Food System Rethinking: Can Food Fermentation Drive Vulnerable Traditions towards Resilient Innovations?

SAPIENZA
UNIVERSITÀ DI ROMA

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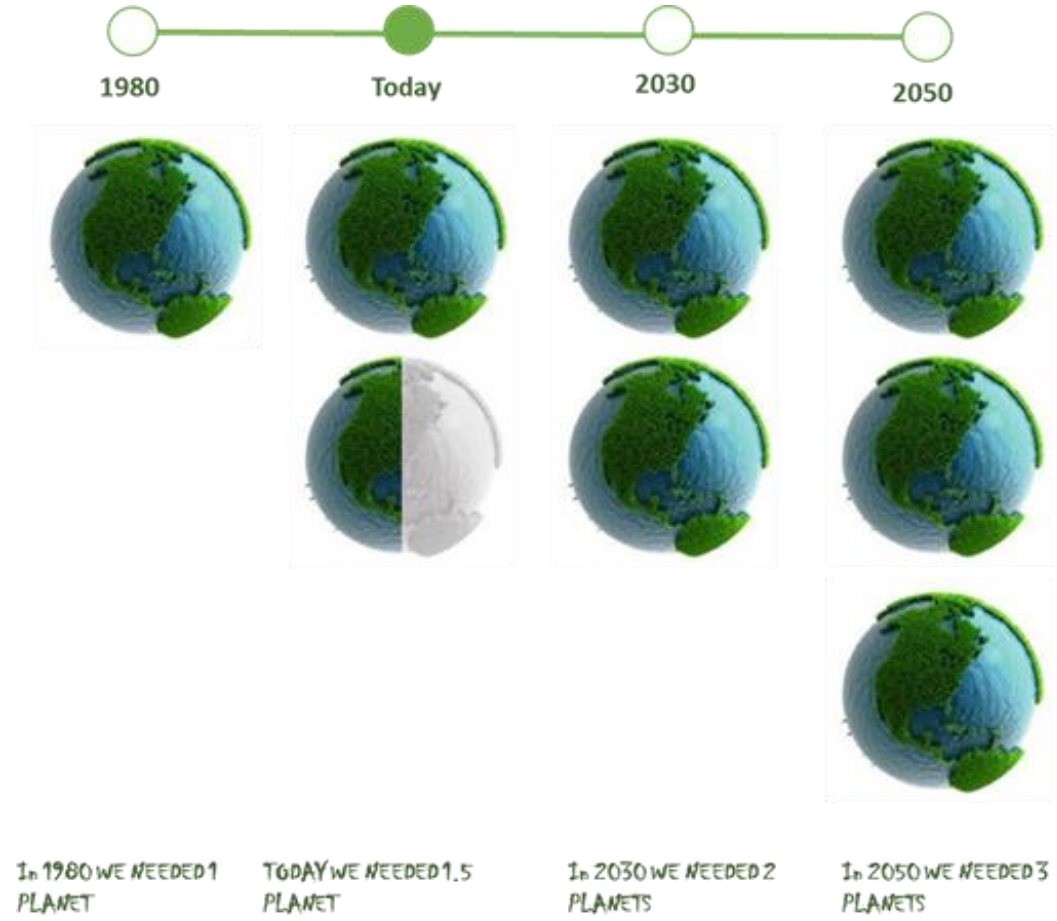
Where we are?



Protecting our planet and our shared environment is our generation's defining task. It is an urgent moral, human and political obligation .... Those who act first and fastest will be the ones who grasp the opportunities from the ecological transition.' -

Ursula von der Leyen, President, European Commission

Over-exploitation and rising consumption means that by 2050 we will need 3 planets' worth of natural resources

EUROPEAN GREEN DEAL

Global Covid-19 pandemic (2020-2022)

Drought in North America (2021)

Wildfires in North America (2021)

Tropical cyclones in the Indian subcontinent (2021)

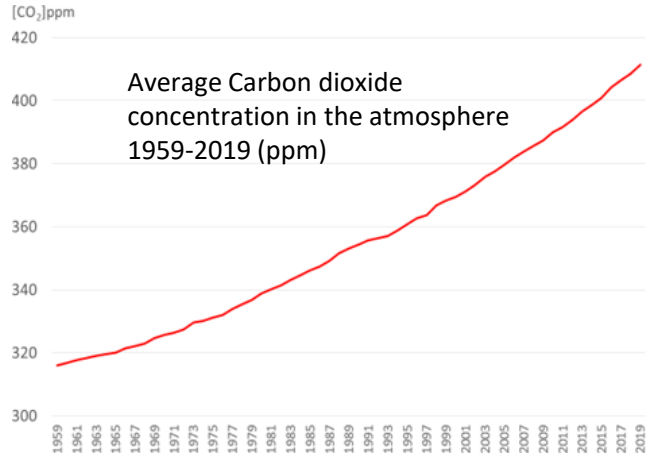
Desert locust swarm in East Africa (2020)

Outbreaks of African swine fever in Asia and Europe (2019-2021)

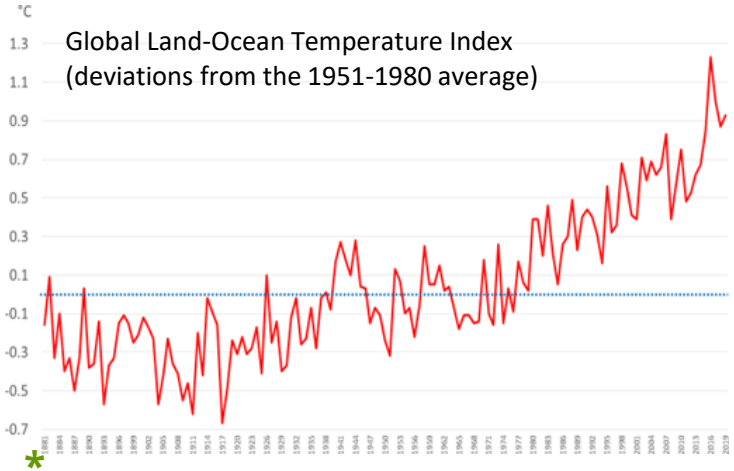
Where are we?

A quick look at vital indicators of how we are managing our planet, and ourselves

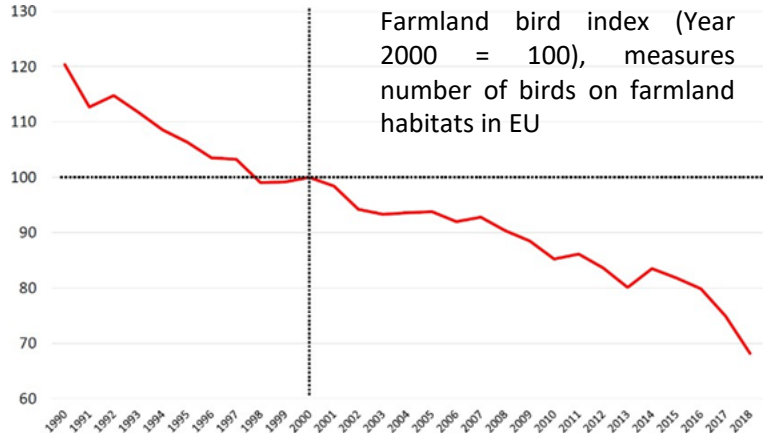
CO_2 concentration is rising…*



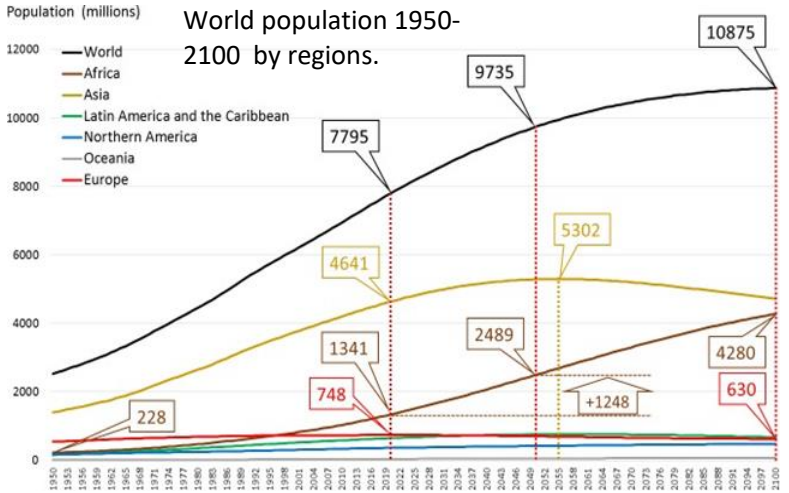
…temperatures are climbing…*



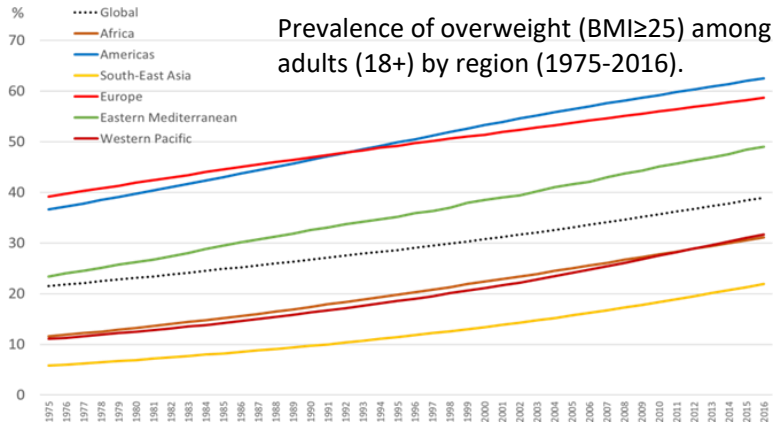
…and wildlife is suffering*



Meanwhile, population is growing…*

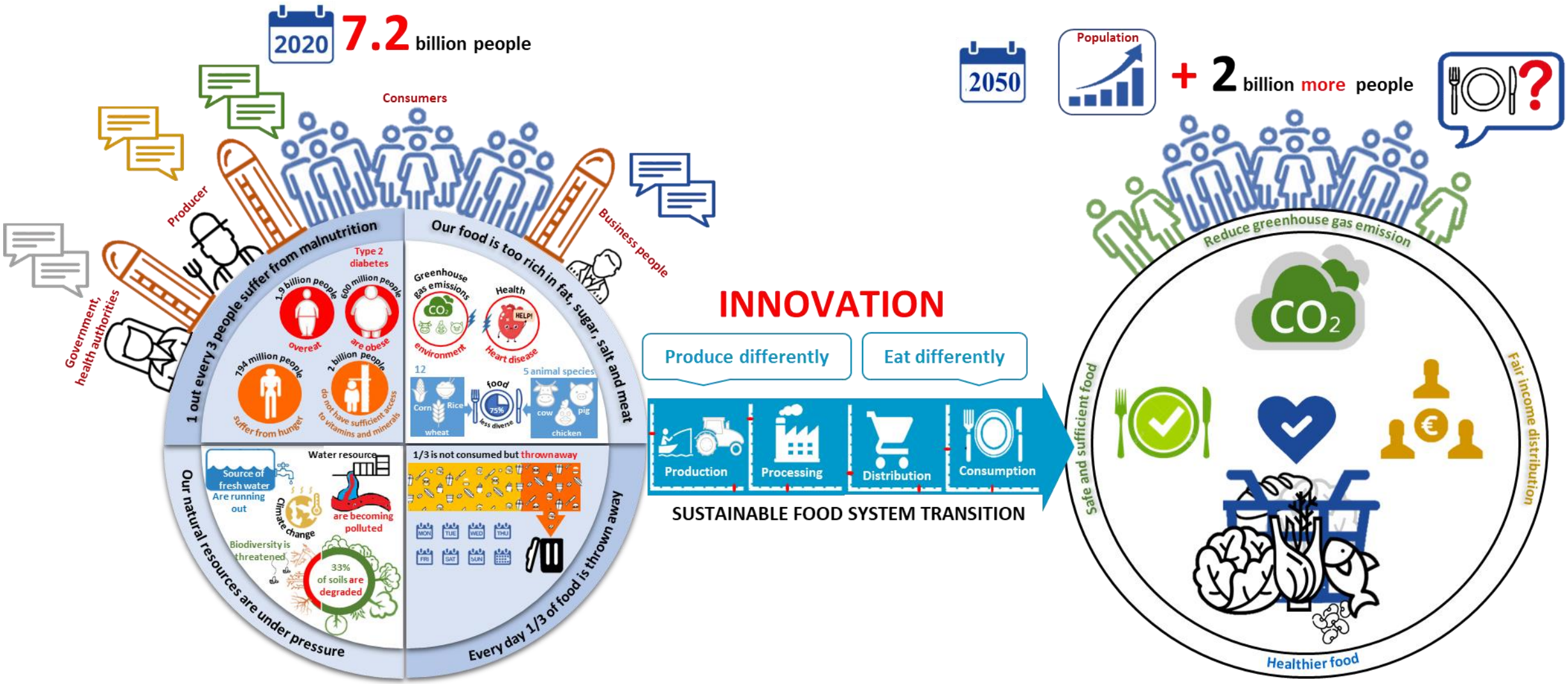


…even as more people than ever before are overweight*



*Source: H2020 Expert group on the 5th Foresight Exercise of the Standing Committee for Agricultural Research (SCAR).
RESILIENCE AND TRANSFORMATION
Natural resources and food systems: Transitions towards a 'safe and just' operating space. 30 September 2020

Food system limitations and main goals to reach a sustainable and healthy diet



2024 GLOBAL REPORT ON FOOD CRISES

JOINT ANALYSIS FOR BETTER DECISIONS

FIG. 1.9 **Numbers of people in IPC/CH Phase 3 or above or equivalent by primary driver, 2018–2023**

	2018	2019	2020	2021	2022	2023
Conflict/ insecurity	73.9M 21 countries	77.1M 22 countries	99.1M 23 countries	139.1M 24 countries	117.1M 19 countries	134.5M 20 countries
Weather extremes	28.8M 26 countries	33.8M 25 countries	15.7M 15 countries	23.5M 8 countries	56.8M 12 countries	71.9M 18 countries
Economic shocks	10.2M 6 countries	24.0M 8 countries	40.5M 17 countries	30.2M 21 countries	83.9M 27 countries	75.2M 21 countries

Economic shocks include the indirect impact of COVID-19 in 2020 and 2021 and the effects of the war in Ukraine in 2022. Food crises are the result of multiple drivers. The GRFC has based this infographic on the predominant driver in each country/territory.

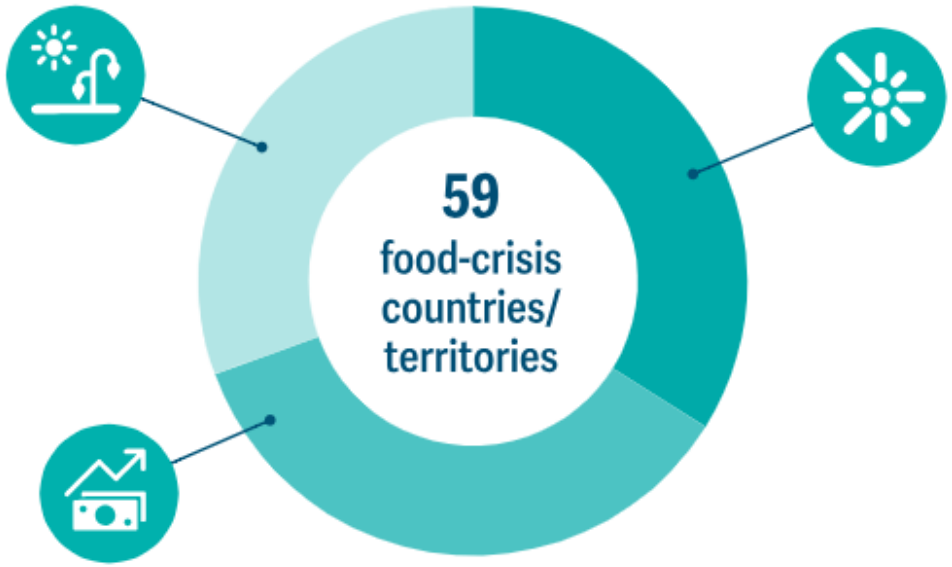
Source: FSIN, GRFC 2019–2023.

Drivers of acute food insecurity

The drivers of food crises are interlinked and mutually reinforcing. Acute food insecurity is rarely driven by a single shock or hazard, but rather by the interaction between shocks and underlying poverty, structural weaknesses and other vulnerability factors. Still, it is possible to identify a primary driver for each country/territory.

Weather extremes
18 countries where **71.9M** people faced high acute food insecurity

Economic shocks
21 countries where **75.2M** people faced high acute food insecurity

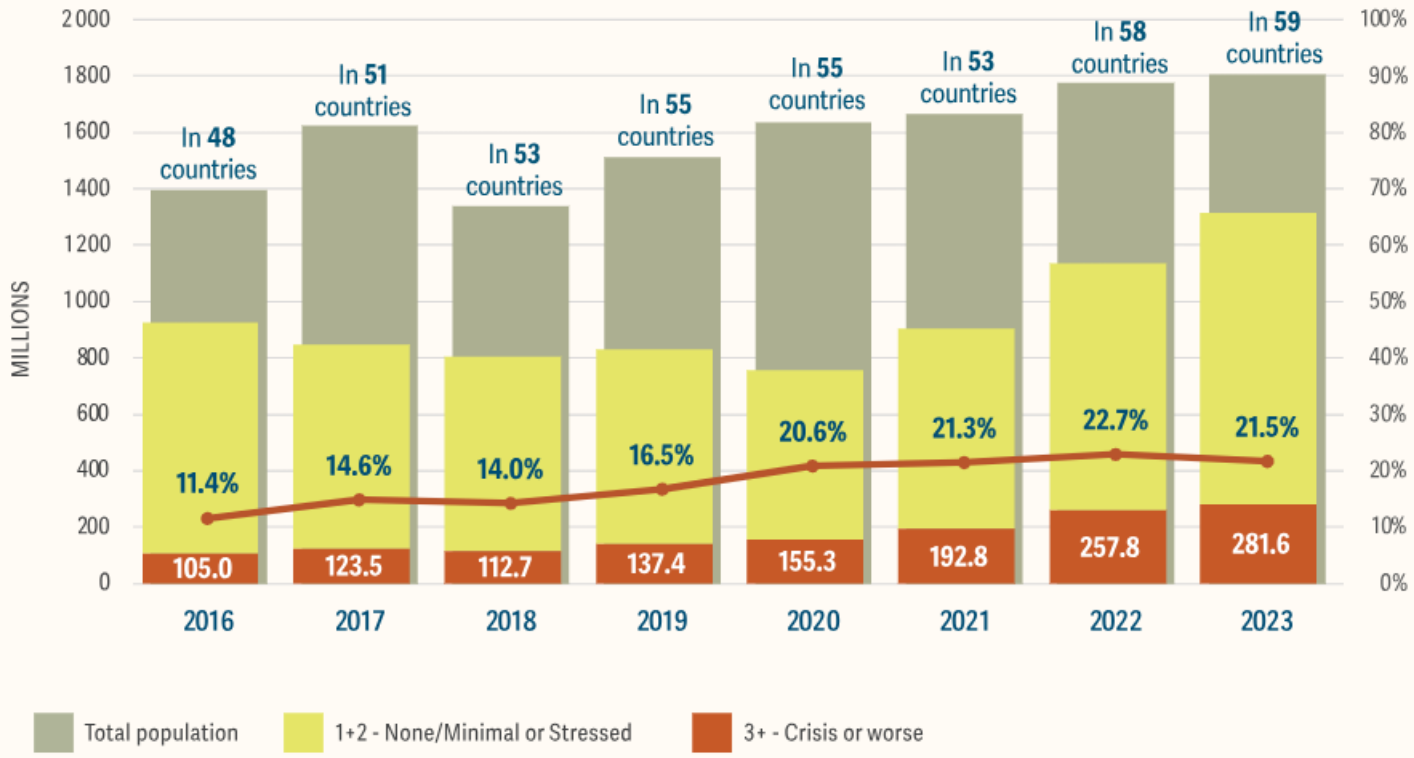


Conflict/insecurity
20 countries/ territories where **134.5M** people faced high acute food insecurity

2024 GLOBAL REPORT ON FOOD CRISES

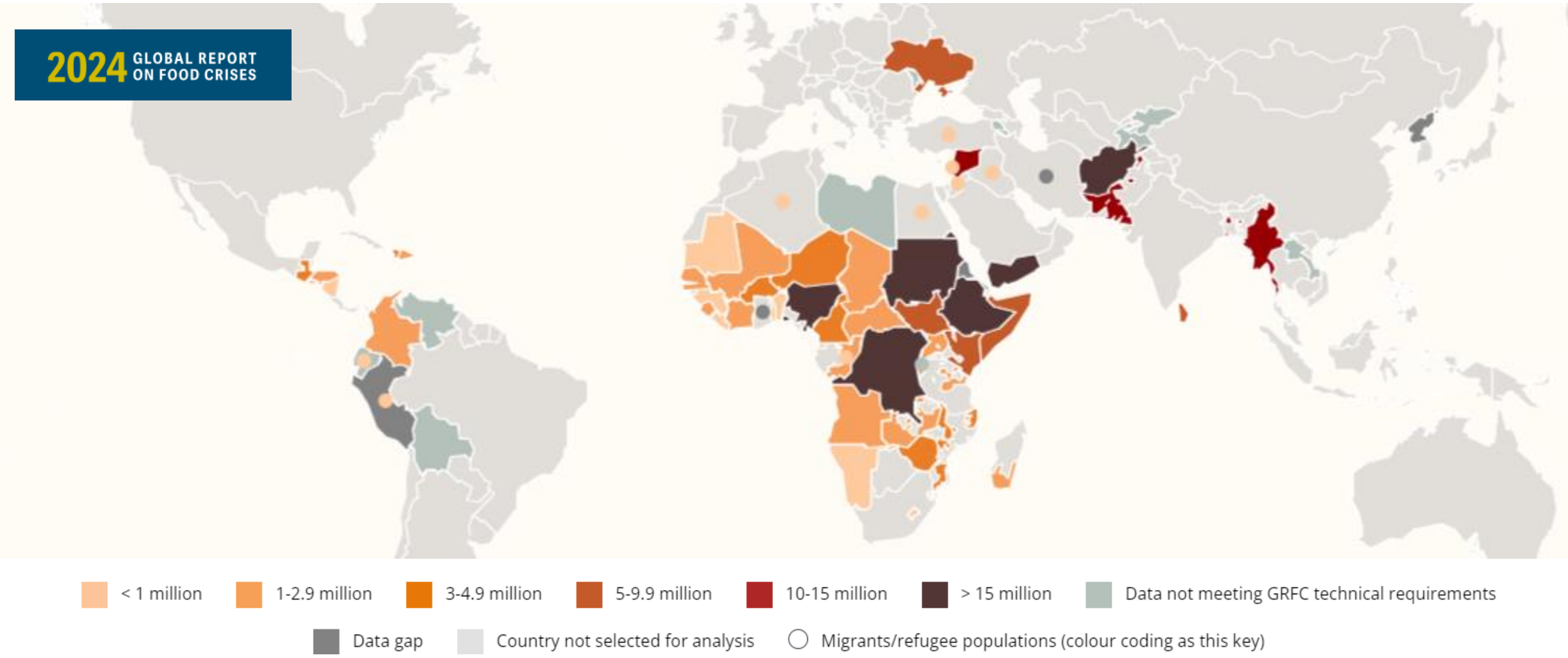
Numbers of people and share of analysed population in GRFC countries/territories facing high levels of acute food insecurity 2016-2023.

2024 GLOBAL REPORT ON FOOD CRISES



- population facing high levels of acute food insecurity increased sharply from **14 percent** in 2018 to more than **20 percent** each year since 2020, reaching an eight-year high in 2022 (23 percent).

Number of people facing high levels of acute food insecurity in 59 countries/territories, 2023

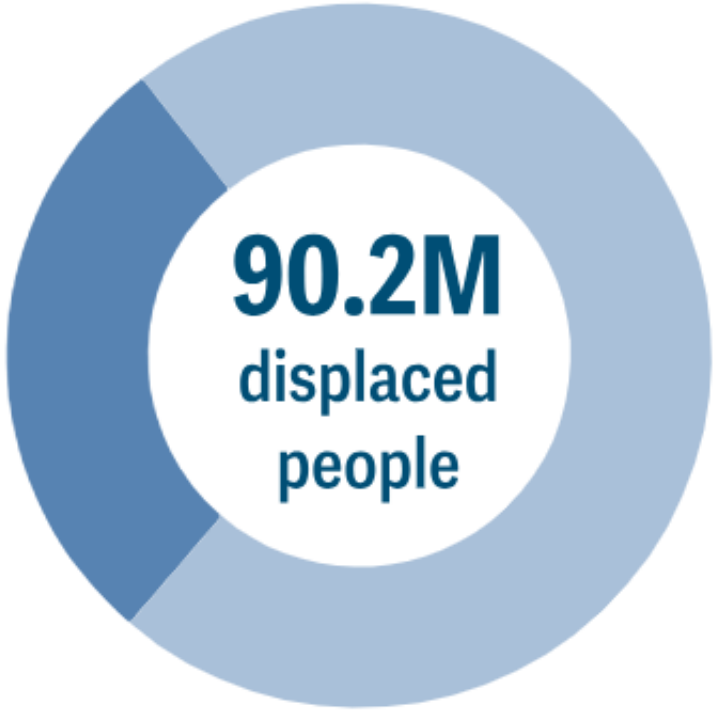


Displacement overview

New, escalating and protracted conflicts, extreme climatic events and economic hardship resulted in another year of increasing numbers of people forced to flee their homes in 2023.

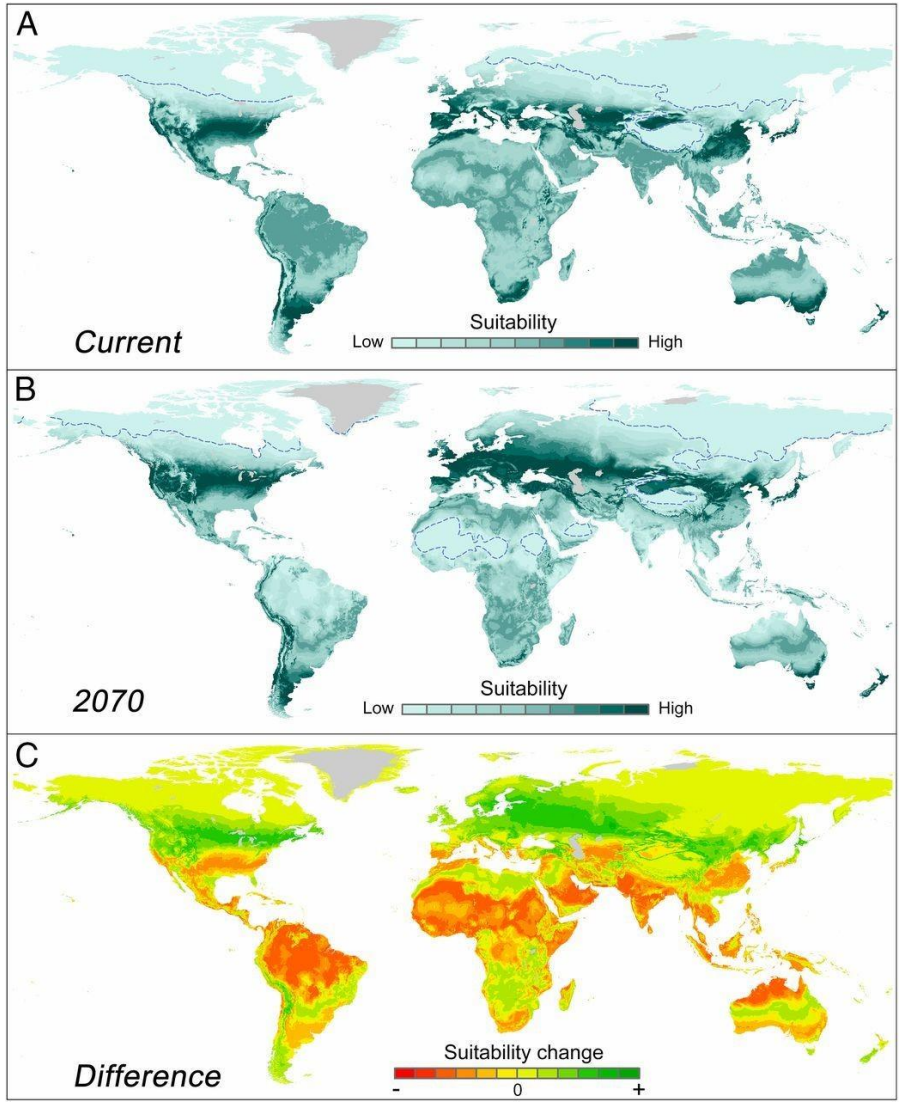
2024 GLOBAL REPORT ON FOOD CRISES

26.0M
refugees and asylum-seekers in 56 countries



64.3M
IDPs in 38 countries/ territories

Future of the human climate niche

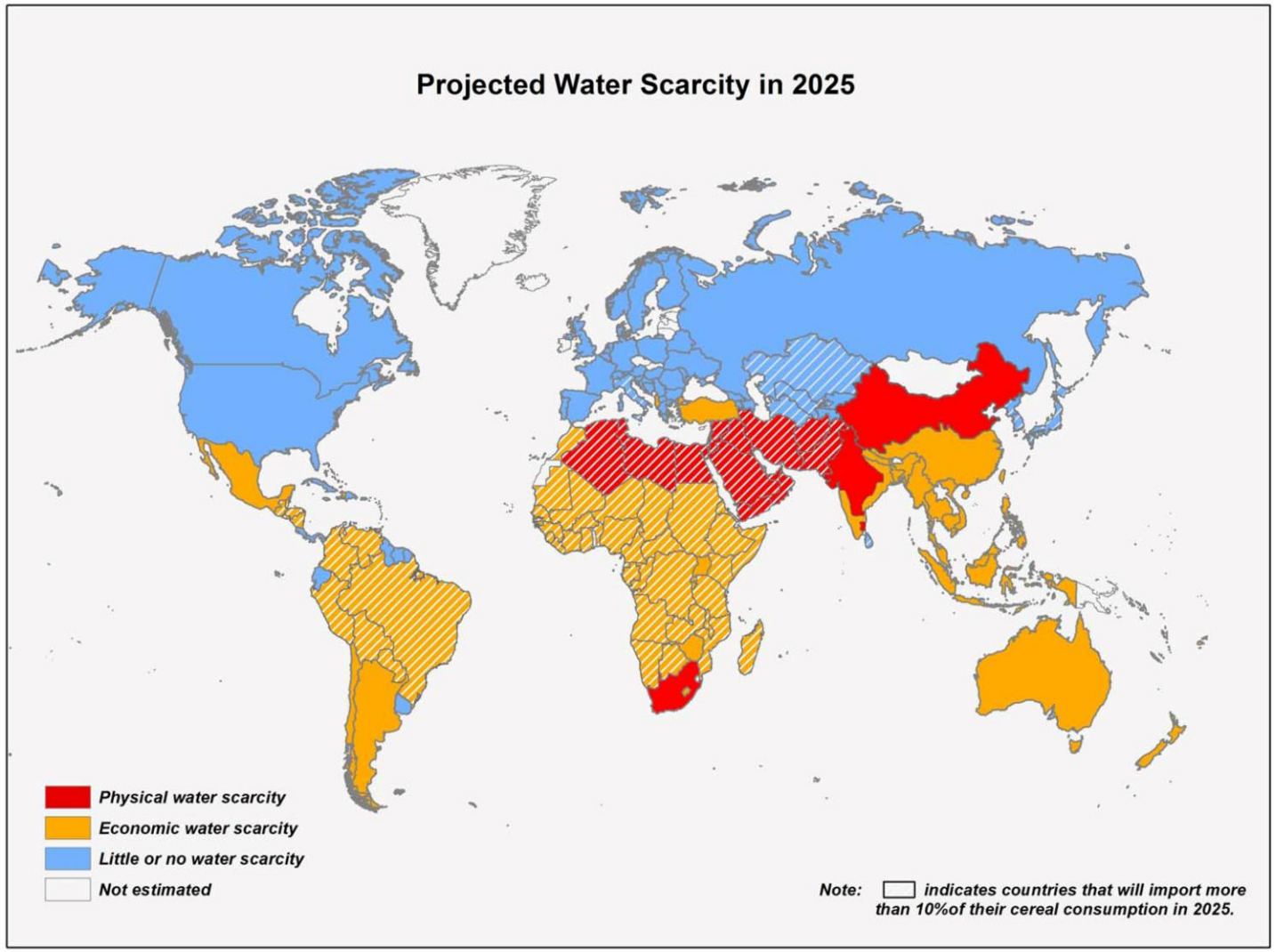


- By 2070, one-third of people could be living in conditions that are outside humanity's comfort zone.

- The bottom line is that over the coming decades, the human climate niche is projected to move to higher latitudes in unprecedented ways. At the same time, populations are projected to expand predominantly at lower latitudes, amplifying the mismatch between the expected distribution of humans and the climate.

The projected shift in temperature would affect the geographic distribution of people. Image: Proceedings of the National Academy of Sciences of the United States of America/ Chi Xu, Timothy A. Kohler, Timothy M. Lenton, Jens-Christian Svenning, Marten Scheffer [CC 4.0]

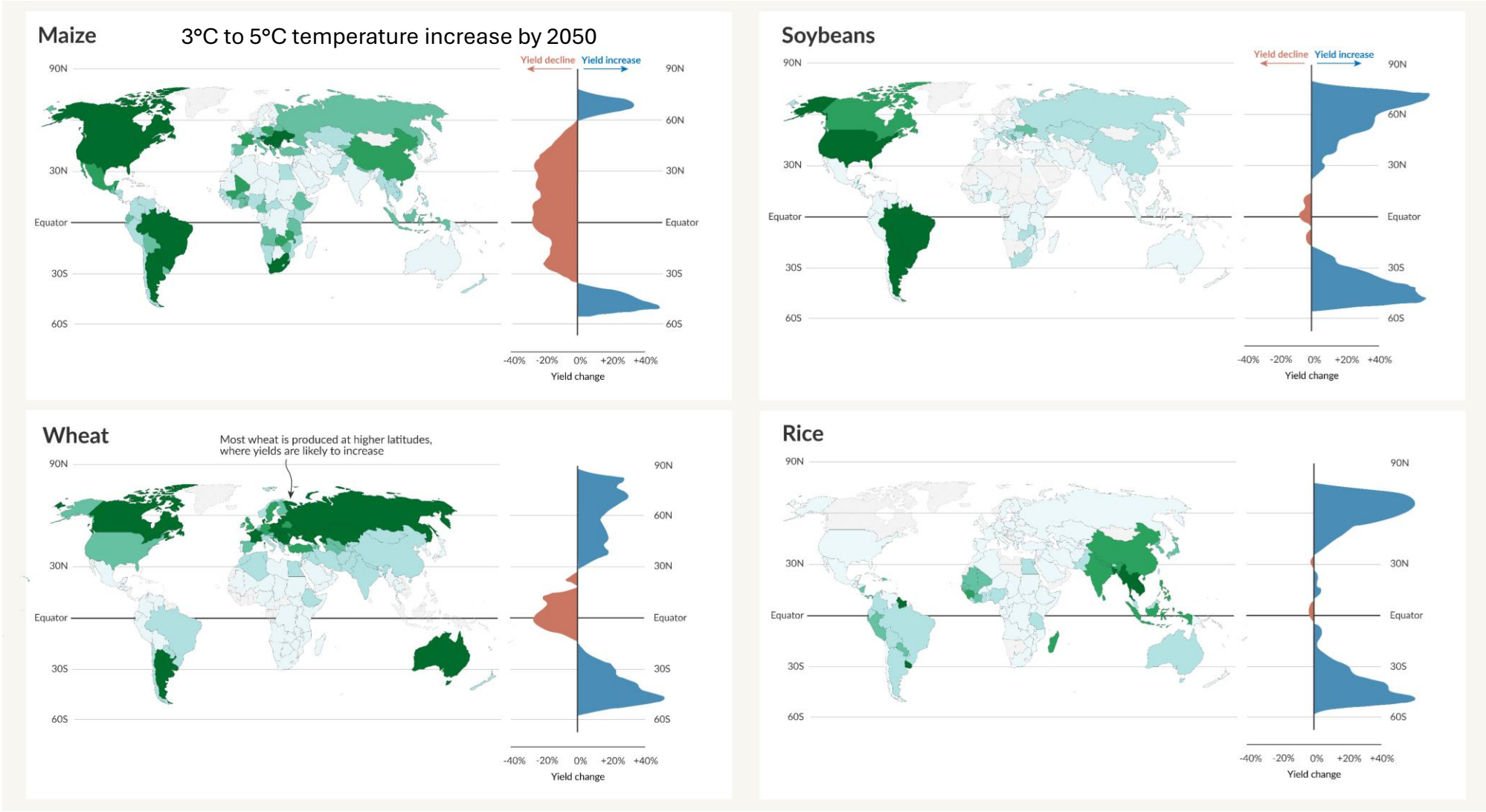
Agriculture areas will be water stressed



Projected physical and economic water scarcity by 2025 in the Southern African Development Community (SADC) region compared with the rest of the world. Note: countries marked with stripped yellow and red lines indicate those that, although the respective countries show economic water scarcity, will, however have physical water scarcity by 2025 if no remedial solutions are taken now. The countries marked with stripped blue lines show countries that although they have little or no water scarcity, the trend is moving towards water scarcity by 2025.

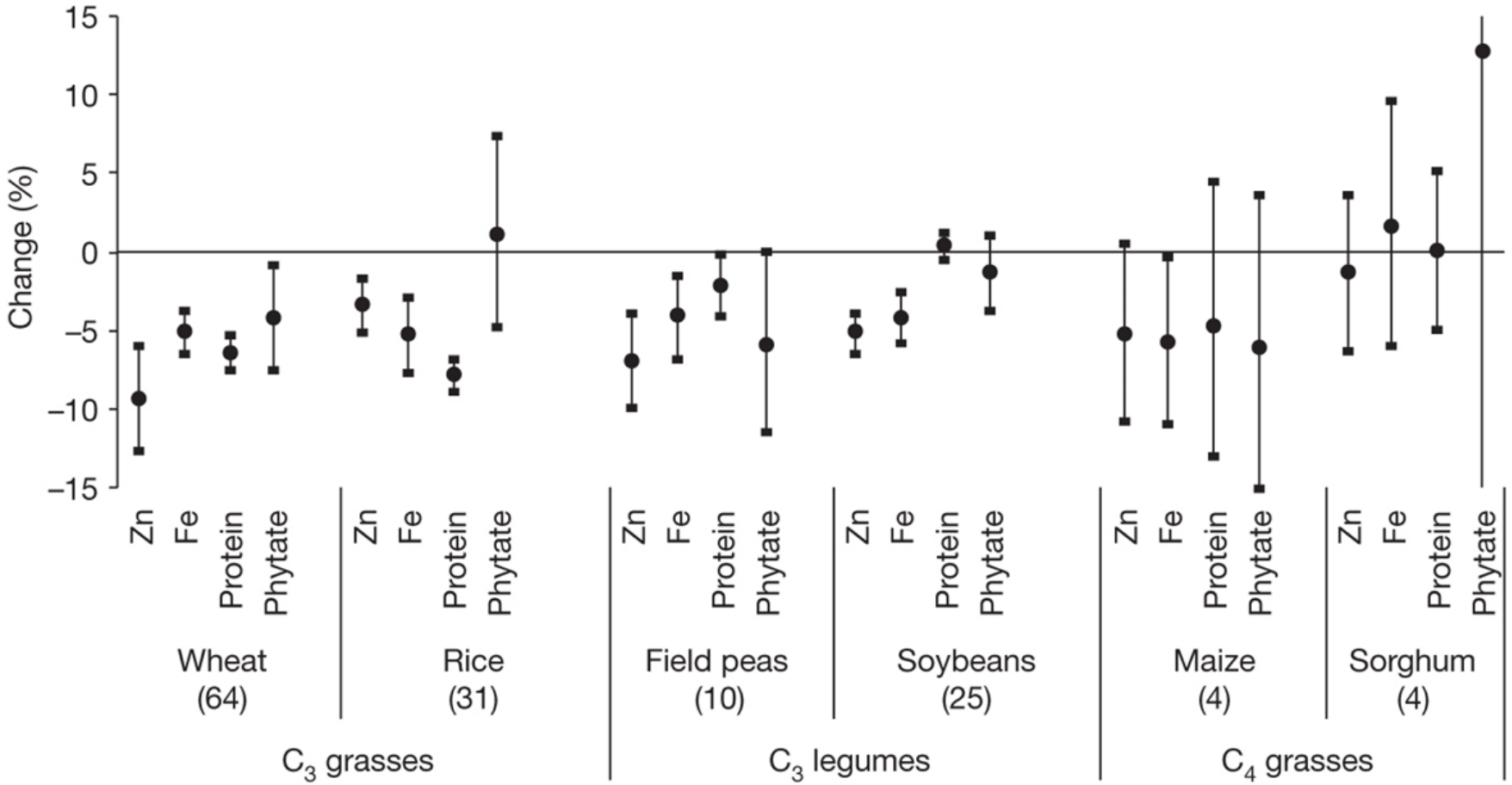
Mabhaudhi, T.; Mpandeli, S.; Madhlopa, A.; Modi, A.T.; Backeberg, G.; Nhamo, L. Southern Africa's Water–Energy Nexus: Towards Regional Integration and Development. Water 2016, 8, 235. https://doi.org/10.3390/w8060235

The potential impact of climate change on crop yields across the world



Jägermeyr, J., Müller, C., Ruane, A. C., Elliott, J., Balkovic, J., Castillo, O., ... & Rosenzweig, C. (2021). Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. Nature Food.

Nutritional quality of crops and elevated $C0_2$ effects



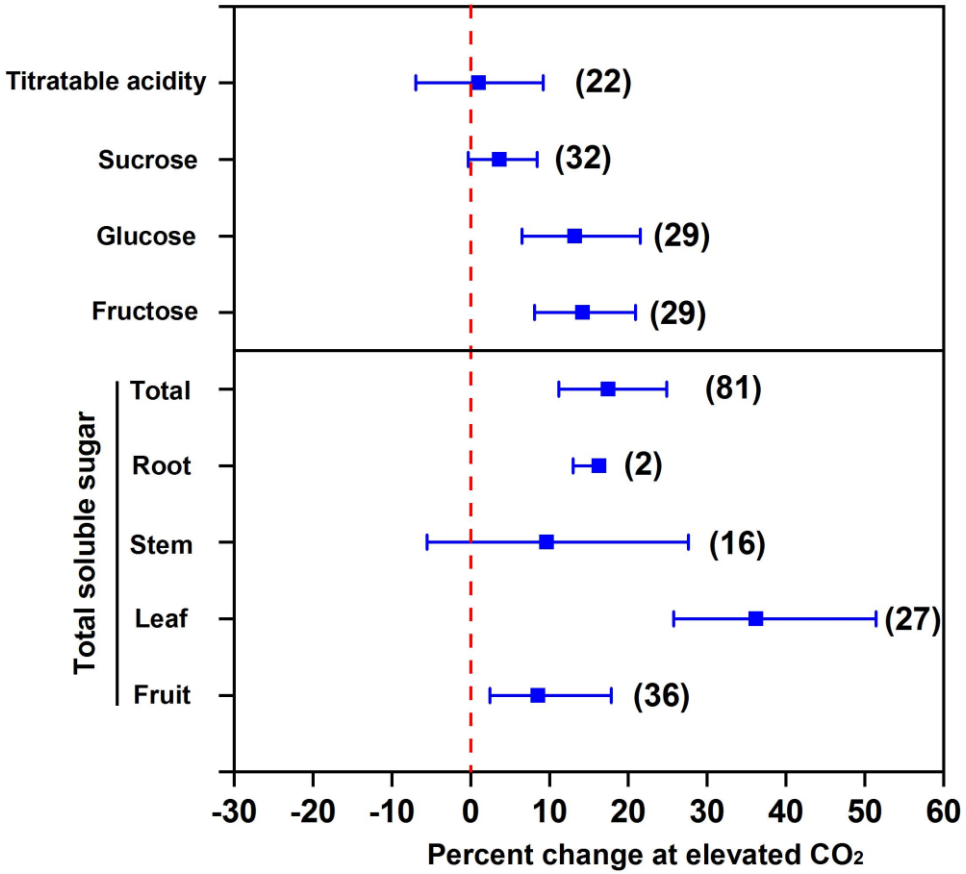
Percentage change in nutrients at elevated [CO_2] relative to ambient [CO_2].

Elevated [CO2] was associated with:

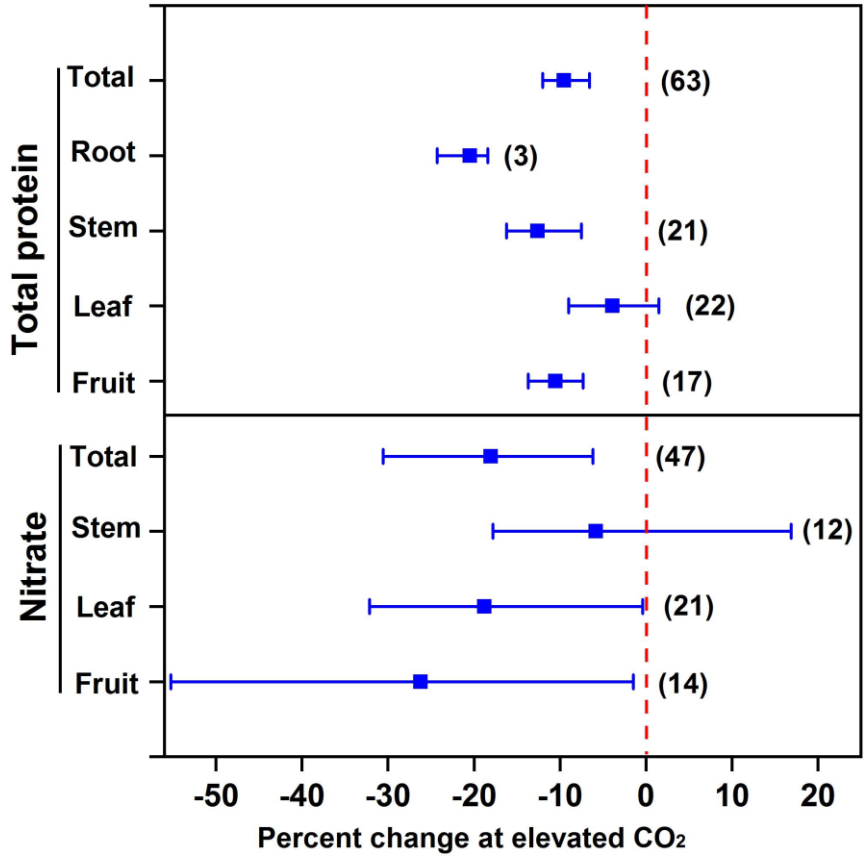
- significant decreases in the concentrations of zinc and iron in all C3 grasses and legumes (for example, wheat grains grown at elevated [CO2] had 9.3% lower zinc (95% confidence interval (CI) −12.7% to −5.9%) and 5.1% lower iron (95% CI −6.5% to −3.7%) than those grown at ambient [CO2].
- lower protein content in C3 grasses, with a 6.3% decrease (95% CI −7.5% to −5.2%) in wheat grains and a 7.8% decrease (95% CI −8.9% to −6.8%) in rice grains.
- a small decrease in protein in field peas, and there was no significant effect in soybeans or C4 cropsElevated

Myers, S., Zanobetti, A., Kloog, I. et al. Increasing CO_2 threatens human nutrition. Nature 510, 139–142 (2014). https://doi.org/10.1038/nature13179

Nutritional quality of fruit and vegetables and elevated CO_2 effects



Effect of elevated CO_2 on soluble sugar and acidity concentrations in vegetables. Data are means of percent change with 95% confidence intervals (indicated with error bars) under elevated CO_2 compared to ambient CO2. The number of observations is in parentheses.

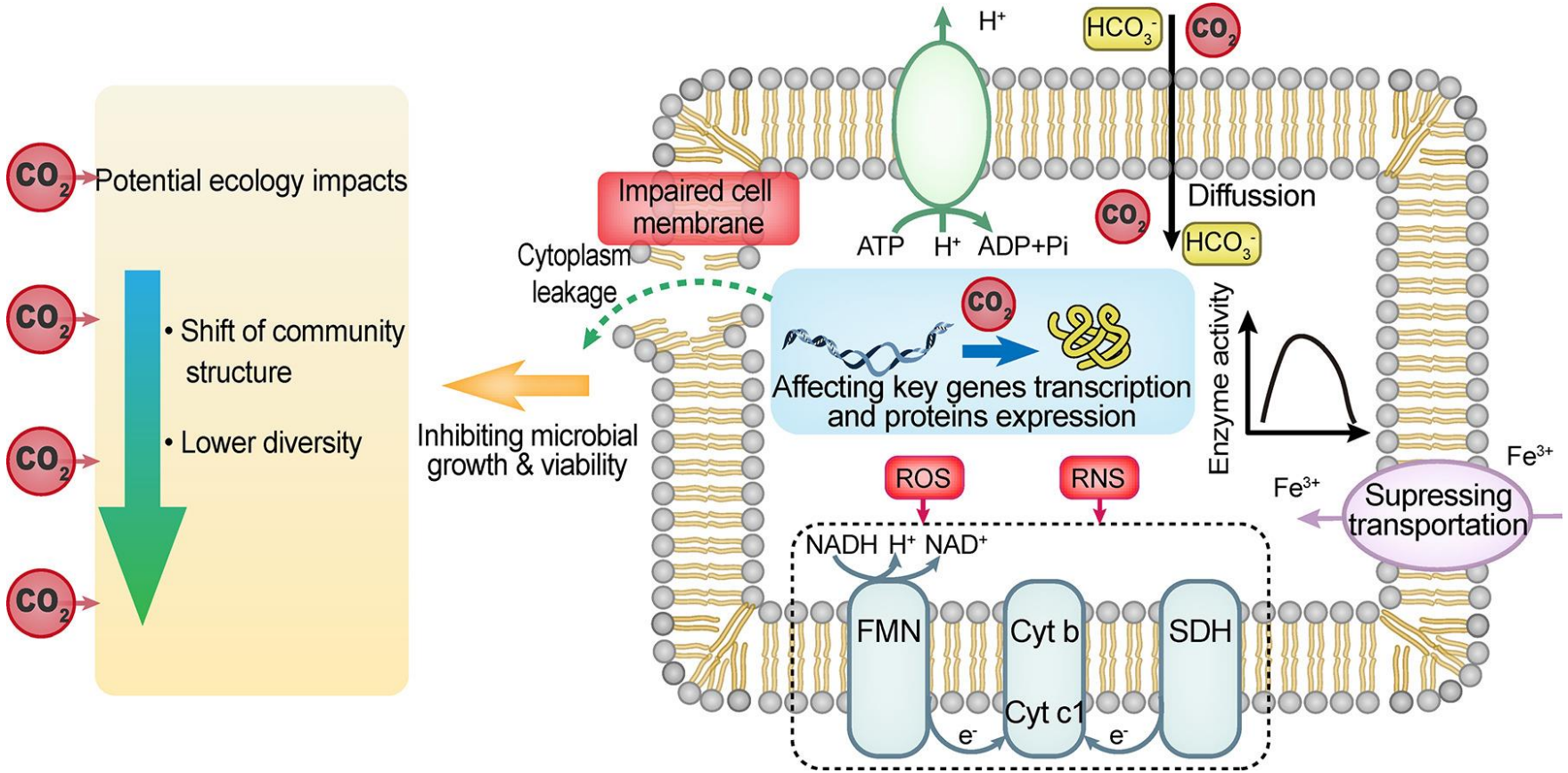


Effect of elevated CO_2 on the concentrations of total protein and nitrate in vegetables. Data are means of percent change with 95% confidence intervals (indicated with error bars) under elevated CO2 compared to ambient CO_2. The number of observations is in parentheses.

Dong Jinlong , Gruda Nazim , Lam Shu K. , Li Xun , Duan Zengqiang (2018).Effects of Elevated CO2 on Nutritional Quality of Vegetables: A Review. Frontiers in Plant Science.DOI10.3389/fpls.2018.00924

Effects of elevated carbon dioxide on environmental microbes and its mechanisms

- Elevated CO_2 shifts the community structure and lowers the microbial diversity.
- CO_2 leakage severely inhibits microbial growth.
- High CO_2 levels destroy the cell structure of microbes.
- The microbial metabolism can be affected by CO_2



Tong Yu, Yinguang Chen. Effects of elevated carbon dioxide on environmental microbes and its mechanisms: A review, Science of The Total Environment, Volume 655, 2019, 865-879. doi.org/10.1016/j.scitotenv.2018.11.301

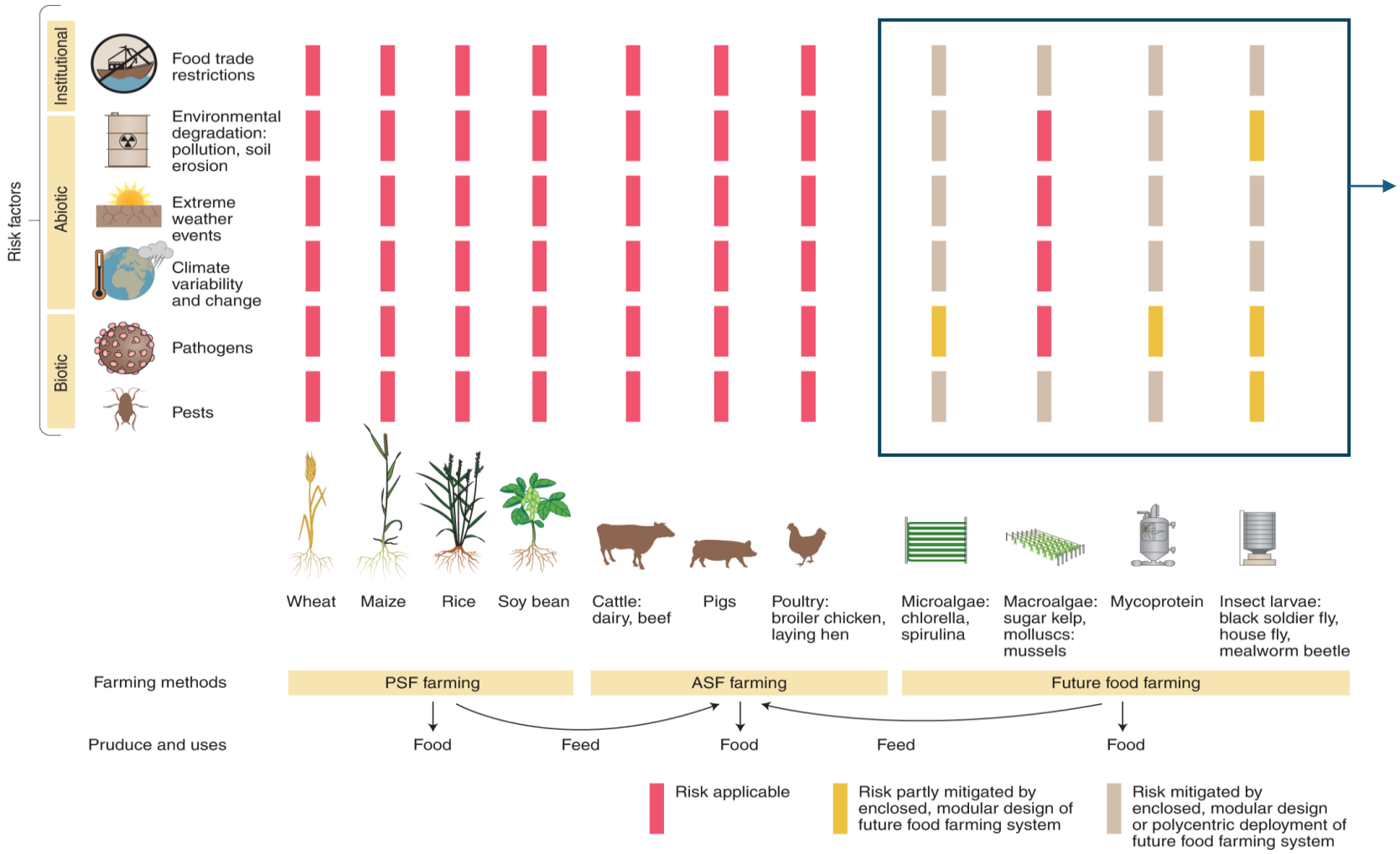
Traditional fermented Foods in Europe

Southern European countries have a more traditional food character due to a greater market share of small companies and a better climate, which supports a more widespread availability of traditional food products.

- Protected Designation of Origin (PDO),
- Protected Geographical Indication (PGI)
- Traditionally Specific Guaranteed (TSG).

This encourages the production of **unique foods based on their soil, synthetic and sensory characteristics, as well as their preparation methods.**

Current risk landscape of animal source food (ASF) and, plant source food and future foods farming systems.



Each bar denotes a hazard threatening a particular farming system. The enclosed, modular design or polycentric deployment of future foods farming systems can mitigate the risks to which the open-environment farming systems of traditional ASF and PSF are vulnerable. *(Tzachor, A., Richards, C. E., & Holt, L. (2021). Future foods for risk-resilient diets. Nature Food, 2(5), 326–329. https://doi.org/10.1038/s43016-021-00269-x)*

Resilience advantages

-Reduce exposure to biotic and abiotic risk factors
-Fostering modulatory
- Dietary consistency of essential nutrition

Close environment

-Stable farming system → consistent and efficient production performance
-Higher control of spoilage and pathogen m.o.

Modular design

-Flexible response to unexpected disruptions
- Potential contamination are confined → High system-wide stability
-Adjust production to meet oscillating demand

Polycentric food networks

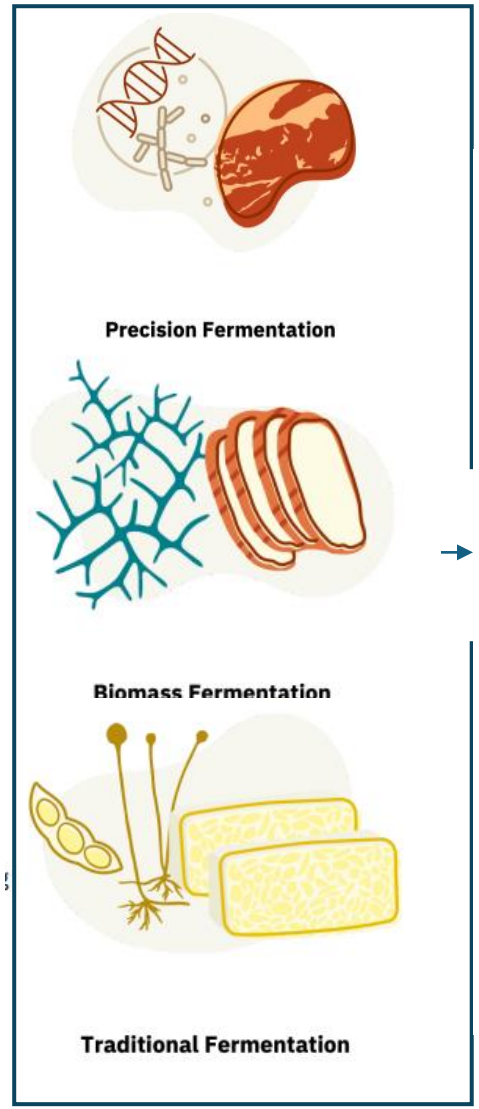
-Decentralised and localised the food production regardless to the environmental conditions (benefit for isolated communities in remote regions)
-Production plant placed in or near to urban centres
- Democratization of the food systems

Deployment challenges

Technical barriers

- Consistency energy supply from renewable sources, -Biorefinery infrastructures, Biotic risks from the feeding systems, Institutional barriers
- Technical expertise, Financial investment
- Regulatory framework (safety aspects)

Single-cell protein as Alternative Protein Source



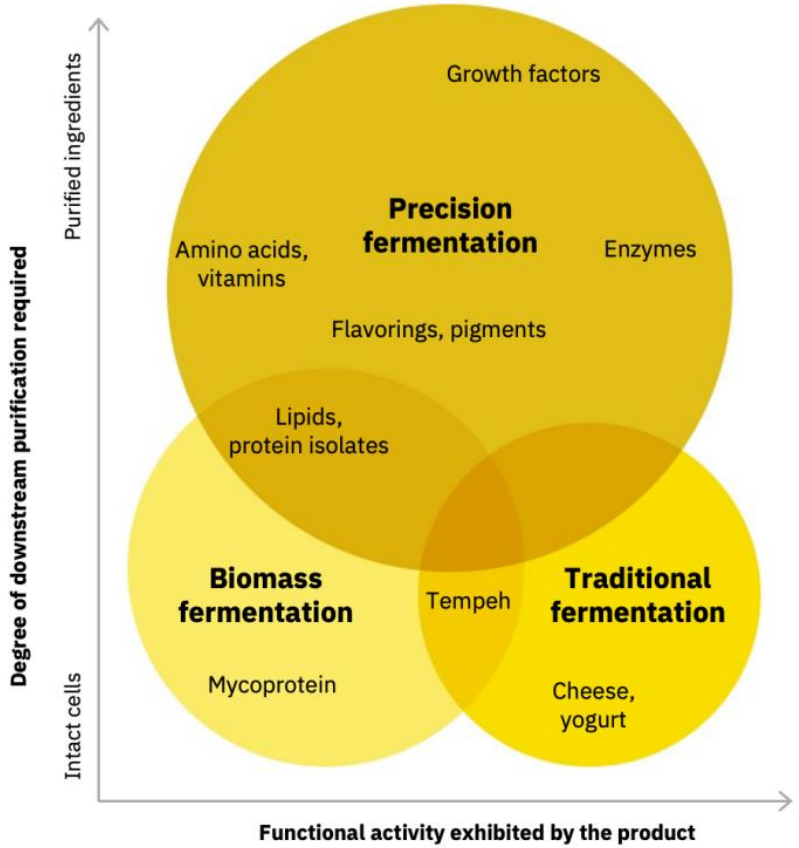
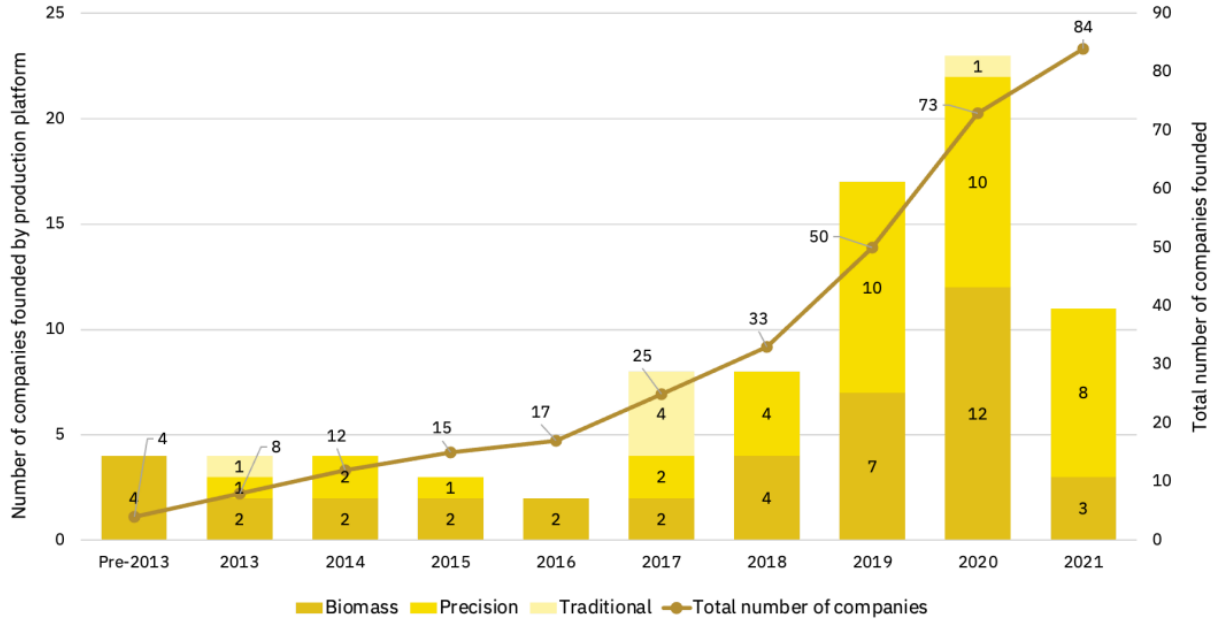
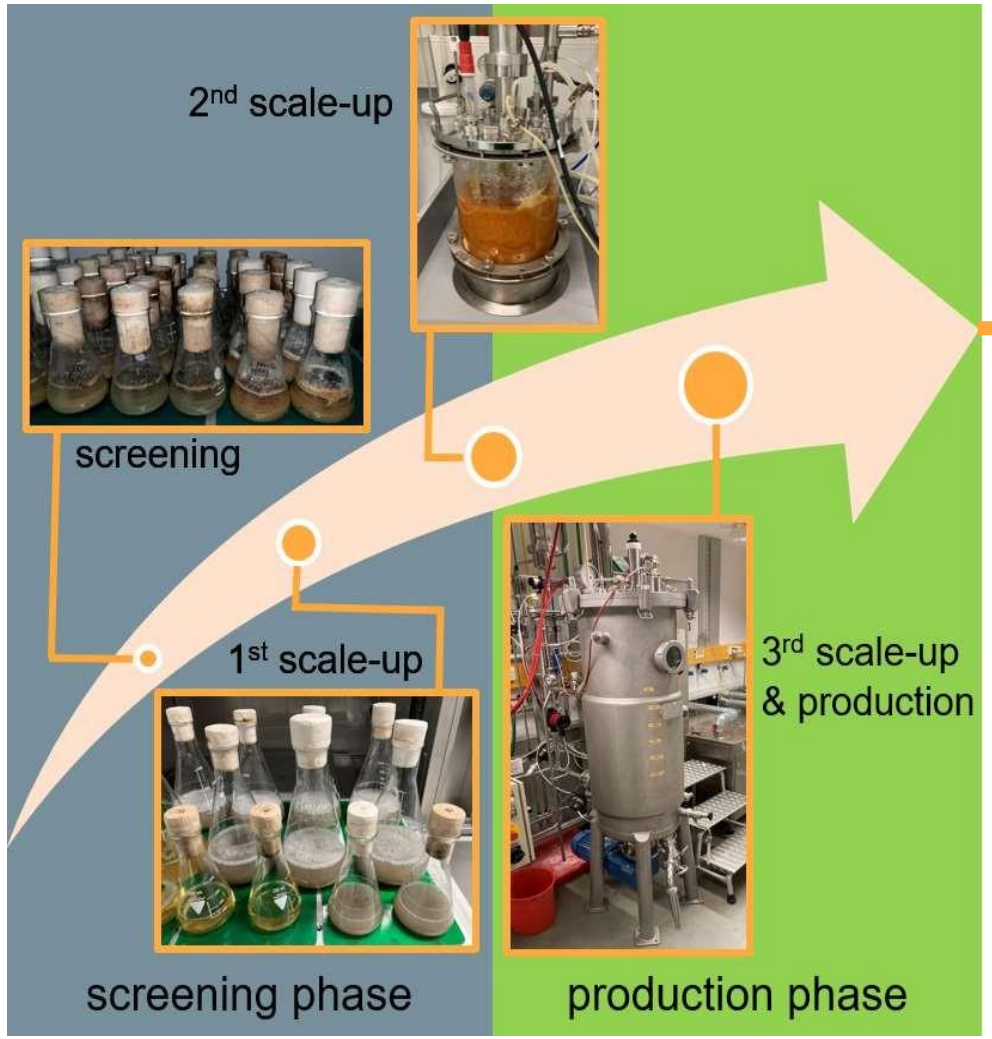


Figure 4: Number of companies in fermentation-enabled alternative proteins by year founded



Source: GFI company database.

Liquid state fermentation (LSF)

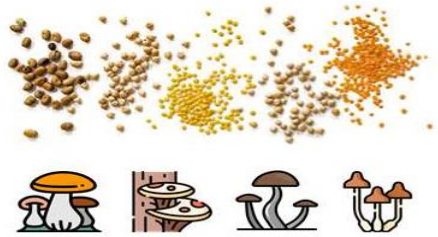


- pasta residues and *Marasmius palmivorus* on wheat bran
- 3rd scale-up: Fermentation of *M. scorodonius* on pasta residues optimised in 4.7 L-scale scale-up to 80 L for production of several kg of mycelium for WP partners
- **Final scale-up**: *M. scorodonius* production process successfully scaled up to a 1,400 L stirred vessel bioreactor by Doehler under industrial conditions, 37 kg mycelium with 20% dry matter

Liquid state fermentation (of sidestreams)	**Key Performance Indicators**	**Smart Protein Outcomes**
	Product yield: 0.4 g/g dry substrate	**0.7 g/g substrate**
	Amino acid profile: balanced, high biological value of at least 80)	**86 - 92**
	Handling of batch-to-batch variability	**No noteworthy batch-to-batch variations**
	Target applications	**Flavour-enhancing extract and/or meat analogue.**

Solid-state fermentation (SSF)

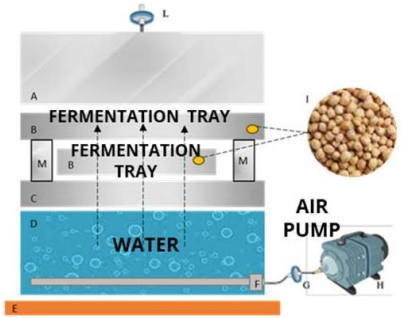
Optimisation of substrate blends and fungal species



Substrate	By-product additives	Fungal species	Type of fermentation
Rice Red lentils Quinoa Chikpeas Faba beans Soybeans	Pasta leftovers Bread crust Malt rootles Spent yeast	*Aspergillus oryzae* *Rhizopus oligosporus*	Non axenic
Millet	Pasta leftovers Bread crust Malt rootles Spent yeast	*Pleurotus eryngii* *Hericium erinaceus* *Cyclocybe aegerita*	Axenic

- ☐ General composition:
  - Fibre
  - Protein
  - Fat content
  - α- and β-glucans
- ☐ Aminoacids
- ☐ Antinutrients reduction
- ☐ Mycotoxins

Upscaling of SSF for the production of mycelium cakes



The tray bioreactor system allowed an increase the load per production batch

from **0.5 kg**

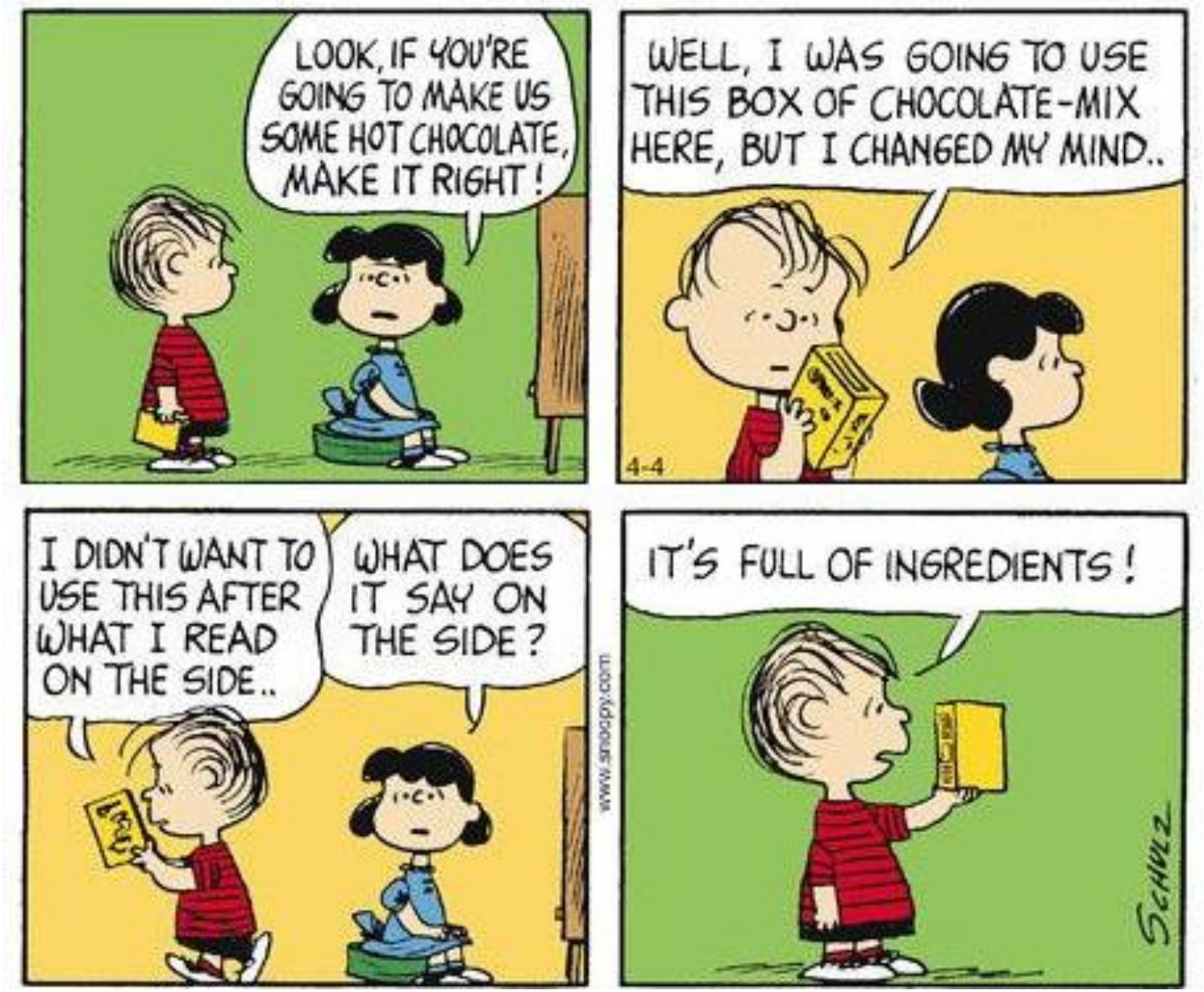
to **6.5 kg**

Test with chickpeas: enrichment in **protein content**, increasing from **22%** in the raw substrate to **28.9%** after fermentation in the upscaled system

Mycelium cakes production for prototyping activities

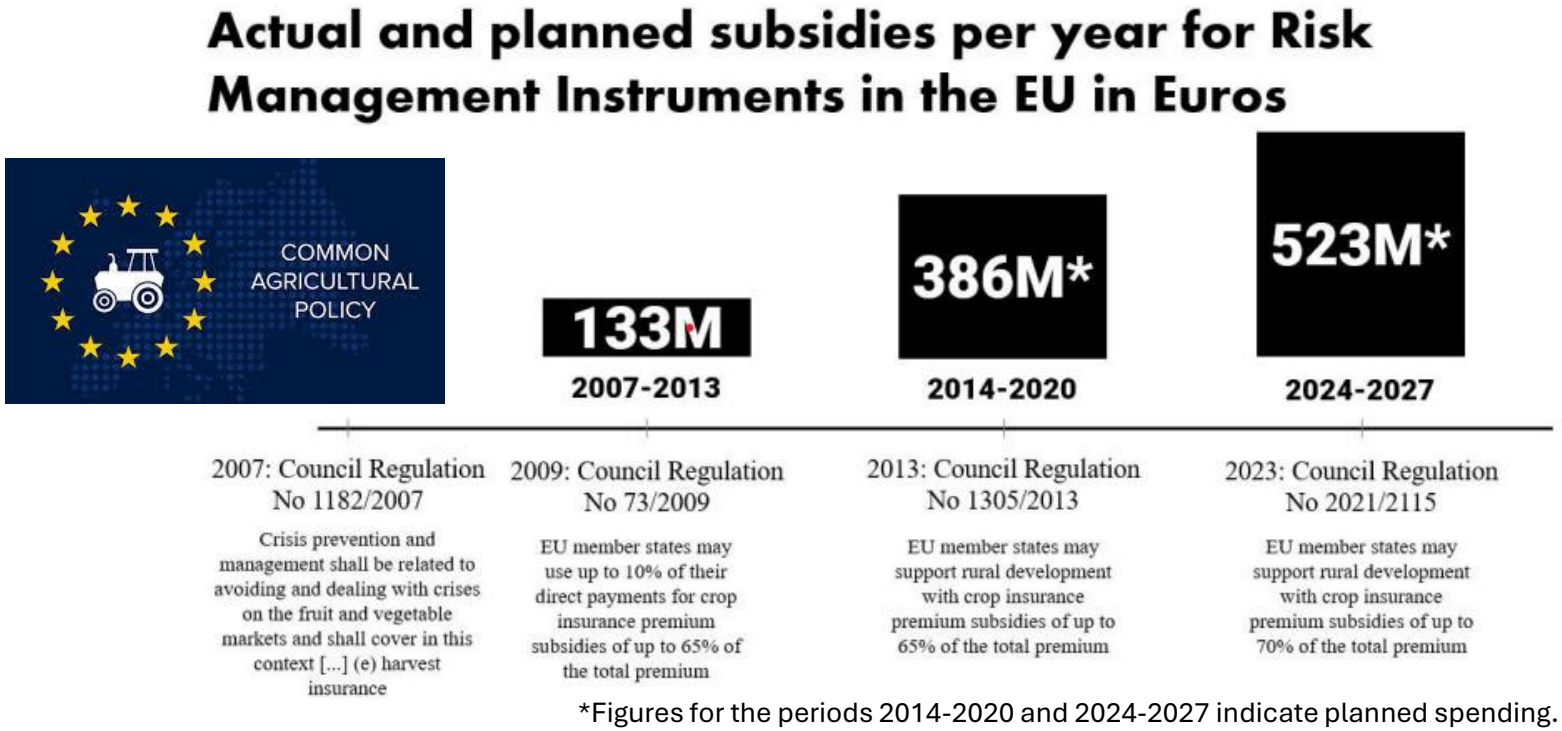
unibz UCC

Clean eating is Today's Big Food Trend



Gluten-free
Sugar-free
Oil-free
Grain-free
Legume-free
Plant-based-vegan
.....

EU Insurance Policy on Primary Food Production



*Figures for the periods 2014-2020 and 2024-2027 indicate planned spending.

Higher subsidization

↓

larger environmental impacts through:
(i) changes in input use per hectare,
(ii) changes in the crop mix - for example, towards more risky and input-intensive crops and
(iii) conversions of marginal land into crop production.

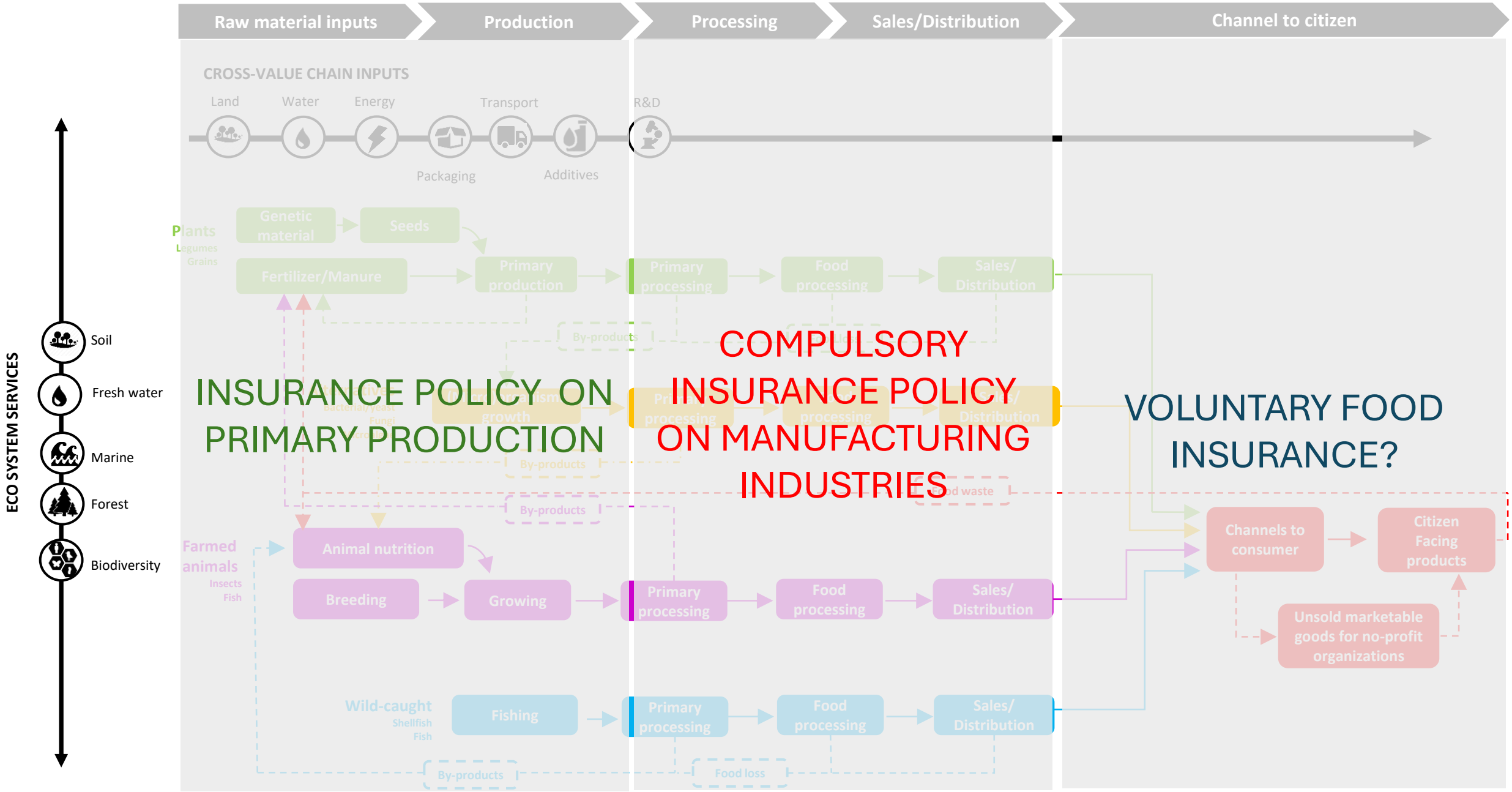
USDA

The USDA, Risk Management Agency (RMA) oversees (Federal Crop Insurance Program) FCIP. It offers agricultural producers financial protection against losses due to adverse events including drought, excess moisture, damaging freezes, hail, wind, disease, and **price fluctuations**.

Dalhaus, T., Wu, J. & Möhring, N. Rapidly growing subsidization of crop insurance in Europe ignores potential environmental effects. *Nat. Plants* **9**, 1938–1939 (2023). https://doi.org/10.1038/s41477-023-01569-9

Italian Budget Law on mandatory insurance against catastrophic events

Law No. 213 of 30 December 2023 (the Budget Law) has introduced a **new obligation for companies** with registered offices in Italy and companies with registered offices abroad with a permanent establishment in Italy. **As of 31 December 2024, these companies will have to take out insurance to cover damage to assets caused by natural disasters and catastrophic events occurring on national territory.**


Raw material inputs
Production
Processing
Sales/Distribution
Channel to citizen
CROSS-VALUE CHAIN INPUTS
Land
Water
Energy
Transport
R&D
Packaging
Additives
ECO SYSTEM SERVICES
Soil
Fresh water
Marine
Forest
Biodiversity
Plants
Legumes
Grains
Genetic material
Seeds
Fertilizer/Manure
Primary production
Primary processing
Food processing
Sales/ Distribution
By-products
INSURANCE POLICY ON PRIMARY PRODUCTION
COMPULSORY INSURANCE POLICY ON MANUFACTURING INDUSTRIES
VOLUNTARY FOOD INSURANCE?
Farmed animals
Insects
Fish
Animal nutrition
Breeding
Growing
Primary processing
Food processing
Sales/ Distribution
Channels to consumer
Citizen Facing products
Unsold marketable goods for no-profit organizations
Wild-caught
Shellfish
Fish
Fishing
Primary processing
Food processing
Sales/ Distribution
By-products
Food loss

Sustainable future food....

DAMIEN HIRST * 1965, British

Das letzte Abendmahl

The Last Supper

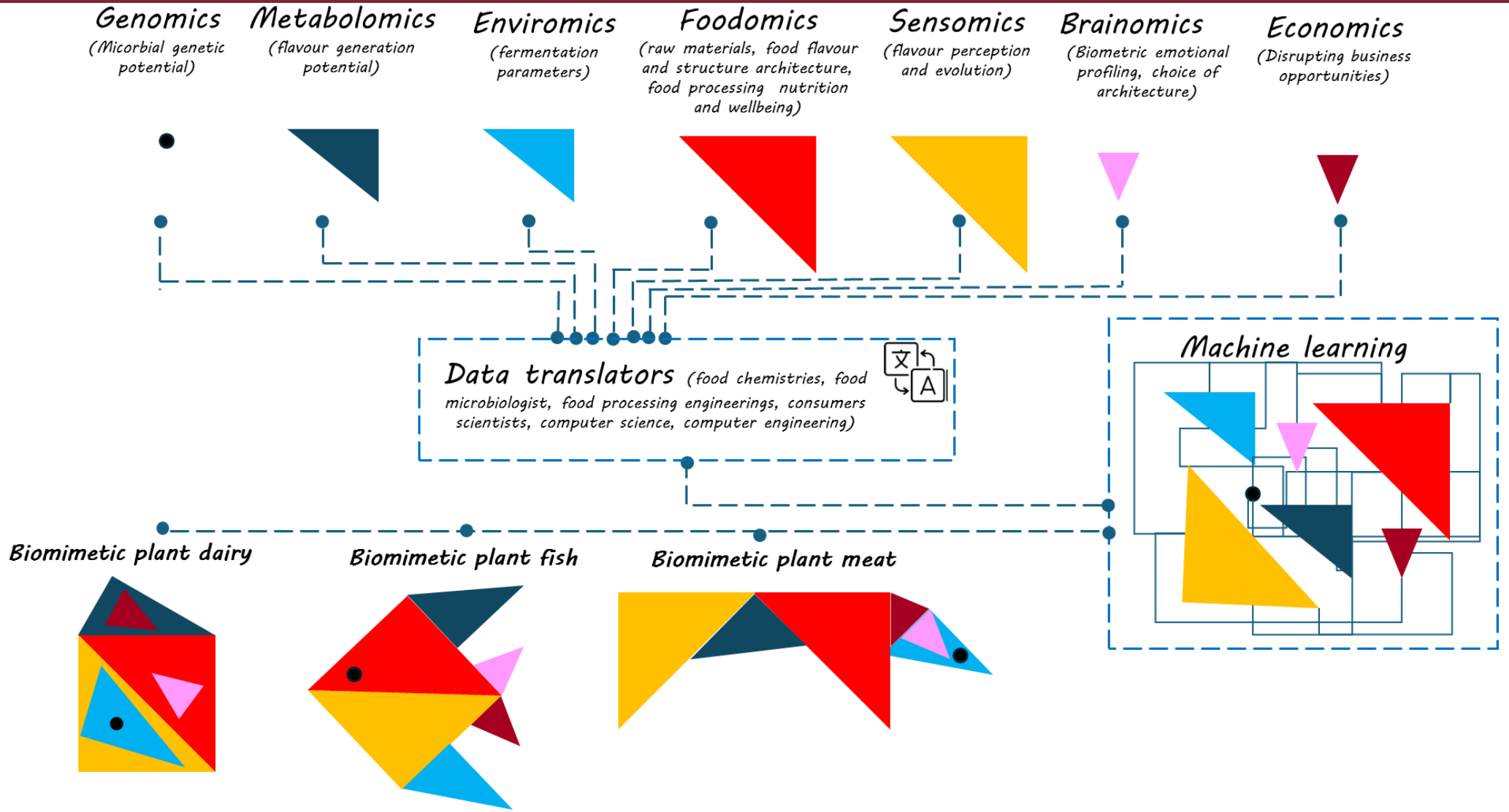
1999

.....so.....

Can Food Fermentation Drive Vulnerable Traditions towards Resilient Innovations?

Yes.....but

Multidisciplinary strategies needed...



Thanks for your attention!

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