia-agropecuaria	high	Fabian Jaras
Subsecretaría de Gestión del Riesgo y Protección Civil	Government	https://www.argentina.gob.ar/seguridad/gestion-del-riesgo-y-proteccion-civil	high	Sebastian Portillo (https://www.linkedin.com/in/sebaportillo/)
Instituto Nacional de alimentos de Argentina (ANMAT)	Government	https://www.argentina.gob.ar/anmat	high	Telephone: (54-11) 4340-0800
Comisión Cascos Blancos	Government	https://www.cancilleria.gob.ar/es/politica-exterior/cascos-blancos	Low	comca@cancilleria.gob.ar
Innovaciones Tecnológicas Agropecuarias S.A.	Government	https://www.argentina.gob.ar/intea	Medium	It is the same as the National Institute of Agricultural Technology (INTA)
Instituto de Agrobiotecnología del Litoral (IAL)	Academy	https://ial.conicet.gov.ar/	Medium	ial@santafe-conicet.gov.ar
Instituto Geográfico Nacional	Government	https://www.ign.gob.ar/	Medium	https://www.ign.gob.ar/contacto/

Name	Category	Web page	Relevance	Contact information
Red Científico-Tecnológica para la Gestión Integral del Riesgo	Government	https://www.argentina.gob.ar/ciencia/sact/gestion-del-riesgo	Medium	The same from the Secretariat of Scientific Articulation
Secretaría de Articulación Científico Tecnológica	Government	https://www.argentina.gob.ar/ciencia/sact	Medium	Juan Pablo Paz, sact@mincyt.gob.ar
Secretaría de Cambio Climático, Desarrollo Sostenible e Innovación	Government	https://www.argentina.gob.ar/ambiente/cambio-climatico	Medium	Cecilia Nicolini
Secretaría de Coordinación Militar en Emergencias	Government	https://www.argentina.gob.ar/noticias/la-secretaria-de-coordinacion-militar-en-emergencias-del-ministerio-de-defensa-continua	high	Carlos Hospital
Servicio Geológico Minero Argentino	Government	https://www.argentina.gob.ar/economia/segemar	Medium	Eduardo Zappettini, atencionalciudadano@segemar.gov.ar
Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA)	Government	https://www.argentina.gob.ar/senasa	Medium	respond@senasa.gob.ar

experts

Name	Relevance	National / International	Ambit	Organization	Area
Matt James Boyd	high	International	Academy	Adapt Research Ltd	RGC
Fernando Dellatorre	high	National	Academy	Laboratorio Algas Marinas Betónicas, CESIMAR	Algae
Maria Laura Escuder	high	National	International cooperation	FAO Argentina	Food safety
Alejandro Bustamante	high	International	International cooperation	ECLAC	Risk management ECLAC
David Denkenberger	high	International	NGO	ALLFED	Food safety
Farrah Jasmine Dingal	high	International	NGO	ALLFED	algae in nuclear winter
Mariana Antonietta	high	National	NGO	ALLFED	Argentine food production
Florian Ulrich	high	International	NGO	ALLFED	algae solution
Morgan Rivers	high	International	NGO	ALLFED	Prioritization solutions Argentina

Name	Relevance	National / International	Ambit	Organization	Area
Michael Hinge	high	International	NGO	ALLFED	Economy and politics
Ross Tieman	high	International	NGO	ALLFED	Food resilience in nuclear winter
Juan García Martinez	high	International	NGO	ALLFED	ASRS Food Solutions
Claudio Schbib	high	National	Government	Dirección Nacional de de Prevención y Reducción del Riesgo de Desastres.	Risk management
Silvia La Ruffa	high	National	Government	SINAGIR	Risk management
Maria de Estrada	high	National	Government	OMEGA	Agricultural risk management
Carlos Ospital	high	National	Government	Secretaría de Coordinación Militar en Emergencias	Emergency care

Appendix 3 Interviews

David Denkenberger
Director and Co-Founder of the Alliance to Feed the Earth in Disasters (ALLFED) and Assistant Professor at the University of Canterbury

Denkenberger pointed out that Argentina is an interesting country because it is not possibly the target of a nuclear attack and because, in the event of ASRS, it can produce enough food to export and pointed out that a possible contagion effect can be evaluated in a scenario of non-commercial exchange in which the country could not import inputs and materials necessary to guarantee and increase food production. To better estimate this capacity, some factors include: your crops, food storage, paper production capacity, and plastic production for greenhouses.

The most recommended actions to follow for an ASRS scenario are: a preparation and response plan, the creation of greenhouses, the relocation of crops, the transformation of factories and industries (e.g., paper and biorefineries), and deployment of new industries (single-cell protein), rationing system, carrying out information campaigns and a communication plan, determining the use of animal feed for humans, how to plan the reduction of animal population and food waste. It is essential to mention that in the case of relocation of crops and transformation and deployment of new industries, the cost-benefit is key (price-calorie ratio). Algae are excellent for this, but fungi and insects are not because they are expensive.

Fernando Dellatorre
Professor-researcher Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) of Argentina

For the production of algae, the Argentine continental shelf has several advantages (enormous biodiversity, ideal depth) and several drawbacks (lack of protected areas, variation in tides). The industry peaked in the 1960s and 1970s when production exceeded 30,000 tons of wet algae per year. However, the numbers fell drastically, and current production is practically nil. The most promising species is Undaria pinnatifida, which has a high growth rate, resistance, and food use.

The logistics for producing seaweed are straightforward: it can be mass-produced with rudimentary methods and limited space. Argentina has access to technical knowledge but lacks qualified personnel and equipment, especially ropes. This infrastructure should be minimally prepared before the hypothetical catastrophe.

Internationally, there is commercial interest in various Patagonian algae, which could boost the industry. However, regulatory barriers and opposing interests still impede growth (primarily due to ecological and environmental issues).

Mariana Antonietta
Associate researcher ALLFED and assistant researcher CONICET

Antonietta affirms that an ASRS scenario has not been considered in Argentina from a scientific or institutional point of view.

He also points out that for the ASRS scenario, it is important to consider the actors involved. In Argentina, for example, the agricultural sector has enormous power since it represents one of the country's largest foreign currency sources. In particular, the large producers concentrate the extensive production of cattle, corn, wheat, soybeans, and sunflowers, and they have a lot of lobbying capacity in Congress and the government; In contrast, small food producers have many limitations as they are subject to precarious conditions such as not owning the land and being subject to the prices imposed by intermediaries.

The Pampas region (where production is concentrated) is the most important area because it has very good soil fertility and favorable climatic conditions. Most of it is agricultural, and livestock farming is concentrated in the southeast. He affirms that most of it is clayey, and in some regions, double cultivation is practiced (wheat/soybean, wheat/corn).

Antonietta indicated the importance of validating simulation models through experimentation. The simulation models have not been validated with experiments that combine the conditions of an ASRS (low temperatures, low solar radiation, reduced precipitation, high UV-B, and high relative humidity). Therefore, the results of the simulation models must be interpreted with caution. In addition, crops adapted to high latitudes would be the most suitable for an ASRS scenario. However, there is no large-scale production of these varieties because they are in marginal environments.

Morgan Rivers
ALLFED Associate Researcher

Morgan Rivers has stressed the importance of knowing the water capacity that Argentina currently has and has also mentioned the importance of knowing how Argentina manages its drinking water and how it is distributed, and if they have water pumps. He mentioned that the water pumps consume much energy and normally do not have backup power and that generally, the institutions that have these backups are primarily hospitals and health and welfare organizations, so if there is no backup power, it is possible that if electricity were to be interrupted by nuclear winter, drinking water would be in short supply.

Morgan also mentioned the relevance of the government's role when having food rationing plans since it is a very effective initiative, and nutrition could also be improved in terms of macronutrients. In the same way, he also mentioned the relevance of having food storage to cope with the catastrophe initially but verify, if possible if these storages are carried out in the private or public sector. Another low-tech alternative he mentioned as a resilient food was seaweed, and that it would be relevant for ALLFED to have a map of where the seaweed would be generated, as well as determine if it would be for human or animal consumption.

Michael Hinge

Senior Economist ALLFED

For Michael Hinge, the economic models in the case of ASRS are in their early stages, so it is very difficult to accurately determine the cost-benefit of the solutions and the actions to be taken. For example, in the case of Argentina, livestock must be essential, but it is associated with determining other factors, such as the amount of pasture available in an ASRS. He also considers that using greenhouses can be very expensive and would triple the prices of the products, but it could be justified for fruits and vegetables.

In this scenario, the most logical thing is that prices tend to increase a lot, so Hinge recommends that each country adjust the level of state intervention according to its context. One could reasonably think of a state intervention (like the United Kingdom in World War II) that generates a system of rationing and secure purchase on production. However, it is also important that the principles of a free market are maintained and especially that the actors at the most local levels can make decisions very flexibly (low-tech solutions and the exchange of ideas at this level would be great). In Hinge's words, these people at the local level will be able to make better decisions. In this scenario, the most logical thing is that prices tend to increase a lot, so Hinge recommends that each country adjust the level of state intervention according to its context.

Hinge states that a nuclear war scenario has a significant risk of occurring, especially in current times. However, for an ASRS to activate, it takes hundreds or thousands of detonations that are unlikely to occur. However, should it occur, governments will be able to avoid further tensions if a plan is presented to the civilian population; It is also better to prepare now because if the scenario occurs, the necessary solutions and technologies may take 7 years to be produced, while it will only take 7 months to 1 year for the climatic effects to take effect.

Finally, Hinge affirms that some countries may vary in their crops, but others will need international help, so an organization like the United Nations will be essential.

Florian Ulrich Jehn

ALLFED Associate Researcher

Florian Ulrich does not consider Argentina one of the Latin American countries most affected by an ASRS since temperatures would drop to unsustainable low levels for food production. This would apply above all to algae: according to (Harrison et al., 2022), the oceans would suffer drops of 10-15ºC, so the southern part would freeze. For the species of alga *Gracilaria tikvahiae* (studied at ALLFED), the temperature range necessary for its growth is very narrow, and it would not occur in a post-catastrophic Argentina because its growth would be very slow. Ulrich sees more promise for algae production in more northern and western parts of South America, such as Peru.

Several points are considered to scale up algae production: people with previous experience in algae cultivation, the initial stock, the number of ropes available, efficient technology to dry it, and the possibility of automating cultivation. In any case, Ulrich considers that algae without nutritional modifications should not account for more than 10-20% of the diet due to its high iodine content. Moreover, he doubts the cost-effectiveness of algae, which, according to (DeAngelo et al., 2022), have a very high cost-benefit.

Outside of aquaculture, the possibility of building greenhouses in the north of Argentina is briefly mentioned, and an estimate is made of whether there is the amount of water available to do so. For uses such as fertilizers, the wealth of guano in several countries is discussed. At a strategic level, he considers it important that there be cooperation between South American countries so that they specialize and generate exchange dynamics.

Matt Boyd
Director and founder of Adapt Research

Boyd points out the importance of having better national risk assessments and being more transparent in the information that contains them. He mentions the article by (Kohler, 2023) and takes as advice they need to take examples from other countries and perfectly adapt them to the national context: such is the case of the new RCG law in the United States (2022) that can be a starting point in several countries. He also cites as an example his work in New Zealand, where, based on what happened due to the pandemic, the impact on merchants and businesses in the event of a nuclear winter is being defined, which helps decision-makers to make a better idea of the risk the island might face.

However, to achieve these better assessments, it stresses the need to better 'agree' on assumptions and the implications of those assumptions (e.g., in risk understanding and communication); it suggests considering all the information possible and ordering it from the one with the most significant impact to the one with the most negligible impact, for example, from the number of crops that would be frozen in an ASRS and the types of crops that could be used in a mixed way (wheat and carrot case) to the number of ambulances that would be required.

Finally, he points out the importance of articulating technical aspects with logistics. In his opinion, logistics is as necessary as all the science behind evaluating these risks. For example, for the production of food, fertilizers, and pesticides will be needed, which the food-producing country would not necessarily have, so it is necessary to know where they will come from; It is also the case for transport and energy and the question is how these needs will be met.

Claudio Schbib

National Director of Prevention and Disaster Risk Reduction of the Undersecretary of Civil Protection and Risk Protection of the Ministry of Security of Argentina

Claudio Schbib points out that the National Directorate for Disaster Risk Prevention and Reduction reports to the Undersecretary for Civil Protection and Risk Protection, which is attached to the Federal Security Articulation Secretariat. There they work with other governmental and non-governmental organizations and members of the scientific-technical committee.

Risk management work in Argentina takes the SENDAI framework and United Nations guidelines as a reference and is governed by Law No. 27,287 in which SINAGIR is created, as well as Decree 383, which implements said law. Accordingly, SINAGIR comprises two large councils: the National Council, which convenes all the ministries that may influence risk management, and the Federal Council, which convenes all 24 provinces of Argentina. Being a federal country, the 24 jurisdictions of the Republic of Argentina are independent, but work is done jointly for risk management. In addition to these two large councils, there are other minor councils, such as the Consultative Council of Civil Society Organizations, which brings together NGOs, and the private sector, among others; this implies the extension of risk management to the whole of society.

In particular, the National Directorate for Disaster Risk Prevention and Reduction is in charge of risk analysis, mapping, and training, working together with the emergency monitoring team. The other Directorate is in charge of operations and response. Regarding the scientific-technical organizations (autonomous entities attached to the ministries), they meet with the SINAGIR dependencies once a month; there, they work on the quarterly evaluations. To respond to extreme weather events, the scientific-technical body in charge is OMEGA, the Agricultural Emergency Management Office located in the Ministry of Agriculture.

In addition, it explains what SINAME is, the National Emergency Alert and Monitoring System (SINAME), a risk management tool that makes it possible to map and monitor hydrometeorological threats and the permanent exchange of information for monitoring potential adverse situations in the country.

Silvia La Ruffa

Secretary of the Secretaría de Articulación Federal de la Seguridad del Ministerio de Seguridad de la Argentina

Dr. Silvia La Ruffa states that Argentina's risk system is relatively new. It has been in force for 7 years and was given in the framework of the Sendai talks. Compared to Chile, its system is 20 years old. The Argentine system is based on Law 27,287, which legally creates the National System for Comprehensive Risk Management and Civil Protection (SINAGIR). This system involves all governmental and non-governmental actors in risk management. It creates the National Council for Comprehensive Risk Management and Civil Protection as the highest authority for decision-making, articulation, and coordination of the resources of the national State.

The Chief of Staff chairs this Council, and five areas have as a common point the Executive Secretariat of SINAGIR. The five areas are (i) the Ministry of Security that brings together the civil protections of the 24 subnational jurisdictions, (ii) a network of technical scientific organizations coordinated by the Ministry of Science and Technology, (iii) a registry of organizations of the civil society that resulted in the organization via regulatory decrees of a council for civil society organizations, (iv) an advisory council and (v) another advisory council for the business sector.

The National Council approves a five-year plan currently valid for 2018-2023. This plan is created by technical and scientific organizations, that are the National Meteorological Service, the National Water Institute, the National Institute of Seismic Forecasting, the Maritime Geological Service (which includes the Volcanic Activity Observatory), the Office of Monitoring of Agricultural Emergencies (OMEGA), among others. Two offices that may be of interest were also mentioned, such as the National Agrifood Health and Quality Service and the Salta Malvaran Institute* (confirm name).

Finally, the importance of international coordination is highlighted. On this, La Ruffa highlights three different levels. In the Argentina-Chile case, it has occurred within the framework of bilateral cooperation; At the regional level, Mercosur and Celac have been the organizations through which the countries have sat down to agree on risk management plans or share experiences. The typical plans have occurred in border plans. Finally, at the continental level, within the same framework of Celac, there have been joint actions with the European Union to develop cooperation in risk management. In June of this year, a multilateral meeting will be held in Brussels.

Maria de Estrada

Coordinator of Oficina de Monitoreo de Emergencias y desastres Agropecuarios (OMEGA) of the National Directorate of Agricultural Emergencies and Disasters of the Ministry of Agriculture, Livestock and Fisheries of Argentina

María de Estrada highlights the importance of the technical component in SINAGIR. He affirms that the system is under construction and the technical components are solid despite possible budget and personnel variations in the entities and offices. In his specialty, from the Agricultural Emergency Monitoring Office, he highlights that significant work has been done to monitor droughts in the country.

Another important aspect is communication between entities. As in other entities, it stands out that the system is designed, and that is how it works so that technical organizations can periodically provide risk prevention information. For example, there is the GDE, the internal mail and institutional notification system, and the SINAME, which allows viewing different threats and scenarios.

Lastly, it indicates that for the investigation being carried out, the National Commission for Agricultural Emergencies would be the essential institution, since all producer entities, producer federations, provinces, INTA, and the INTI.

Carlos Ospital

Secretary of Secretaría de Coordinación Militar en Emergencias del Ministerio de Defensa de Argentina

The Hospital Secretary points out that the Secretariat for Military Coordination in Emergencies has two essential functions. Provide logistical support in emergencies through the requirements made by local governments, provinces, or SINAGIR itself. Furthermore, to serve as a link between the military and civilian actors during emergencies.

He clarifies that two offices develop all the emergency logistics according to the event's needs. All logistical support is requested from the Secretariat for Military Coordination in Emergencies concerning military capabilities and from the Federal Security Articulation Secretariat (with the Undersecretary for Risk Management and Civil Protection) in everything related to capabilities of a civil nature.

Regarding the articulation part, it indicates that the Secretariat it directs is the political nexus of the Ministry of Defense, the Armed Forces, and the provinces and local governments since it coordinates all these actors within their functions (emergencies, social vulnerability, aid humanitarian).

It indicates that in the event of a case such as the one raised by ASRS, civil protection is initially in charge of acting and is coordinated by the Federal Security Articulation Secretariat. Moreover, suppose additional support is required, or there is a better capacity for something specific. In that case, the Articulation Secretariat communicates with the Secretariat that he presides over to request what they need in terms of logistics.

From there, internally, communications and requirements are carried out between the Secretariat for Military Coordination in Emergencies and the Headquarters of the Joint Chiefs of Staff, with the Military Emergency Support Directorate (DIMAE), or with each of the headquarters of each weapon.

Appendix 4 Literature review

Summary of the sections of the literature review.

Abrupt Sunlight Reduction Scenario (ASRS)

The articles review various aspects of food safety in scenarios of abrupt reduction in sunlight (ASRS). These scenarios can be caused by events such as volcanic eruptions, the injection of soot due to a nuclear war (Robock, 2015) that would generate variations in T° of between 1 and 15°C depending on the severity of the event or the impact of asteroids (the latter only mentioned by the authors, the first two causes being more important) and can have severe consequences for the production of crops, fishing, and livestock, which could generate famines worldwide, (Xia et al., 2022a).

To deal with this problem, solutions are proposed, such as the adaptation of the food system and the maintenance of the global food trade, as well as the production of crops in low-light greenhouses (Alvarado et al., 2020b), the relocation of tolerant crops, the production of algae, the extraction of proteins from plant biomass (Rivers, et al., 2022) and the use of microbial proteins from hydrogen (Martínez et al., 2021). In addition, there is a need to consider balanced and resilient diets that meet the caloric requirements to face these scenarios (Pham et al., 2022).

The impacts of past events are analyzed, such as the eruption of the Tambora volcano in 1815 (Wilson et al., 2023), and the Laki volcano in 1783 (Oman et al., 2006), which may be a sample of the impact that it could have. a nuclear winter and that produced decreases in average terrestrial temperatures of between 1 and 2 °C, generating climate changes and drops in food productivity that compromised the food security of millions of people in subsequent years to understand the consequences of similar events in the future.

In summary, these sources address the challenge of maintaining food security in ASRS situations (Denkenberger & Pearce, 2014) based on models that include climate parameters (Xia et al., 2022a) and the response of countries and populations before the scenarios of nuclear conflicts that affected the entire population and in the worst scenarios caused the death of up to a third of the world population, in addition to proposing possible low and high technology technological solutions and policies to face this catastrophic scenario.

International Solutions and Policies regarding ASRS

The articles review various strategies and policies to deal with the Abrupt Reduction in Sunlight Scenario (ASRS) and ensure food security during events such as nuclear war or volcanic eruption. Hypothetical solutions are proposed, such as the creation of refuges on islands that can preserve part of humanity (isolated bunkers, submarines, or islands) (Boyd & Wilson, 2022a), the management of food reserves, the exponential construction of nurseries (Alvarado et al., 2020b), (ALLFED, 2022), resilient food production (Rivers, 2022), crop relocation, the adaptation of technology to increase water productivity (ALLFED, 2022), analyze the possibility of HEMPs (Denkenberger et al., 2017) and the reuse of industrial facilities for the production of sugars from plant biomass (Throup et al., 2022).

The feasibility and cost-effectiveness of these solutions are also analyzed (Denkenberger & M. Pearce, 2017), and the need to improve the methods and participation of the different actors in national risk assessments is raised primarily by decision-makers. (Boyd & Wilson, 2022b). In addition, the role of seaweeds as a possible resilient food source after an ASRS event is highlighted; however, it is highlighted that they would be an option not available for countries such as Argentina in severe cases more significant than 40 Tg (Jehn et al., 2023) and addresses the importance of understanding uncertainties and catastrophic and existential risks as a fundamental issue.

In general, these sources seek to propose strategies to guarantee food security in situations of ASRS (Wilson et al., 2022) and explore the feasibility of various technological and political solutions (ALLFED, 2022) to face this catastrophic scenario at the world level. Risk assessment and risk management plans are essential and practically nonexistent in most countries.

Risk management and policies in Argentina

These sources deal with resilience in the face of climatic adversities and disaster risk planning and management efforts in LAC, especially in Argentina (ANIMUS, 2017). The initiatives for the transfer of climate technology and the promotion of innovation to adapt to climate change and reduce the vulnerability of agri-food systems (ANIMUS, 2016) stand out; all these projects are still under development between the Ministry of Agriculture, Livestock and Fisheries in conjunction with cooperation institutions such as IICA, Fontagro, WFP, for which only their objectives are known. However, they have intermediate products that contain information on the country's production at present without adaptations (AGRO XXI, 2022).

National policies and programs are also mentioned, such as the National Plan for Disaster Risk Reduction in Argentina 2018-2023 (Borús & Caranta, 2018), which seeks to establish comprehensive risk management and civil protection in the country, framed in the SENDAI agreements of 2015, designating SINAGIR (National System for Disaster Risk Management) as the management body, which includes various national and local institutions outlined in Law 27.87 (Law, n.d.); Characterizes frequent risks in Argentina and assign some responsibilities.

As shown by the CELAC report and the reading of the PNRRD, Argentina presents a low development in the matter concerning the region in terms of risk management, with only about 3% of local plans (Bello et al., 2020) and without having fulfilled the dates established in the same plan for their elaboration, which demonstrates a low interest in the subject, possibly linked to the low occurrence of natural phenomena in the country; however, the country is currently facing one of the most significant droughts associated with accelerated climate change, which demonstrates the vulnerability of the agricultural system. The country must deepen the matter and adopt risk management policies for RCG due to its importance in the region in the area of food production.

In general, these sources advocate for the sustainable and inclusive development of the agri-food sector and the need for adequate planning and management to face climate challenges, there are no national sources focused on the management of an ASRS, but the sources worked are relevant due to which show, on the one hand, the actors involved in agri-food management, projects in development and, on the other hand, show a general plan of risk management in the country.

Solutions in Argentina

These sources address different aspects related to comprehensive risk management in the rural agro-industrial system in Argentina (project under development) (IICA, 2021), appropriate technology in the productive regions of the national territory (greenhouses adapted to each of the 5 bioclimatic regions) (Lenscak & Iglesias, 2019), and the promotion of resilient and sustainable agri-food systems for family farming *(PROSAF*, 2022). In addition, the potential of Argentine marine macroalgae and its use as a food option are discussed, and data on marine algae resources in Argentina are presented (Camurati et al., 2019).

The Comprehensive Risk Management Program in the Rural Agroindustrial System in Argentina, developed by IICA, seeks to improve response capacity in emergencies and strengthen comprehensive risk management in the agroindustrial sector. Likewise, reference is made to the Program for the Promotion of Resilient and Sustainable Agrifood Systems for Family Farming (PROSAF), which aims to promote the development of sustainable and resilient agrifood production systems in rural areas, not including ASRS, only focusing on the production of food throughout the territory taking into account climate change as a risk factor.

On the other hand, studies are presented on the potential of Argentine marine macroalgae as a food option due to its high nutritional value and fiber content. A report on seaweed resources in Argentina is also mentioned, focused on its production, bio-ecological research, and the challenges for its development, evidencing the current state of the almost disappeared national industry and highlighting the importance of its reactivation due to the high potential, especially in the Chubut region (Camurati et al., 2019), this resilient solution is supported by multiple laboratories and experts in the field at the national level.

Finally, the importance of appropriate technology in the productive regions of the Argentine national territory is discussed, particularly the use of greenhouses to improve agricultural production (Lenscak & Iglesias, 2019). These sources present a broad vision of different aspects related to risk management, and the promotion of resilient agri-food systems, in addition to the importance of appropriate technology in agricultural production, being evident in the role that INTA (National Institute of Agricultural Technologies) would have against an eventual ASRS.

Appendix 5a List of actors

Solutions	Government agency in charge	Other local entities	National Experts	External organizations	International Experts
Increase in agricultural production (Relocation of crops, extension of cultivation areas)	Ministerio de Agricultura, Ganadería y Pesca Instituto Nacional de tecnologias Agropecuarias (INTA), Oficina de riesgo agropecuario (ORA) - Sistema de Evaluación de Riesgo Agropecuario (SERA), Oficina de Monitoreo de Emergencias Agropecuarias (OMEGA)	Agencia de Planificación. Confederación Intercooperativa Agropecuaria (CONINAGRO) Confederación Rural Argentina (CRA) Federación Agraria Argentina (FAA) Instituto de Agrobiotecnología del Litoral (IAL) Instituto Geográfico Nacional. Secretaría de Cambio Climático, Desarrollo Sostenible e Innovación. Sociedad Rural Argentina (SRA) Instituto Tecnológico Chascomús (INTECH), Comité de emergencias Agropecuarias.	Mariana Antonietta (ALLFED) Fernando Scaramuzza (INTA) Diego Villarroel (INTA) Jamil Macedo (IICA) Elizabeth Kleiman (FAO)	ALLFED,FAO, IICA, FONTAGRO, FIDA, Jahn Research Group IIASA IFPRI	David Denkenberger (ALLFED) (IFPRI) Ross Tieman (ALLFED) Molly Jahn (Jahn Research Group) Michael Obersteiner (IIASA) Joseph Glauber

Solutions	Government agency in charge	Other local entities	National Experts	External organizations	International Experts
Greenhouse construction	Ministerio de Agricultura, Ganadería y Pesca Instituto Nacional de tecnologias Agropecuarias (INTA), Oficina de riesgo agropecuario (ORA) - Sistema de Evaluación de Riesgo Agropecuario (SERA)	Agencia de Planificación. Confederación Intercooperativa Agropecuaria (CONINAGRO) Confederación Rural Argentina (CRA) Federación Agraria Argentina (FAA) Sociedad Rural Argentina (SRA)	Mario Pedro Lenscak (INTA) Dra. Ing. Agr. Norma Iglesias. (INTA)	ALLFED, Penn state University, FAO, IICA, FONTAGRO, FIDA	Sizhuo Chen , Myungjin Lee (Penn State University)
Aquaculture Solutions (Seaweed)	Ministerio de Agricultura, Ganadería y Pesca, secretaria de agroindustria, Servicio Nacional de Sanidad y Calidad Agroalimentaria, Instituto Nacional de alimentos de Argentina (ANMAT)	Laboratorio Algas Marinas Betónicas, CESIMAR, Universidad Nacional de La Plata Universidad Nacional de San Martin	Fernando Dellatorre (CESIMAR) Paula Raffo Patricia Arenas (UNLP) Dra. Salomone Vanesa (UNSAM)	ALLFED, Penn state University, IICA	Florian Ulrich y Farrah Jasmine Dingal (ALLFED), Marjorie Jauregui Tirado (Penn State University)
Decentralized production of food from non-edible dairy vegetable fiber.	Ministerio de Agricultura, Ganadería y Pesca Instituto Nacional de tecnologías Agropecuarias (INTA), secretaria de agroindustria, Oficina de riesgo agropecuario (ORA) - Sistema de Evaluación de Riesgo Agropecuario (SERA)	Agencia de Planificación. Confederación Intercooperativa Agropecuaria (CONINAGRO) Confederación Rural Argentina (CRA)	Dra. Silvana Cabrini (INTA) María Cecilia Paolilli (INTA) Ing. Agr. Gerardo Gagliostro (INTA) Ing. Agr. Francisco Antonio Fillat (INTA)	FAO, IICA FONTAGRO	Dr. Frank Mitloehner (UCDavis) Dr Mitch Kanter (Global Dairy Platform)

Solutions	Government agency in charge	Other local entities	National Experts	External organizations	International Experts
High technology solutions for food production.	Ministerio de desarrollo productivo, Instituto Nacional de Tecnología Industrial (INTI), Ministerio de Agricultura, Ganadería y Pesca Instituto Nacional de tecnologías Agropecuarias (INTA), secretaría de agroindustria, Servicio Nacional de Sanidad y Calidad Agroalimentaria	Oficina de riesgo agropecuario (ORA) - Sistema de Evaluación de Riesgo Agropecuario (SERA), Universidad nacional de San marcos, Tomorrow foods, AGBM, Bio4, CADER, MAIZAR	Maria Laura Aparicio (UNSAM) Pablo Saleme (INTA) Mario Bragachini (INTA) Ricardo Rosenberg (BID) Guillermo Lentini Agustin Belloso Jose Antonio Porta Guillermo Lentini (Tomorrowfoods)	FAO, IICA FONTAGRO, Penn State University, BID	Juan García Martínez (ALLFED), Charles T. Anderson (Penn State University)
Supply and communication	Instituto Nacional del Agua, Secretaría de agricultura ganadería y pesca,Ministerio de Desarrollo Social de la Nación, secretaría de comercio, Ministerios de comunicaciones y de seguridad	Fuerzas armadas, Secretaría de Protección Civil y Abordaje Integral de Emergencias y Catástrofes ENACOM (Ente Nacional de Comunicaciones) Centro Nacional de Organizaciones de la Comunidad	Claudio Schbib (DNPRRD), Silvia La Ruffa (SINAGIR) y Carlos Ospital (Secretaría de Coordinación Militar en Emergencias)	CEPAL ALLFED FAO WFP BID	Matt Boyd (Adapt research Ltd.), Morgan Rievers (ALLFED)

Appendix 5b Responsible in case of ASRS

Preparation	Answer	Relevance
INTA	Ministerio de Seguridad	High
Ministerio de economía	Fuerzas Armadas y de Seguridad	
Secretaria de agricultura, ganadería y pesca	Secretaría de Protección Civil y Abordaje Integral de Emergencias y Catástrofes	
Oficina de riesgo agropecuario (ORA) Sistema de Evaluación de Riesgo Agropecuario (SERA)	Dirección Nacional de Operaciones de Protección Civil	
MINISTERIO DE CIENCIA, TECNOLOGÍA E INNOVACIÓN PRODUCTIVA DE LA NACIÓN	Subsecretaría de Gestión del Riesgo y Protección Civil	
Secretaría de Articulación Científico Tecnológica	Secretaría de Coordinación Militar en Emergencias.	
INTI	Ministerio de Desarrollo Social	
Ministerio de seguridad	Oficina de Monitoreo de Emergencias Agropecuarias (OMEGA)	
Ministerio de Desarrollo Social	Ministerio del Interior, Obras Públicas y Vivienda	Medium
MINISTERIO DE AMBIENTE Y DESARROLLO SUSTENTABLE DE LA NACIÓN	Ministerio de defensa	
MINISTERIO DE HACIENDA Y FINANZAS PÚBLICAS DE LA NACIÓN	MINISTERIO DE TRANSPORTE DE LA NACIÓN	
Secretaría de Política Económica y Planificación del Desarrollo	MINISTERIO DE COMUNICACIONES DE LA NACIÓN	
Gabinete Científico Tecnológico	Secretaría de Obras Públicas	
Secretaría de Gestión y Articulación Institucional	Comisión de cascos blancos	

Preparation	Answer	Relevance
Secretaría de Coordinación y Desarrollo Territorial	MINISTERIO DE HACIENDA Y FINANZAS PÚBLICAS DE LA NACIÓN	
Dirección Nacional de Prevención y Reducción del Riesgo de Desastres	Secretaría de Política Económica y Planificación del Desarrollo	
Subsecretaría de Gestión del Riesgo y Protección Civil	MINISTERIO DE ENERGÍA Y MINERÍA DE LA NACIÓN	
Red Científico-Tecnológica para la Gestión Integral del Riesgo.	Dirección Nacional de Operaciones de Protección Civil	
Oficina nacional de presupuestos	Secretaría de Protección Civil y Abordaje Integral de Emergencias y Catástrofes	

Appendix 6 Model

Two main scenarios were used to facilitate the visualization of the effects of an ASRS on the percentage of people fed. The first scenario is based on caloric production in Argentina without a catastrophic event, and the second considers a large-magnitude event (150 Tg) and its corresponding variations. This was done to evaluate different solutions using the parameters of Figure 6. Scenarios 1a (Graph 1) and 1b (Graph 2) consider the same caloric output. However, the latter reflects gross caloric output by including the redirection of food used in the animal industry and biofuels for human consumption.

In scenario 2, four different conditions of a 150 Tg ASRS were assumed: i) scenario 2a (Graph 3) shows the situation after the event without making changes to the current production scheme; ii) scenario 2b (Graph 4) shows the impact of redirecting food used in animal production and biofuels to human consumption; iii) scenario 2c (Graph 5) shows the impact of adding solutions for food production, such as algae farming or the production of industrial sugars; and iv) scenario 2d (Graph 6) shows the impact of deploying intensive solutions, such as increasing greenhouse coverage and expanding cultivation areas up to 70 million hectares in the first three years after the catastrophic event.

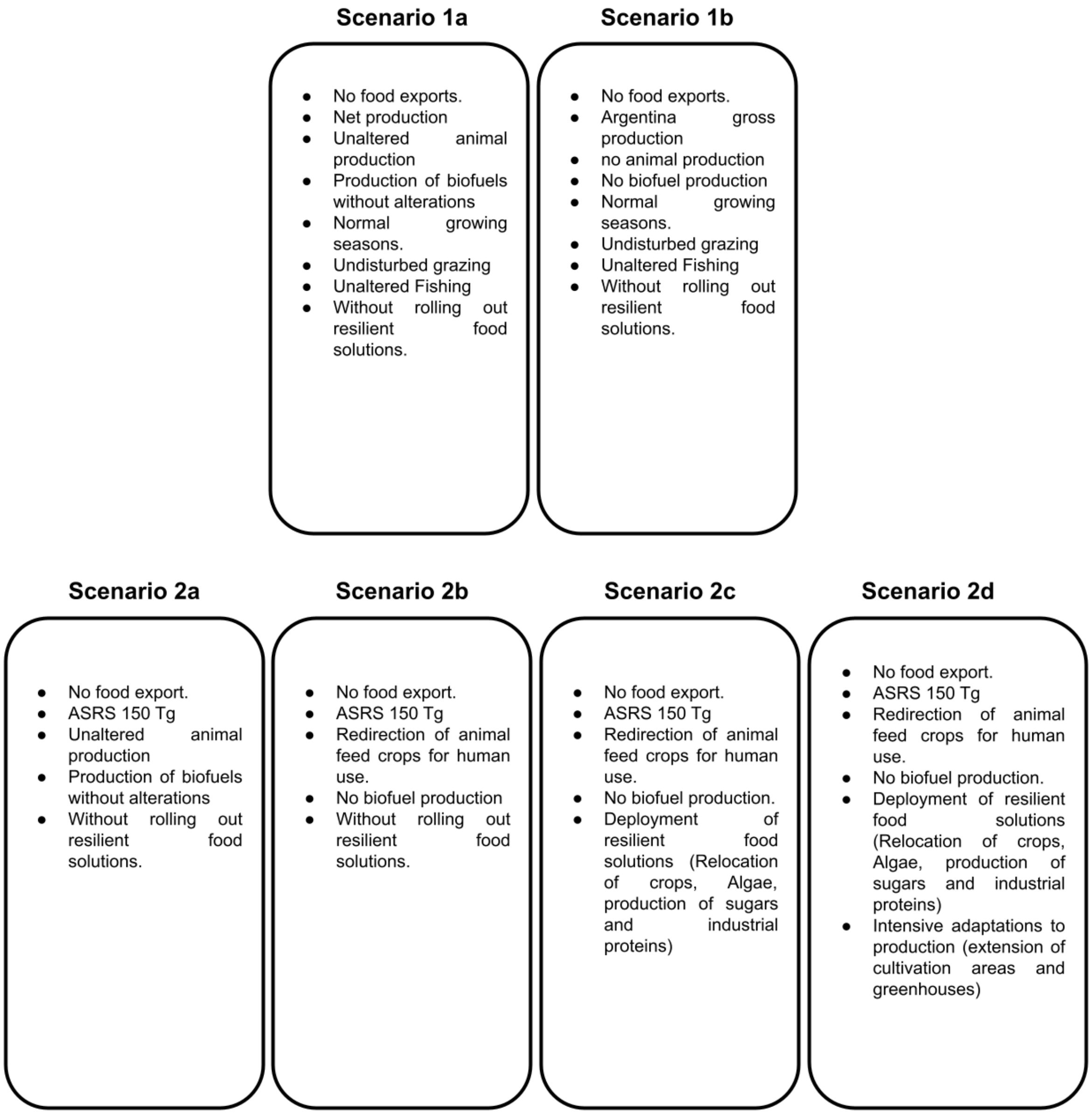

Image 6. Various scenarios contemplated for an ASRS in Argentina.

Considering the four scenarios, we can see in Graph 7 that, in the case of an ASRS of 150 Tg, there is a significant decrease of 238% in the number of people that can currently be fed, going from Scenario 1a to Scenario 2a. This indicates that if this catastrophe were to occur, the country would face food insecurity and would be at risk of coming dangerously close to the caloric requirement limits of its population. Therefore, various solutions will be needed to redirect food, prioritize humans and increase production. Consistent with this, in Scenarios 2b, 2c, and 2d, where food is redirected and low-tech and high-tech resilient feeding solutions are implemented, production in an ASRS can be increased by between 238% and 586% compared to scenario 2a, where no solution is applied. This would make it possible to supply internal caloric consumption and continue exporting food.

The difference between scenarios 2c and 2d is found in the intensity of the adaptations in production, being more significant in the latter. Scenario 2d proposes an expansion of cultivation areas up to 70 million hectares and a significant increase in greenhouse coverage. Both scenarios include the deployment of resilient foods, such as algae, and high-tech resilient foods, such as the production of sugar from lignocellulosic material (Throup et al., 2022) and single-cell protein from methane (JB García Martínez et al., 2022).

Appendix 7. Expansion model of arable areas

Contains a spreadsheet with production data in tons and cultivated areas during the last three years in Argentina to estimate the average yield of the main crops and later calculate caloric production, taking into account the loss in yields before ASRS of 0 to 150 Tg. Check in the repository https://doi.org/10.5281/zenodo.7863880

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