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Food Security in a time of Climate-Food-Water-Energy Convergence

Across the planet, human security is under increasing threat from climate change. Central to this are its direct and indirect impacts on food security.

Food-system risks are amplified by converging stresses including climate change, worsening water scarcity, biodiversity loss, lag in energy transition, and entrenched socioeconomic inequalities. These are now intensified by destabilised hydrologic and ocean systems which constitute a major threat to ecological, food, and human security.

We are forced to move from incremental to systemic adaptation where such cascading risks can be understand and managed. A systems-based nexus approach focussing on the entire agrifood system under climate change offers an important approach in the face of rising risk complexity.

Because climate and food systems are tightly coupled food production both suffers from climate impacts (on land and sea) and drives them (contributing an estimated 21-37% - roughly one third - of greenhouse gas emissions). Consequently it is necessary both to reshape practices to safeguard availability and cut greenhouse gas emissions.

Addressing the nexus of Food-Water-Energy, already an important component of the Sustainable Development Goals, requires measures to decrease inequality, address rising geopolitical trade risks, and overcome structural bottlenecks. Increasing climate volatility leads to food price volatility, imperilling those least able to pay. A just transition is needed that channels finance and practical support, including appropriate scale technical opportunities, to small producers and vulnerable communities, to secure equitable access to food.

Here are some of the steps we identify which are available and can play a crucial role in averting a food-security crisis developing in the face of climate change.

Recognise food security is already under stress

Although the agrifood system produces enough calories for every human on earth and the prevalence of undernourishment has reduced over the last decade, in a range of regions food insecurity remains widespread. Last year 295.3 million people faced high levels of acute food insecurity across 53 countries—the sixth straight annual rise with prevalence risen to 22.6% (from 21.5% in 2023.[1] Of these 95.8 million forcibly displaced people lived in food-crisis countries and 2.3 billion people were moderately or severely food insecure.

The increasing volatility of extreme climate events (such as heat, drought, fire, floods) destabilises supply. More generally climate change affects availability, access, stability, and the ways food supply can be used.

[1] UN, Global Report on Food Crises, 2025, www.fsinplatform.org/grfc2025

This year's UN HLPE Report[2] emphasises that under a high-emissions scenario, climate change is projected to render 10% of currently useable land unsuitable by 2050, rising to 34% by 2100 for major crops and livestock. And in Africa, agricultural productivity has already declined by 34% since 1961, largely due to climate change. Further warming will shorten growing seasons and increase water stress. Added to this, world population is expected to grow from 8.2 to 10.3 billion in the 1980s, increasing the number to be fed by 26%.[3]

Utilise the many ways forward offered by science

Food security requires full application of the available science including: soil-health and nature-based approaches, smarter land use, sustainable use and management of waste and nutrients, changes in food sources, diet and public-health shifts, circular waste and nutrient flows, monitoring and early warning of hunger hot spots, and clean energy compatible with agricultural productivity, augmented by precision agriculture (for example, sensors and drones) to raise yields while reducing inputs.

Food supply is stressed by changing life-styles and consumption patterns in economically advancing populations. There is also vast waste in the current food system (variously estimated at some 30%) providing a need to tackle growing insecurity by increasing efficiency. Cutting this waste by half has been demonstrated in some cities and constitutes a realistic and important economic goal.

In building resilience to increasing risk, vulnerability, and exposure, agriculture and food needs to be understood as a global and regional agrifood system. It includes all dimensions including for example, population growth, employment opportunities and poverty, supply stability, education and health infrastructure needs, and climate change. The MAST framing (mitigation, adaptation, societal transformation) developed in Africa to proactively build climate resilience is a useful exemplar.

Solution pathways to systems climate sustainability and resilience, should be science based, but also co-designed with all relevant stakeholders. We should engage in participatory co-design approaches that empower stakeholders to understand the science, the technological, financial and governance solution and become co-designers and shareholders of the solutions they will be called to adopt and use. Systems thinking is a powerful analytical framework for such co-design.

Some stand-out approaches using best current science include:

- Develop and utilise tools such as the FABLE calculator/simulator to map scenario pathways across water–food–soil–energy, with geo-resolution to regions/countries out to 2050 and multi-stakeholders (eg from business, government, farmers, and NGOs) for national solution design.
- Develop and utilise low energy zero carbon sources and systems which can detect deterioration in the environment, notably in water and the oceans.
- Re-shape cities via green buildings and smart Internet of Things based systems to cut energy use, waste (notably food), and emissions while creating more efficient and liveable urban environments, and improving services and quality of life.

[2] UN FAO, HELPE 20, 2025, Building Resilient Food Systems, https://sfcs.fao.org/media-cnt/docs/devhlpelibraries/report-20/hlpe20_executive-summary_en_web.pdf
[3] UN, World Population Prospects 2024, https://population.un.org/wpp/

- Develop and utilize AI and digital twins to identify emerging risks on land and in the oceans and model options for constructive paths forward.
- Support use of tools becoming available for smart agriculture based on new agricultural digital tools integrated with systemic sensor and data sources and optimisation algorithms.

Frame policy that recognises that the impact of changes in the oceans is understudied but profound

Oceans feed billions and seafood security is critical. Climate change warming is already shifting stocks toward cooler waters, disrupting both artisanal and commercial fisheries. Other climate impacts—acidification, pollution (including microplastics), marine heatwaves, habitat loss, sea-level rise—are eroding productivity and contributing to mass fish kills and aquaculture losses. Overfishing, heavily subsidised globally at an estimated $50 billion, greatly exacerbates these trends.

To understand, predict and protect against climate change risks, knowledge of key ocean-climate interactions (including the El-Nino Southern Oscillation and Indian Ocean Dipole) needs to be increased and utilized. Basin wide interactions on scales of decades also affect keystone species such as small, climate-sensitive pelagic fish.

Those most immediately facing challenges from transforming oceans, for example those in small island states and the Arctic, need to be internationally supported. The potential for immediate effective action is illustrated by current Asia Development Bank investments in coastal fishery regeneration in Cambodia, climate-smart sea farming in Indonesia, and blue-economy policy reforms in the Philippines.

Recognise risks to food security and human health are strongly linked

Climate hazards such as heatwaves and extreme precipitation concurrently damage health, livelihoods, and food production. Food security and human health varies with many factors from vulnerability to extreme events, to economic strength, to increasing levels of armed conflict (potentially in the face of increasingly scarce basic resources), migration pressures, nutrition related diseases, and changing age profiles. Consequently it is important to study these sorts of interlinks and build climate-resilient, low-carbon health systems.

Transform agrifood to a mitigator of climate change

The potential exists to transition agrifood from net emitter to mitigator of greenhouse gas emissions through proven technical and nature-based options—curbing methane (e.g., in cattle), halting deforestation, and scaling on-farm carbon sequestration and efficiency.

Such innovations are particularly relevant to global drylands. These currently cover some 40% of the Earth's land and are the largest biome, supporting more than 3 billion people. They are expected to cover 51% by 2100. Here soil inorganic carbon (which exceeds the stock of soil organic carbon) may be sequestered using a range of chemical and biological processes with a technical potential of some 1 Pg C per year).

Potential cutting-edge innovations include genetic modification to enhance carbon sequestration in soils and crops, and engineering plants for climate resilience. The deployment of such modified organisms remains controversial. But if significant objections

can be satisfied it could prove vitally important both for food security and carbon sequestration. Recent prize-winning work on suberin-rich row crops to enhance root mass could boost sequestration. Transferring nitrogen-fixing capacity from legumes to cereals would also materially support food security.

Overall, a transition is required to regenerative agriculture where, inspired by eco-innovation, powered by non-carbon energy, driven by a circular economy and green infrastructure, and supported by the re-carbonization of the terrestrial biosphere these reformed practices become the bedrock of sustainable development.

Address food and water security together

Because water mediates most climate impacts and underpins adaptation, it is integral to agrifood systems. A key task is to strengthen water management, restore water cycles, strengthen early warning and anticipatory action, and plan and invest on a risk basis across rainfed, irrigated, and groundwater systems.

There are widely held misunderstandings on how water and the food system interacts and hence some critical gaps. The climate changes in response to changes in energy and water, and thus climate change is also water change by virtue of this profound physical interdependency. The challenge is to incorporate into analysis and policy the fact that water risks are systemic and converging - ranging across the health, ecologic, economic, social and all aspects of food systems. They are cascading, and inadequately understood.

The 2023-4 El Nino provided an illustration of consequent vulnerabilities. It exacerbated the stresses of climate change in many parts of the world with drought striking hardest in climate hotspots - already under pressures from rising heat, growing populations and weak infrastructure.

With every increment of warming, escalating hydrologic risks (droughts, floods, shifting monsoons and seasonality, altered river flows and sea-level rise) create systemic threats to food security. As one in ten year risks become one in 5 year risks the challenges to maintain safety intensify. This necessitates changes in water and land-use practices together with support for stronger disaster and heat resilience—especially for poorer communities and smallholders in the global south.

Climate change compounds other water-cycle drivers, including land conversion and ecosystem change. Thus agriculture is both a major disruptor and a major victim.

Water purification and energy-efficient desalination, water recycling, and advanced filtration can secure safe drinking water in water-scarce regions.

In drylands, water-smart agronomy (conservation cover crops, water–fertility management, supplemental irrigation, hydrogels) can be coupled with carbon-farming incentives and eco-intensification to lift food security and realise large soil-carbon potential while avoiding salinisation.

Link forest sustainability to food security

Forests play a vital but often unrecognised role in shaping rainfall patterns, storing and regulating soil moisture, and buffering droughts, with materially significant impacts on GDP growth and agricultural resilience.

Loss of natural forests dries soils, reduces yields, and globally imposes some US$379 billion in annual costs (representing some 8% of global agricultural GDP).

During droughts, natural forests cut yield losses by more than half—a protective effect not replicated by plantations or monocultures.

Reverse the growth of salinisation

According to the FAO, over 1.38 billion hectares of land worldwide, or about 10.7% of the global land area; salinisation causes an estimated €1.5 to €2 billion in annual economic losses.

Salinisation, remains under-researched despite major food-security impacts. It must be prioritised for study and active management, including socio-economic assessment leading to policy and governance initiatives.

Projects from the Institute for Environmental Studies - from Mazambique to Argentina - demonstrate that real progress on reducing salinisation can be made by working with those open to change relevant practices in the regions where the actions must be taken.

Emphasise the links between food security and economic prosperity

A transformation towards sustainable consumption is required to cut waste, improve distribution, raise nutritional quality, and develop and deploy substitutes to crops in decline, while shifting toward more localised production–consumption models that strengthen sustainability and economic resilience.

New findings from the World Bank's recent flagship report[4] demonstrate how land, air, and water, all foundational natural endowments, underpin economic prosperity.

Overall a comprehensive large scale investment strategy is required involving private and public finance for action to increase food security, especially for the most vulnerable, and taking full account of climate and other stressors.

Confront political and economic challenges

Many of the food security issues involve transboundary issues whether from water, or crop movements, or multiple system impacts, and their resolution requires governance beyond the jurisdiction of any single nation.

For example, as climate risks increase and are distributed unequally across the planet there is need for greater trade in agricultural goods. Thus, with increased volatility, the world economic system needs to be redirected to increase free-flowing access to trade.

Recent world trends undermine building the international collaboration required. Notably the dismantling of climate and science-supportive institutions (NOAA, USAID, NSF), and the denial of climate change itself, also drives declining international support and investment in humanitarian aid, science, and sustainability, posing a serious blockage to what is needed. The potential for new constructive collaborations and alliances (for example across Asia), need to be explored and realised.

[4] World Bank, *Reboot Development: The Economics of a Liveable Planet, 2025,* https://www.worldbank.org/en/publication/the-economics-of-a-livable-planet

Act to show significant transformation is both necessary and possible. In particular:

Put food security at the centre of climate discourse. Back it with personal and digital communication and outreach that translates the science into readily understandable form tailored and powerfully presented for diverse audiences. Use it to mobilise science, finance, communities, and policy into coordinated action.

Assert the capacity of global agriculture to move from a major part of the problem, creating about 30 per cent of the costs of climate change, to a net contributor to the solution by utilising proven approaches to mitigating emissions.

Pair global tracking and analysis of national food self-sufficiency and supply-chain bottlenecks with innovation in governance—from local to global, especially at the climate–biodiversity interface—and resource the monitoring and diffusion of what works.

Build collaborative action with investment in systems that respond to both scientific evidence and lived experience in communities and regions. In particular ensure that solutions can and are supported to be implemented in the regions where the actions must take place.

Build on a systems nexus policy framework. Expand the four pillars of food security (availability, access, utilisation, stability) to include sustainability and agency. Adopt an agrifood-systems perspective. Apply MAST (mitigation, adaptation, societal transformation) and mainstream science-based innovations across agriculture and actions in water, forests, and oceans.

Build on the goodwill which can be widely seen at local, state and regional level, even when national resistance is encountered, to bring the best scientific assistance, engagement and collaboration to reinforce climate resilience and food security.

Enhance the human ability to shape our collective future by exploring and developing new governance frameworks from local to global, in particular at the intersection of the governance of climate change and biodiversity. Develop, monitor and disseminate success in effective governance, governance innovation, and leadership regionally and globally.

Bring food security to the centre of climate change policy and analysis and proceed on the basis that the transformation of the agrifood system is a major requirement in addressing both mitigation of emissions, and poverty and hunger. Recognise that at the global, regional and local levels, appropriate actions taken now can greatly enhance the capacity of food systems to adapt to climate change.

We have enough data and knowledge to mitigate risks and maintain food security across the planet if there is the will to do so. Climate change is undermining the resilience of food systems, but by linking finance, capacity building, policy, community collaboration, accountability and politics at all scales, there is opportunity to enhance resilience. Matching, equipping, enabling, and empowering communities with suitable existing science-based techniques, options and solutions are the remaining crucial ingredients for alleviating the critical threats emerging around the future of food security.

Authorised by Professor Jim Falk (Chair) on behalf of the RACC International Advisory Committee (https://www.stsforum.org/racc2024/iac/), STS Forum, Kyoto, 6 October 2025.

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