



# Future-Proofing Food for a Rapidly Warming Planet

Financing Food for the Future

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December 2024




# About NATURE FINANCE

NatureFinance is an international not-for-profit organization dedicated to aligning global finance with equitable, nature positive outcomes. In realizing this goal, NatureFinance is active in advancing the use of appropriate biodiversity data in disclosing and managing nature related risks, developing purposeful nature markets, advancing financial innovations including in sovereign debt and nature credit markets, strengthening nature related liabilities - especially in addressing nature crimes - and promoting digital approaches to advancing citizen action on nature.


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**Nature Markets:** shaping principles-based nature markets by increasing awareness, innovations and better governance of nature-linked markets including nature credits and soft commodity markets.




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**Nature Data & Disclosure:** Increasing the quality and quantity of nature data, risk assessment and transparency across financial markets to enable integrated assessments of nature-climate risks and impacts.



**Sovereign Debt:** Engaging market actors, and governing institutions in efforts to place nature in the world's sovereign debt markets, including scaling the issuance of sustainability performance-linked sovereign bonds.



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Our use of Fibonacci sequence imagery is inspired by the association of this unique ratio with the maintenance of balance, and its appearance everywhere in nature- from the arrangement of leaves on a stem to atoms, uncurling ferns, hurricanes and celestial bodies.

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## Glossary

<b>AATIF</b>	Africa Agriculture and Trade Investment Fund
<b>AfDB</b>	African Development Bank
<b>BEVs</b>	Battery electric vehicles
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>COP</b>	Conference of the Parties - often refers to the United Nations Framework Convention on Climate Change
<b>CAPEX</b>	Capital expenditures
<b>EEA</b>	European Environment Agency
<b>EU</b>	European Union
<b>EVs</b>	Electric vehicles
<b>FiT</b>	Feed-in tariff
<b>GDP</b>	Gross Domestic Product
<b>IMF</b>	International Monetary Fund
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IoT</b>	Internet of Things
<b>IP</b>	Intellectual property
<b>KPI</b>	Key Performance Indicator
<b>NGOs</b>	Non-governmental organizations
<b>NRF</b>	National Research Foundation
<b>NUE</b>	Nutrient use efficiency
<b>OPEX</b>	Operating expenses
<b>PV</b>	Photovoltaic
<b>RAFT</b>	Resilient and adaptive techniques- term created for the purpose of this report
<b>REDD</b>	Reducing emissions from deforestation and forest degradation in developing countries
<b>R&amp;D</b>	Research and development
<b>SBCE</b>	Brazilian Greenhouse Gas Emissions Trading System
<b>SFA</b>	Singapore Food Agency
<b>UNEP</b>	UN Environment Programme
<b>USAID</b>	United States Agency for International Development
<b>VF</b>	Vertical Farming
<b>WFP</b>	World Food Programme

# Foreword

## Harnessing the Crisis

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In October 2023, in the run up to COP28 in Dubai, NatureFinance published “**Time to Plan for a World Beyond 1.5C**”.<sup>1</sup> The insights piece reinforced the call made by many others to consider more ambitious action to slow down and reverse climate change and nature loss in order to establish viable plans to live in and adapt to a severely climate disrupted world. Crucially, we suggested that the growing realisation that we are failing to remain below safe limits of climate change must catalyse greater will to advance unconventional actions that had to date been considered beyond what is feasible or necessary.

We pointed to examples of such unconventional action in the face of certain types of crises, often in times of war and other disasters, including most recently responses to the 2008 Financial Crisis and the COVID pandemic.

Responses to our provocation were, unsurprisingly, mixed. At one end of the spectrum were those who condemned us for being unhelpfully pessimistic, disloyal to the cause of ambitious action on climate and nature, or worse. At the other end of the spectrum were those who applauded our courage in calling time on the lack of realism about where we are almost a decade on from the auspicious Paris Agreement on climate, and appreciation of linking this recognition with the potential for more radical action on adaptation and resilience.

Common across the entire spectrum was a deep concern that being so far from where we needed to be on climate or nature was already triggering perverse responses, fomenting fear, despair and cynicism, diminishing policy ambition, and empowering those whose interests were not aligned with ambitious action on the climate-nature nexus or solidarity with those most impacted.

Moreover, there was an absolute consensus that such dynamics needed to be resisted at all costs, requiring effective communication about *believable pathways for action in a world warming beyond 1.5°C* rather than just continued statements of hope for what people should do.

## Focus on Food

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Building on this initial thinking, NatureFinance started to apply a 'beyond 1.5° C' lens to its own work. We chose not to focus on solutions that needed grand political compacts or ambitious international arrangements. Instead, we chose to focus on the potential for unilateral or perhaps plurilateral blends of policy, market, and civil actions borne out of any combination of nature and climate ambition, fear, solidarity, and self-interest.

Food is an obvious candidate to focus on through a 'beyond 1.5° C' lens. Accessible, affordable, nutritious food is a pre-requisite for any just transition. A severely climate disrupted world places food supplies at increasing risk. Most obvious are the physical impacts of climate change on food security. Beyond that are major transition risks, such as policy changes, technology shifts and changing consumer preferences, often with a long tail that brings forward and amplifies future physical impacts into the present.

Fears in food exporting countries of domestic food security problems are already resulting in export restrictions that has snowball effects on the availability and cost of staples in international markets. Such long tail dynamics has a particularly negative impact on low and middle income, food importing countries that cannot afford to buy food at inflated prices on international markets.

The question is 'what is to be done' to ensure food security in a worsening climate scenario, or when markets and policy makers build in expectations of such a scenario into their decision making. Short term measures must include humanitarian food assistance, but the scope and scale of the need is already far outpacing the international community's ability to respond. Today, already more than 350 million people are dependent on food aid. The number in need can only be expected to increase dramatically without radical changes to the global production and management of food.

The trillion-dollar question is what longer term measures could be *initiated now* that might meet the challenges of food security in an increasingly climate disrupted world, and how can we sufficiently scale such measures in advance of a foreseeable crisis? Of course, there is no one silver bullet solution. Many actors are engaged in trying to figure out and implement local, national and international approaches, embracing the complex blend of approaches needed, which range from production, technological, market, policy, and consumption aspects to solutions explicitly focused on equity and solidarity.

This paper seeks to contribute to addressing the existential challenge of advancing food security for all in a severely climate disrupted world. It explores the financial innovations needed to rapidly ramp up capital intensive, climate resilient food systems now in order to deliver affordable nutrition to low and middle-income countries in the years to come. Given the early-stage, speculative nature of the work presented here, we look forward to using it as a basis for continued engagement, debate and experimentation.

# Executive Summary

Securing adequate access to affordable, nutritious and sustainable food in a rapidly warming world is one of the most important needs for a just transition.

Scientific consensus is increasingly aligned around the near certainty that the world will overshoot its 1.5°C warming target, with 80% of IPCC scientists putting the number at between 2.5 - 3°C of warming by the end of the century. Extreme drought, heat and heavy rain have dramatically affected the production of crops like soybeans, olive oil, rice, potatoes, and cocoa in regions from the Mediterranean and Eastern Europe to Southern Africa and Latin America.

Across the world, the long-tail effects of severe weather events, shifting growing seasons, trends towards food nationalism, and ongoing geopolitical conflicts are compounding food security challenges. Today's disruptions however are only the beginning. As global warming intensifies, increasing land degradation and water scarcity will continue to accelerate a breakdown in globalised food supply arrangements and diminish local-for-local food production in many parts of the world.

Low and middle-income nations, which are often critical food producers are especially vulnerable to the compounded effects of climate change and nature loss. As their ability to produce food declines, economic fragility deepens, leaving them less equipped to adapt. *Creeping desertification, particularly in vulnerable regions, is already fuelling conflict, creating agricultural pressures, and exacerbating food insecurity as migration and displacement increase.* Globally, extreme weather now accounts for one-third of acute food insecurity shocks, affecting over seventy million people, a number that has more than doubled in five years. These nations are caught in a cycle of vulnerability, at risk of being left behind as food insecurity escalates. In addition, traditional food exporters tend to secure their national security needs first, causing trade disruptions due to pricing hikes and lack of availability.

As the planet edges toward these extraordinary temperature thresholds, the global food system faces mounting challenges from climate change, nature degradation, and geopolitical instability. Addressing these issues requires a dual strategy: scaling innovative food technologies while embracing regenerative farming practices.

## **Regenerative agriculture is an essential part of the solution, but not sufficient.**

Regenerative agricultural practices play a pivotal role in restoring, sustaining and extending the life of food systems by restoring soil health, enhancing biodiversity, improving water retention, and promoting ecosystem resilience. Regenerative agriculture also contributes enormously to climate mitigation efforts by transforming croplands from significant sources of carbon emissions into net carbon sinks. As temperatures begin to increase beyond 1.5°C, regenerative agriculture and related technologies must continue to play a central role in everything from food security and livelihood strategies to climate mitigation, adaptation and resilience efforts.

That being the case, as extreme weather patterns intensify and warming accelerates, the viability of soil-based agriculture will decline in certain parts of the world where reliable access to arable land and water is severely diminished. This is particularly true for the tropical belt countries from the Americas, passing through Africa to Asia. For these parts of the world, regenerative agriculture can be part of a bridge solution, but from a food security and adaptation perspective, these countries will need additional food sources supplied from controlled environment food production systems to meet their basic needs.

## **Technological innovation on 'soil-less' food production will become central to ensuring food security in a warming world.**

Resilient and adaptive food production will need to move beyond soil-based regenerative farming to increasingly rely on enclosed and "controlled environment" food production systems such as vertical farming, edible insect farms, and cultivated meat. Such solutions offer the promise of year-round 'climate independent' production, stable costs, as well as localised production that improves security of supply and reduces waste and other supply chain costs.

## **Deploying these technologies is fraught with challenges.**

These systems are extremely capital intensive and technologically complex, presenting significant challenges for many low and middle-income countries that are most vulnerable to permanent soil-based agricultural disruption in a world warmed beyond 1.5°C. Such solutions remain technologically immature and expensive and are likely to remain so for some time, resulting in high costs of production, with considerable investor caution given technology transfer or development and other associated risks.



Adopting such solutions is particularly challenging for low and middle-income countries. Citizens' relatively lower purchasing power is a core reason, but this problem is exacerbated by higher costs of capital and under-developed enabling policy, competencies, and hard infrastructure. Moreover, the lack of adequate technology transfer heightens the risk of dependence on high or middle-income countries, raising concerns about technological neo-colonialism. This could lead to situations where low-income nations are compelled to offer access to critical resources in exchange for technology, limiting their sovereignty and making them reliant on external providers. In addition, alongside the specifics of adoption are the broader challenges of transitioning the often large numbers of small farmers and dependent communities away from their current livelihoods. This is especially a concern given that many forms of controlled environment food production are far less labour intensive than traditional soil-based agriculture, and in some instances require a much higher level of technical training. The fragile supply chain infrastructure is another barrier.

Given these challenges, it is likely that controlled environment food production will have the greatest chance of being scaled up in the near term in middle income, climate and nature vulnerable countries such as Brazil, India and South Africa. These countries have enough of the early building blocks to begin pivoting away from reliance on conventional agriculture alone as well as the capacity to serve as regional suppliers for less well-positioned neighbours.

## **It is essential to quickly bring down the cost of nutrition delivered by capital intensive, climate resilient food systems.**

The evolving cluster of soil free, controlled environment food production systems require extensive R&D to drive down costs, alongside the productivity and cost gains from operational learning and economies of scale. NatureFinance has estimated the total R&D investment needed to drive down costs to parity with food costs in higher income countries for a selected set of food technologies to be in the order of US\$30-65 billion over the next 10-15 years (see Table 1). This is a modest sum compared to the over US\$7 billion in public subsidies that support conventional agriculture each year, or the US\$1.3 trillion in explicit fossil fuel subsidies, as reported by the IMF. Notably, when including implicit subsidies—such as unpriced environmental and health costs—the total for fossil fuel subsidies rises to a staggering US\$7 trillion annually. Economies of scale might reduce the financing gap needed to drive down costs, especially if middle income countries can become reliable producers not only for domestic but also for regional food production needs. Regulatory frameworks, public policies and trade rules will need to be aligned to incentivise these practices alongside cultivation of transnational solidarity.

## **Financial innovation will be key to scaling these solutions globally.**

Financial innovation will be critical to enable investments to advance at the scale required even during this early period of uncertainty. A comparable example is Germany's use of the feed-in tariff, introduced with considerable controversy, to finance the scaling of renewable energy early in the innovation curve. This instrument lowered the purchase price of green energy by spreading the costs and de-risking investments when they were still high-cost options with considerable associated technology and policy risks.

There is no one-size-fits-all equivalent for scaling capital intensive, controlled environment food production. However, we have identified a cluster of financial instruments, such as nature and carbon credits, performance-linked financing and tax credits, that can be bundled and stacked into standardised financing packages according to specific technologies and contexts. Using such approaches, it would be possible to simultaneously attract scaled private investment, make efficient use of public funds, and lower the cost of delivered nutrition in the context of building out controlled environment food production systems.

## **Deploying capital intensive, food innovations will require a combination of national strategies and international cooperation.**

Financial innovation is needed, but as the case of renewables demonstrates, it is not sufficient on its own. Consequently, there is a critical role for middle and upper-income countries to drive down the costs of these solutions as part of their food security and competitiveness strategies, as well as international cooperation to enable low and other middle-income countries to harness these developments at an affordable cost.

Several technologically developed countries, notably China, but also smaller countries such as Singapore, are already investing heavily in resilient and adaptive food production techniques. Most directly, this is to support their food security goals in the face of growing climate, nature and geopolitical insecurities in global food chains. For China, however, as well as potentially other technically minded countries, these investments and scaled deployment are part of a broader industrial strategy to secure competitive opportunities in future exports of technologies and, more broadly, in climate resilient food production. This opportunity also exists for major food exporters such as Brazil, Europe and the United States. However, these regions face the added challenges of pivoting their massive agribusiness sectors; akin to Germany's challenge of transitioning its automotive industry in the face of policy driven global shifts in mobility technologies.

For climate vulnerable low and middle-income countries, there are significant potential benefits from the national strategies of other countries that drive down the cost and maturity of capital-intensive solutions. International cooperation will, however, remain an essential pillar for such solutions to become a material part of effective food security strategies for low and middle-income countries. Given the accelerating pace of climate change impacts and ecosystem degradation, deployment of these solutions must front-run a decline in the cost curve. Without international co-operation, it will be nearly impossible to secure the affordable transfers of technology, the localisation of technology production, as well as the enabling policy and broader capabilities required to transition farming communities vulnerable to climate-impacted food systems and environmental decline.

Low-income countries will suffer the most from climate-elicited food insecurity, having played no role in creating the crisis, and they are least well positioned to respond to it with high-tech, capital-intensive solutions. Prioritising solidarity in the financing of these technologies is of key importance. Financing and technology transfer will, therefore, need to become embedded in the work of multilateral development banks, bilateral and multilateral aid agencies, and potentially new mechanisms like the “global solidarity levies” currently being explored for COP30.

## **Embracing the implications of beyond 1.5°C warming for food security now is crucial.**

A fundamental shift in mindsets is now needed that embraces the lived experience of many countries and communities which acknowledges the scientific consensus that the planet will likely warm well beyond 1.5°C. While the world works towards a best-case warming scenario through mitigation efforts, we must devote equal attention to investments in adaptation and resilience for existentially critical areas like food security.

Beyond the indispensable push on regenerative agriculture, which has value both for mitigation as well as adaptation/resilience, many parts of the world will need more dramatic, non-soil based alternative sources of food to sustain human life in the coming decades. Unlike the energy transition pathway, which will be challenging but is well understood, the food security transition pathway remains dangerously unclear and slow moving. New innovative thinking is needed as the basis for overcoming the current path dependent inertia.

## **Embracing an Integrated Approach to Financing a Resilient, Adaptive Food Future.**

In certain regions, the traditional agrarian model that has sustained human civilisation for millennia may indeed no longer be viable in its traditional form. As extreme weather patterns intensify and resources like arable land and water become increasingly scarce, communities will face significant disruption. While drought-resistant crops and longer growing seasons may offer temporary relief, the shift to controlled environment agriculture will need to be an important part of the toolkit to sustainably address food security globally. This development must be inclusive and adaptable, accounting for the diverse realities and limitations faced by different regions.

This paper seeks to illuminate the pressing need for bold, out-of-the-box thinking to address the unprecedented challenges of food security in a world increasingly disrupted by climate change and nature degradation. While regenerative agriculture has been widely studied and documented, comparatively little work has been done to explore the financial scaling of controlled environment solutions for middle and low-income countries. This stands in contrast to the progress made in advancing regenerative agriculture in these areas. As such, this piece has been created to contribute to this critical discussion that must be brought to the forefront, particularly as we face ongoing climate realities and ecosystem degradation.

The urgent task ahead is to scale up both regenerative agricultural practices, where they remain feasible, and also controlled environment food production systems in regions where soil-based agriculture is no longer reliable. These two approaches are not mutually exclusive; rather, they are **and must remain** complementary, forming the backbone of a resilient global food system. Regenerative practices help restore ecosystems and build climate resilience, while controlled environment systems ensure stable food production in more extreme environments. Together, they represent a multifaceted strategy that responds to the varying impacts of climate change across regions. Achieving this transformation would require coordinated efforts across governments, the private sector, multilateral organizations, and civil society to mobilize resources, drive innovation, and ensure equitable access to solutions.

The worst-case scenario would be for finance to suddenly fetishise the potential of controlled environment agriculture and neglect an equally ambitious and desperately needed drive to scale up regenerative agriculture and related extension services. Both need to happen together, and shifting resources away from regenerative agriculture to controlled environment agriculture would be disastrous for people, climate, and nature.

The future of food security lies in embracing an integrated approach to sustainable, affordable and accessible nutrition—one that balances nature-based solutions with technological innovation, ensuring both environmental sustainability and the capacity to feed growing populations. Today's major food producers—such as Brazil, India, China and the United States—stand to become the main beneficiaries of proactively addressing these transition challenges. Firstly, this is because they have greater access to the substantial capital required to lead a transition of this scale. Secondly, because they have a strong understanding of the related risks and opportunities that will accompany it, and the capacity to deploy meaningful policy and regulatory incentives to address them. Thirdly and finally, they shape the market and play an important orchestration role in the broader global community. Political leadership and international cooperation in the exploration of scalable financial innovations will be crucial. Only through a concerted global effort can we create a resilient, adaptive, and just food system capable of withstanding the mounting challenges of a warming world.