Greening the Plate: Mycotoxin Risks in Sustainable Food Systems Transition

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14th International Conference
Mycotoxins and Moulds

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National School of Public Health
NOVA UNIVERSITY LISBON

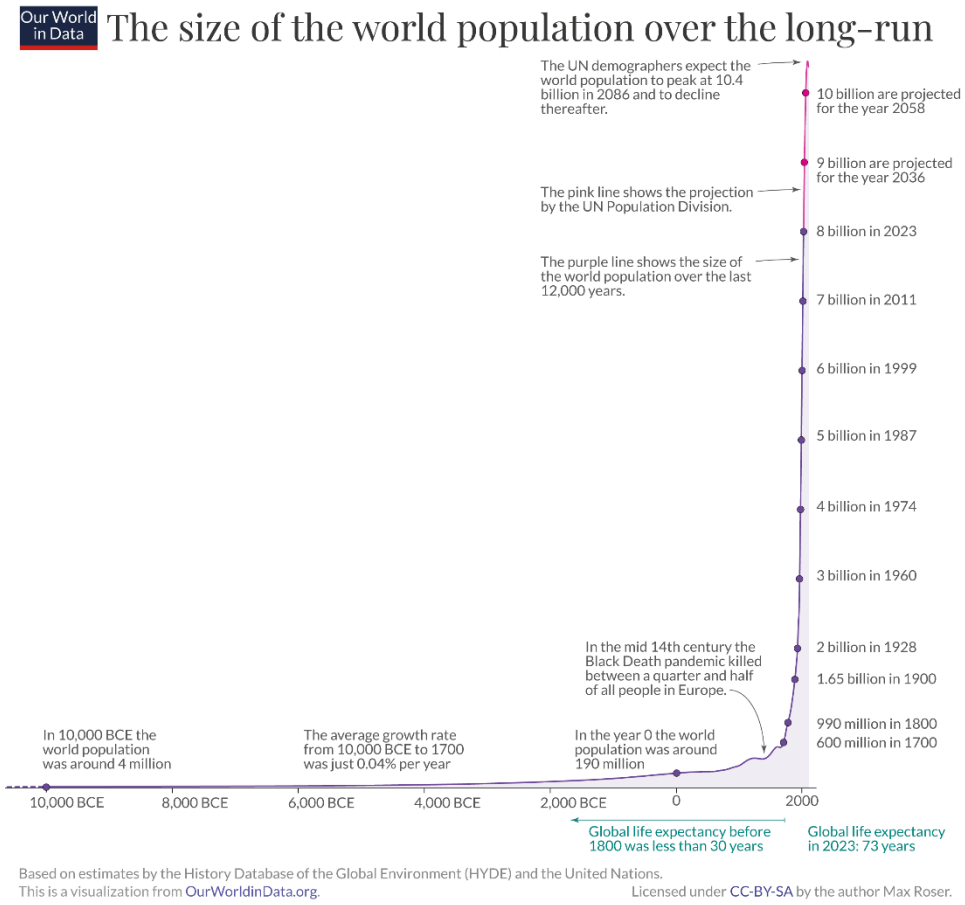
ESCOLA SUPERIOR DE TECNOLOGIA DA SAÚDE DE LISBOA
INSTITUTO POLITÉCNICO DE LISBOA

EGAS MONIZ CENTER for INTERDISCIPLINARY RESEARCH

Outline

- ☑ Environmental Impact of Food Systems
- ☑ Contributions of Food Systems to Climate Change
- ☑ Effects of Climate Change on Food Systems
- ☑ Transitioning to Sustainable Food Systems
- ☑ Sustainable Diets and Alternative Protein Sources
- ☑ Mycotoxins in Sustainable Food Systems

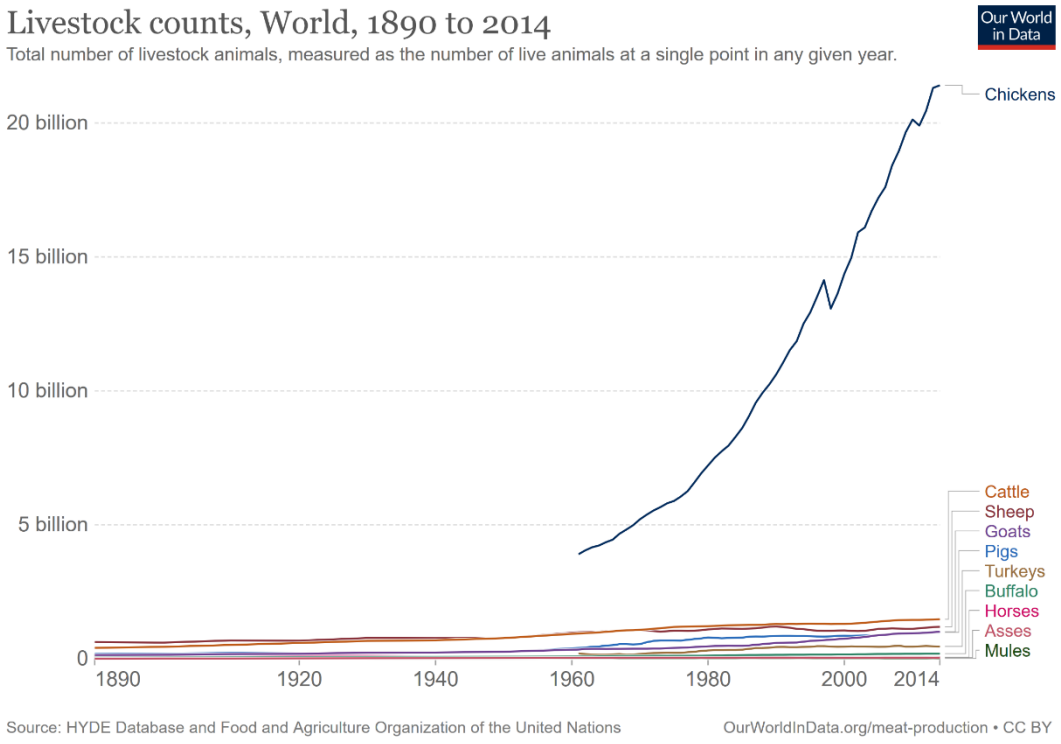
The world population is growing…



The world population has **changed dramatically** over the last few centuries

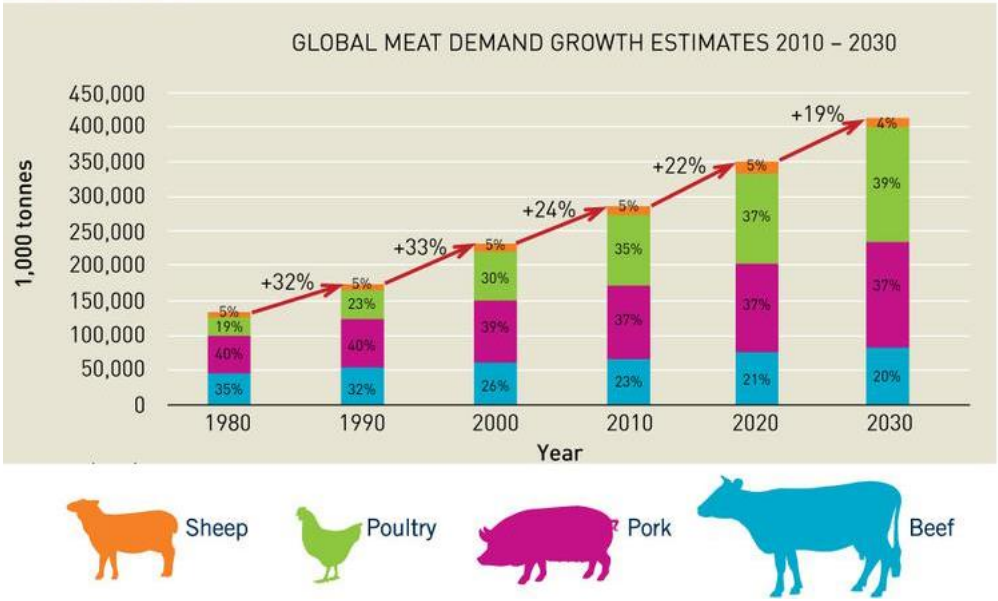
- **Increasing number** of people living on our planet
- The world population today is around **2 000 times the size** of what it was **12 000 ago** when it was around 4 million — less than half of the current population of London

Growing of the animal population…



"According to recent FAO work using longer term population and income projections, global food production needs to increase more than 40% by 2030 and 70% by 2050, compared to average 2005-07 levels." *OECD-FAO Agricultural Outlook 2009-2018*

Source: Rabobank (2011)



https://praedium.com.au/news

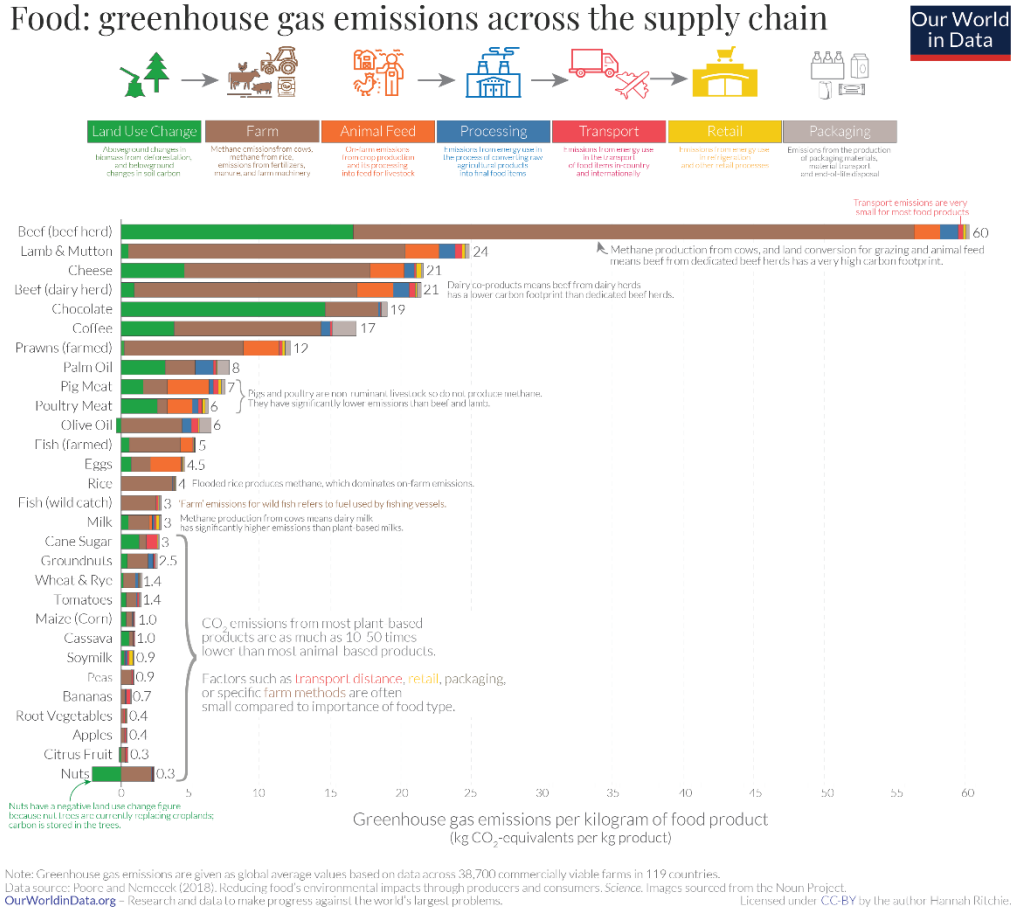
Food systems impacting environment

- Pressure food systems exert to the **environment** has amplified over time
  - Growth of the human population
  - Changes in food consumption patterns
  - Intensification of production systems

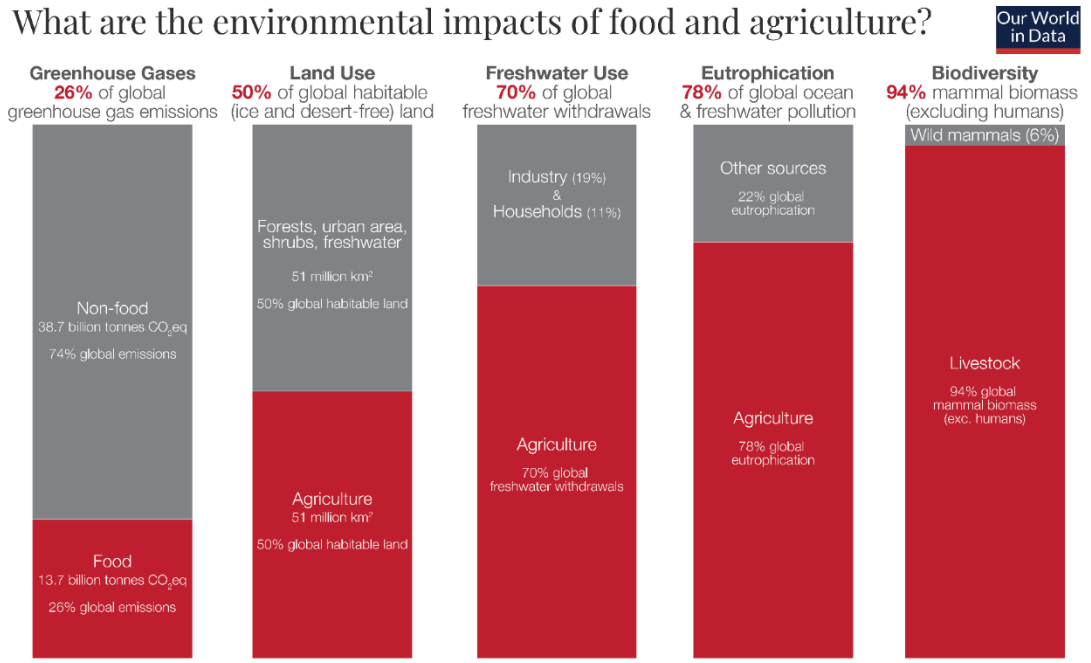
Animal-derived proteins
(e.g. meat and milk)

Fanzo & Davis, 2019; Fasolin et al., 2019; Aiking & de Boer, 2018; Tian, Bryksa, & Yada, 2016; Joyce, Dixon, Comfort, & Hallett, 2012

Pressure of the Food Systems in the Environment



Note: Greenhouse gas emissions are given as global average values based on data across 38,700 commercially viable farms in 119 countries.
Data source: Poore and Nemecek (2018). Reducing food's environmental impacts through producers and consumers. Science. Images sourced from the Noun Project.
OurWorldinData.org – Research and data to make progress against the world's largest problems. Licensed under CC-BY by the author Hannah Ritchie.



Data sources: Poore & Nemecek (2018); UN FAO; UN AQUASTAT; Bar-On et al. (2018).
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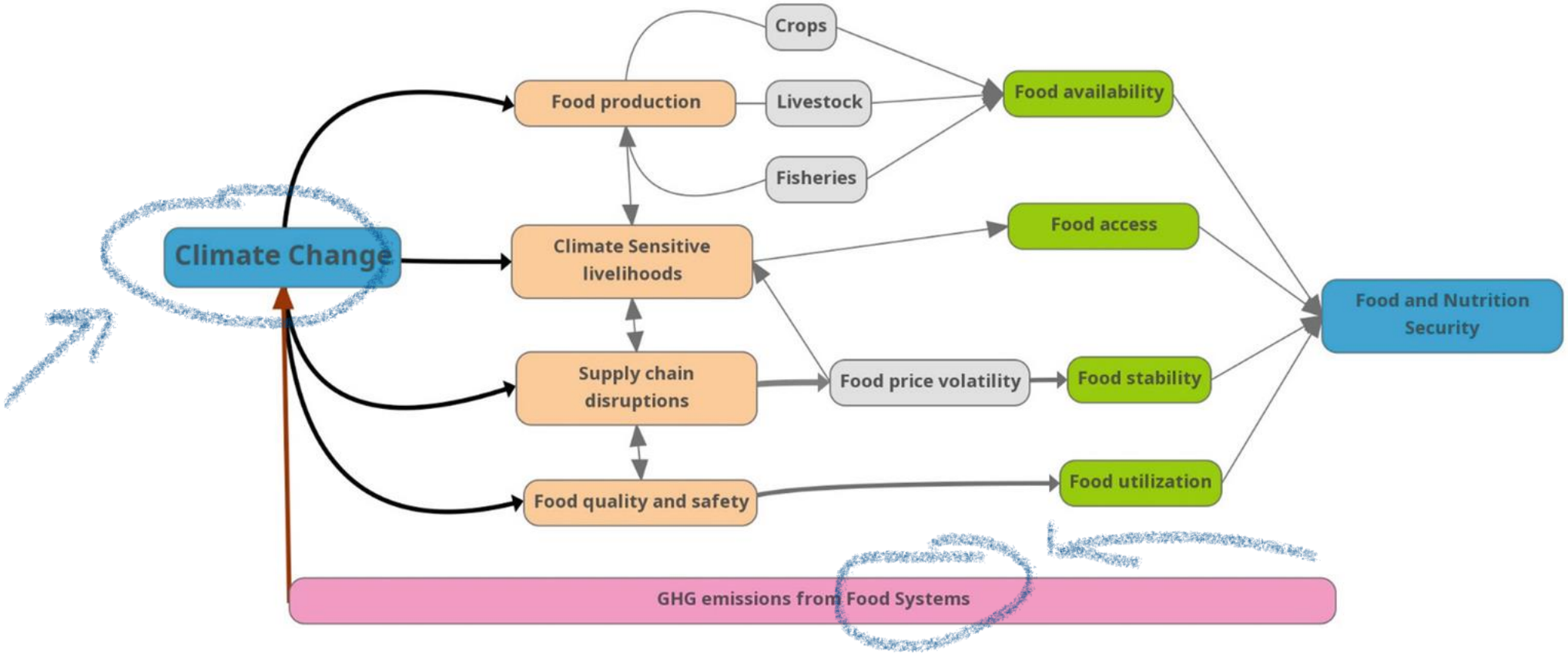
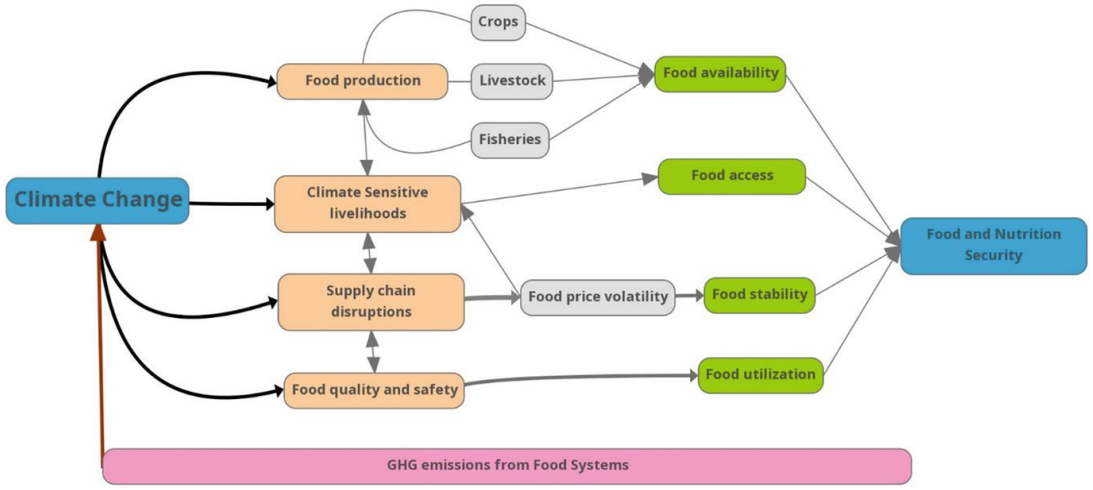
Food Systems & Climate Change



Mirzabaev et al. (2023). Climate Change and Food Systems. In: von Braun, J., Afsana, K., Fresco, L.O., Hassan, M.H.A. (eds) Science and Innovations for Food Systems Transformation. Springer, Cham. https://doi.org/10.1007/978-3-031-15703-5_27

Food systems contribute to climate change



- Food systems contribute to climate change through **GHG emissions** (directly/indirectly):
  - Agricultural production
  - Deforestation
  - Energy use
  - Livestock production
  - Food processing and transportation
  - Food waste
  - …

Mirzabaev et al. (2023). Climate Change and Food Systems. In: von Braun, J., Afsana, K., Fresco, L.O., Hassan, M.H.A. (eds) Science and Innovations for Food Systems Transformation. Springer, Cham. https://doi.org/10.1007/978-3-031-15703-5_27

Food systems contribute to climate change

Human demand expressed in terms of equivalent land units or hectare-equivalentes — **global hectares (gha)** → each gha represents the anual capacity of a hectare of land (for example, crops, pastures, forests and fishing grounds) with world-average productivity to provide ecosystem services that are useful to people

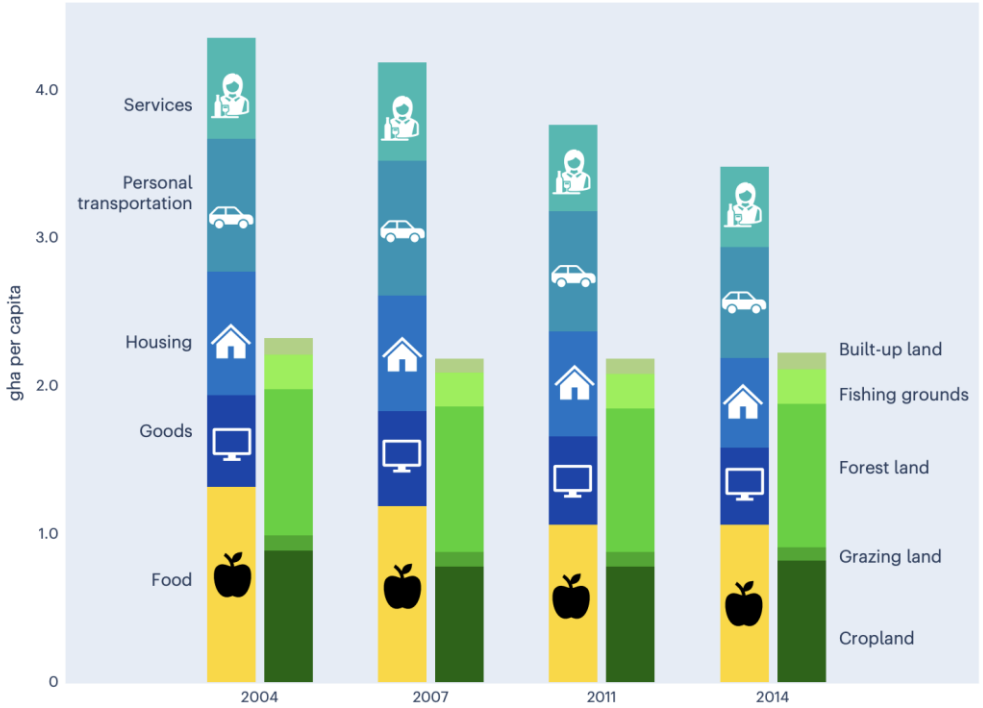


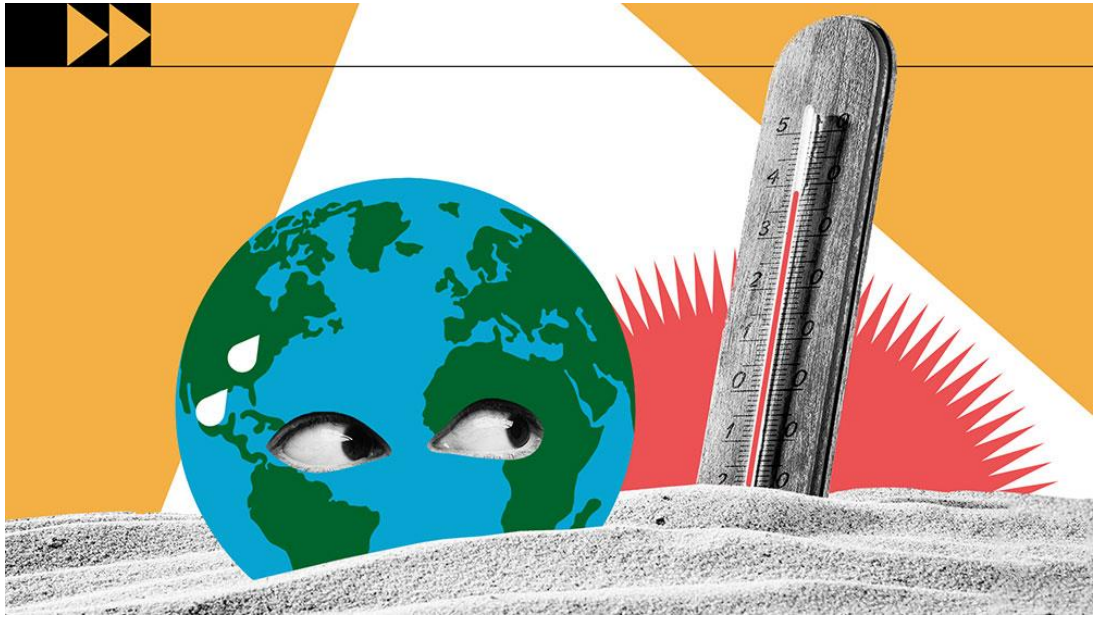
Fig. 1 | EU-27 EF by consumption categories (left) and BC by land types (right) in selected years (2004–2014). The EF consists of five major categories: food, goods, housing, personal transportation and services. Food, in turn, includes a number of food typologies, that is, bread and cereals; milk, cheese and eggs; fruit; meat; plant-based oils and fats; vegetables; non-alcoholic beverages; fish and seafood; animal-based oils and fats; sugar, jam, honey, chocolate, confectionery and alcoholic beverages; food products not elsewhere classified (n.e.c.). This classification is based on the United Nations COICOP coding system. BC consists of five land types: cropland (for the provision of plant-based food, feeds and fibre products), grazing land (for the production of animal products); fishing grounds (for the production of fish products); forests (for the production of timber and other forest products, and for CO_2 sequestration); and built-up surfaces (for the provision of shelter and other urban infrastructures).

"EU citizens **demanded** on average a much **higher amount of biocapacity** (BC) to **sustain their overall consumption patterns** than what the **region could regenerate**, leading to an **ecological deficit**"

Galli, A., Antonelli, M., Wambersie, L. et al. EU-27 ecological footprint was primarily driven by food consumption and exceeded regional biocapacity from 2004 to 2014. Nat Food 4, 810–822 (2023). https://doi.org/10.1038/s43016-023-00843-5

Climate change impact on the food systems

https://www.un.org/en/climatechange/what-is-climate-change



Climate change

Impact on food and agriculture systems

Impact on **food security**
(access to sufficient, safe and nutritious food)

Impact on **food safety**
(assurance that food is prepared hygienically and will not cause any illness to the consumer)

IMPACT ON **PUBLIC HEALTH**

Assunção et al., 2020

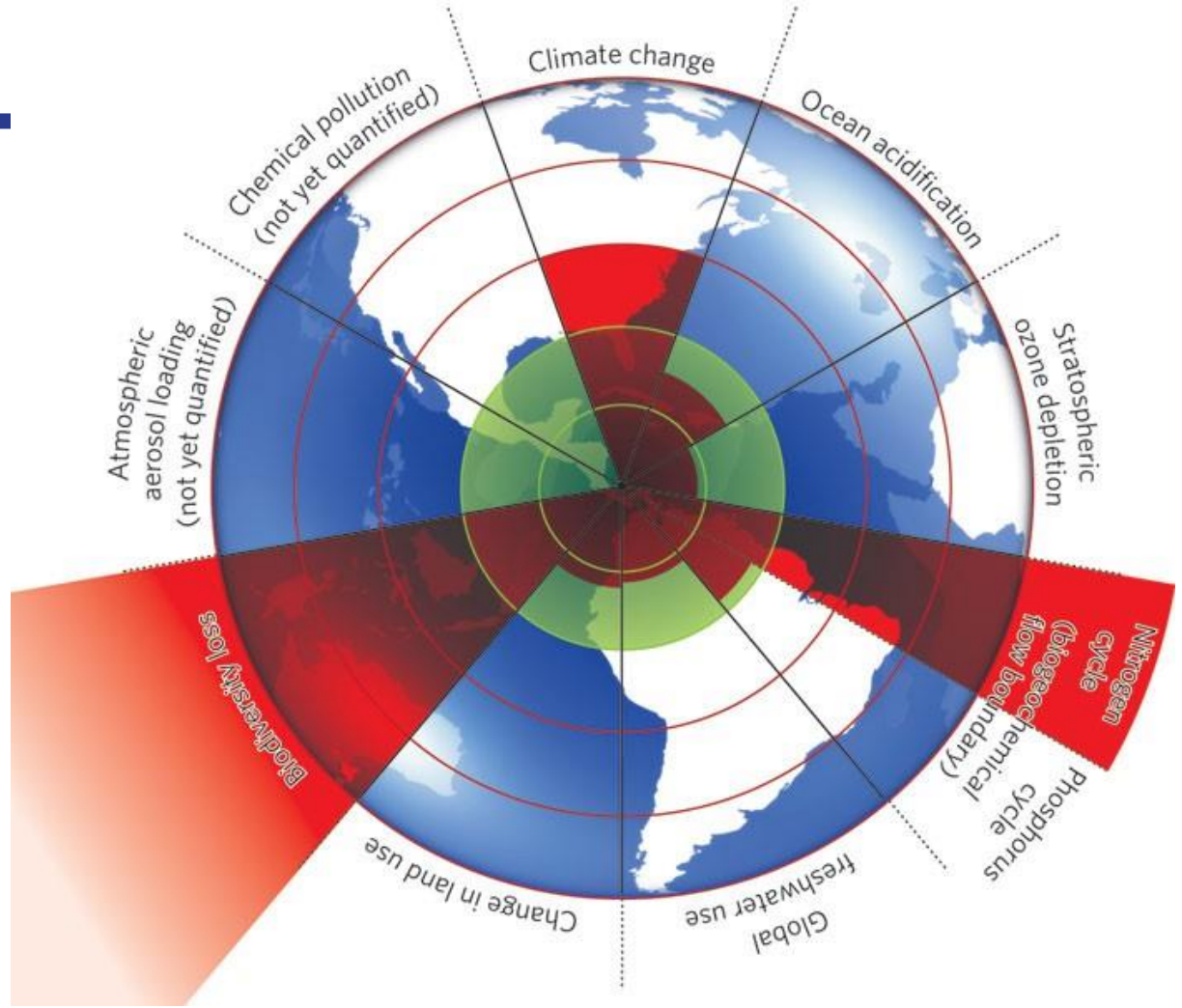
Climate change impact on the food systems

14 April 2022

The climate breakdown is already threatening many of our favorite foods. In Asia, **rice fields are being flooded** with saltwater; **cyclones have wiped out vanilla crops** in Madagascar; in Central America **higher temperatures ripen coffee** too quickly; **drought in sub–Saharan Africa is withering chickpea crops**; and **rising ocean acidity is killing oysters and scallops** in American waters

Planetary boundaries

Boundaries define the **safe operating space for humanity** with respect to the Earth system

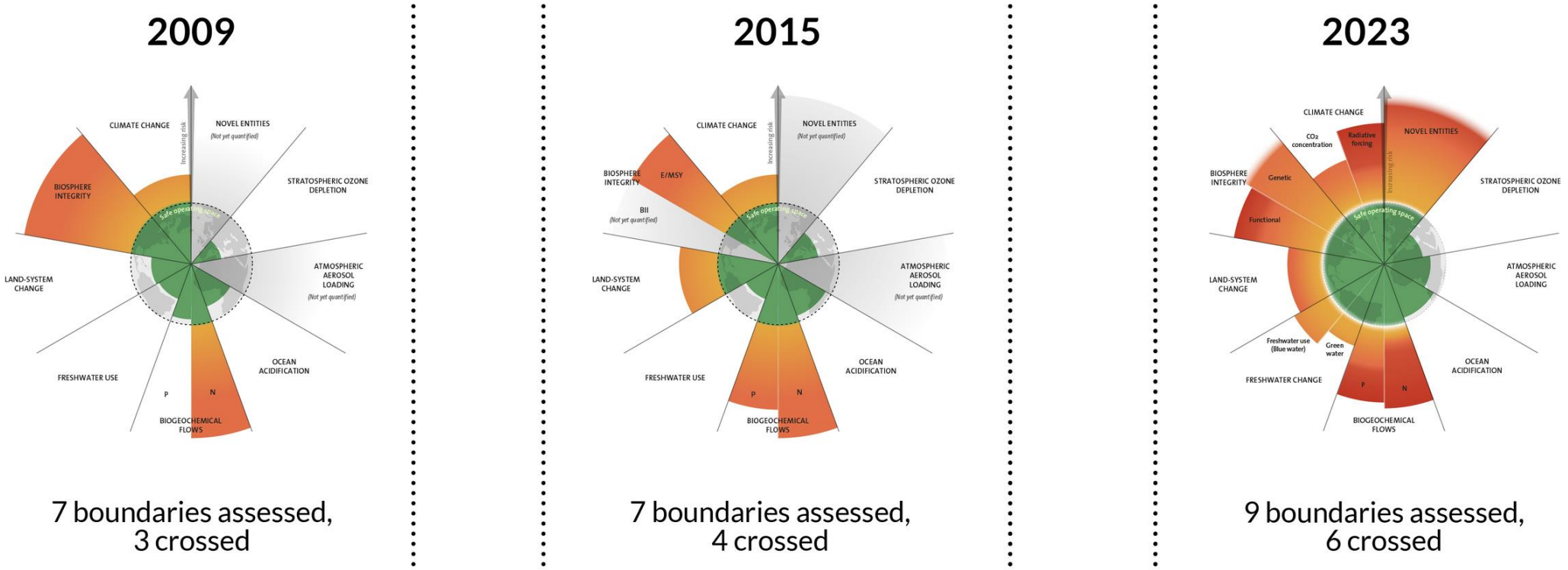


The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

Rockström, J., Steffen, W., Noone, K. et al. A safe operating space for humanity. Nature 461, 472–475 (2009). https://doi.org/10.1038/461472a

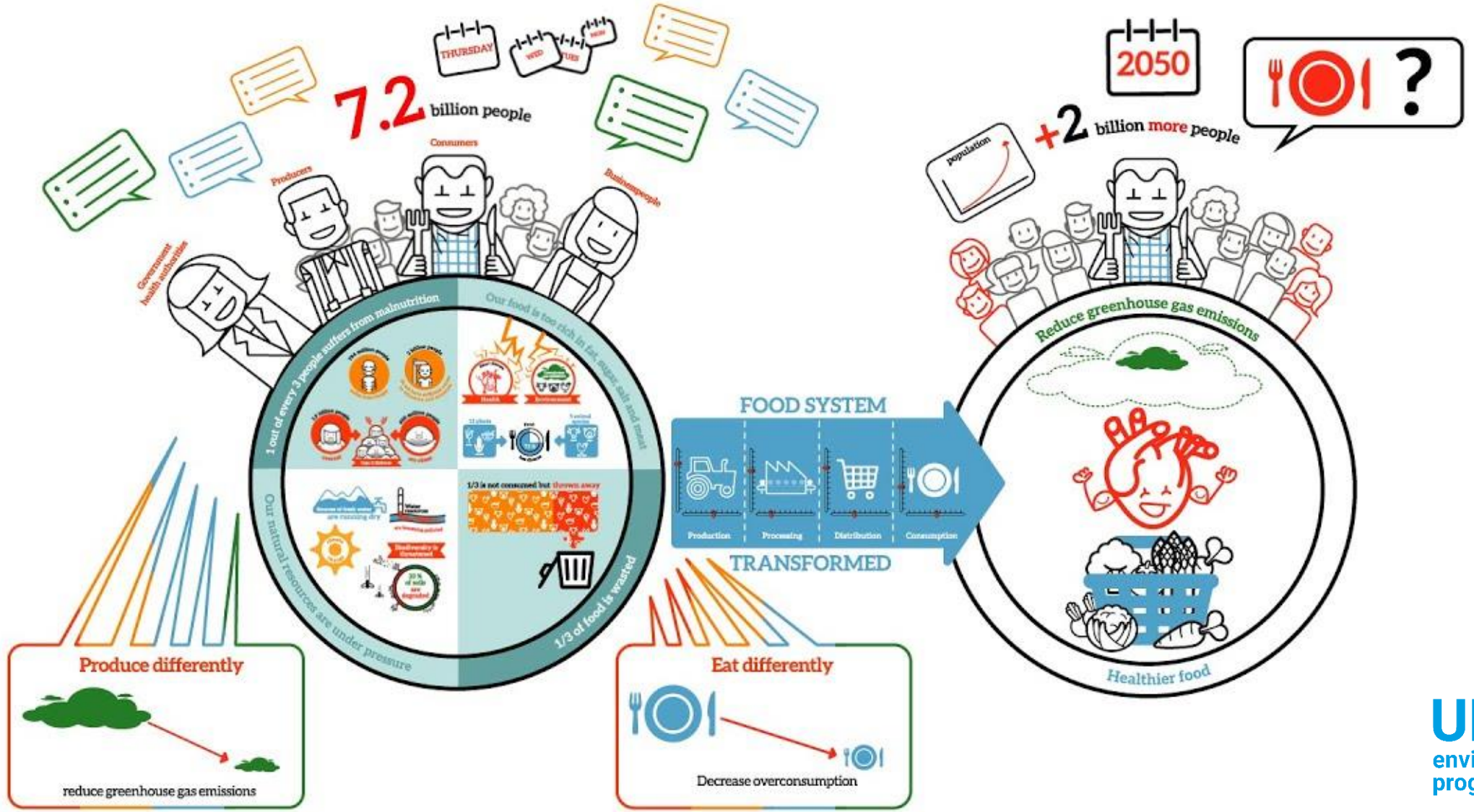
2009

Planetary boundaries



The evolution of the planetary boundaries framework. Licenced under CC BY-NC-ND 3.0
(Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009)

https://www.stockholmresilience.org/research/planetary-boundaries.html

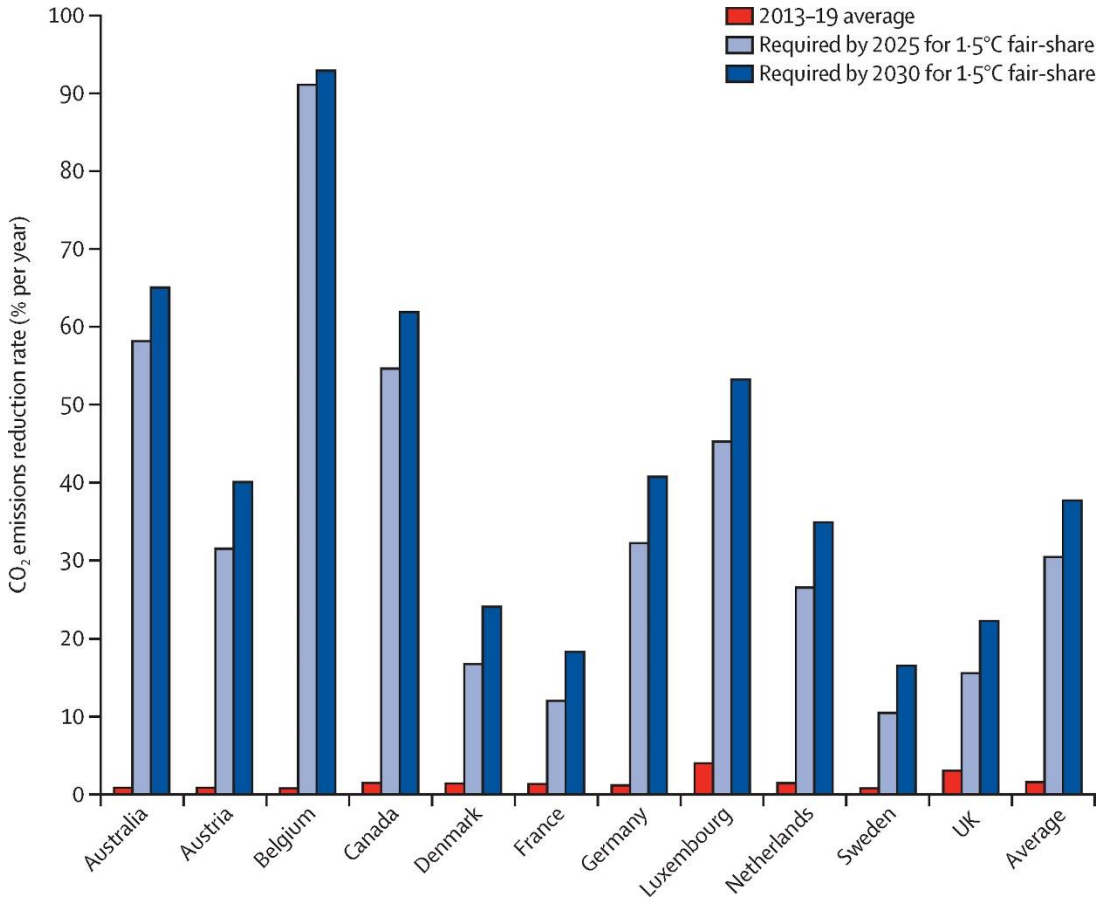


UN environment programme

Why do we need to change our food system?

YouTube https://youtu.be/VcL3BQeteCc

Is this transition (properly) occurring?



Red bars: indicate 2013–19 average year-on-year emission reduction rates

For the 1.5°C fair-share emissions pathways:

Light blue: required year-on-year emission reduction rates 2025

Dark blue: required year-on-year emission reduction rates 2030

Average: refer to the population-weighted average of the 11 high-income countries

Is green growth happening? An empirical analysis of achieved versus Paris-compliant CO2–GDP decoupling in high-income countries
Vogel and Hickel (2023). Lancet Planet Health 2023;7: e759–69. DOI:10.1016/S2542-5196(23)00174-2

How should we do this transition?

How should we do this transition?

Greening the plate!!!

https://www.thegrocer.co.uk/sustainability-and-environment/food-eco-labels-is-it-wise-to-let-industry-mark-its-own-homework/686285.article

Sustainable diets

Sustainable Healthy Diets are dietary patterns that promote all dimensions of individuals' health and well-being; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable

https://www.bda.uk.com/food-health/your-health/sustainable-diets.html

FAO and WHO. 2019. Sustainable healthy diets – Guiding principles. Rome. https://www.fao.org/3/ca6640en/ca6640en.pdf

BDA The Association of UK Dietitians

Planetary Health Diet | EAT-Lancet

- Diet healthy for both people and planet
- Plant-forward diet
  - Whole grains
  - Fruits
  - Vegetables
  - Nuts
  - Legumes

  comprise a greater proportion of foods consumed
  - Meat and dairy → small proportions

https://eatforum.org/eat-lancet-commission/the-planetary-health-diet-and-you/

Mycotoxins contamination of the foods integrating sustainable diets?

Protein sources of plant origin

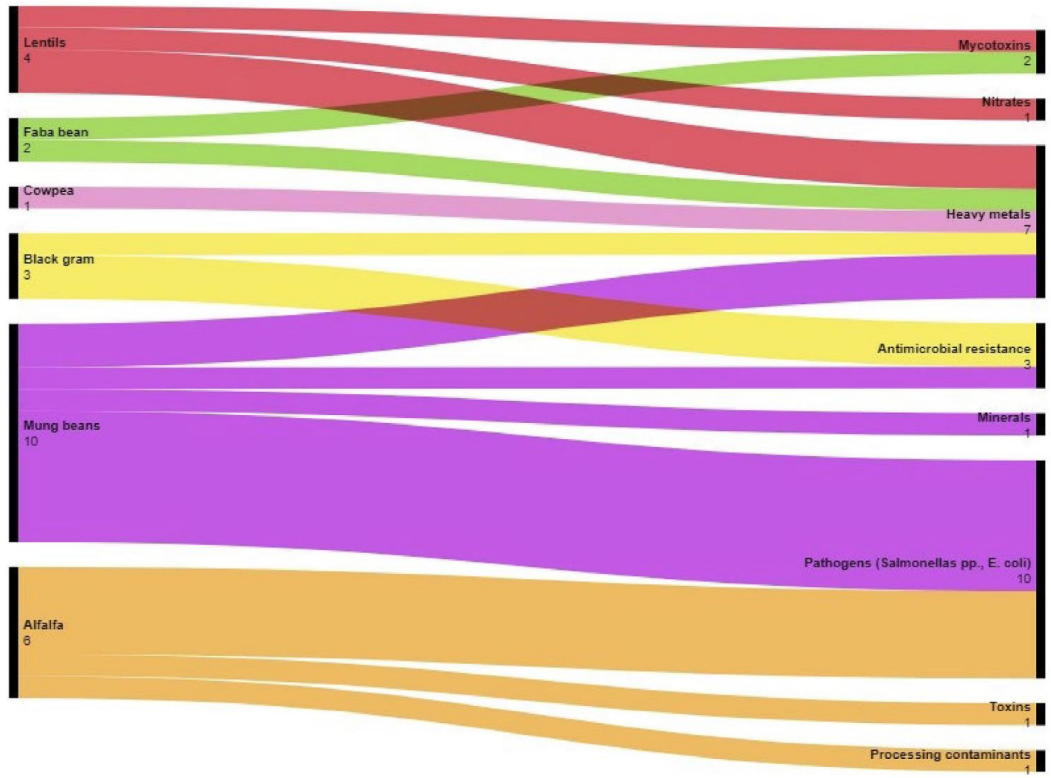


FIGURE 2 Sankey diagram displaying the distribution of papers between the soil-based protein sources and the different topics. The height of the nodes (black rectangles) and the width of the arrows (curved lines) represent flow rate of each "protein source—hazard" pair, that is, higher nodes and wider arrows indicate a larger number of papers. *Source*: RAWGraphs 2.0.

Lentil foods contained mycotoxins (deoxynivalenol: 1.69 µg/kg, β-zearalanol: 2510 µg/kg)

Faba beans contained mycotoxin HT-2 toxin (1.96 – 4.71 µg/kg)

TABLE 6 Mycotoxins occurrence in commercial meat-analogues (µg/kg, upper levels).

	Soy	Pea	Chickpea	Lupin
AFB1	10.1 (m)		4.2 (f)	7.1 (m)
AFB2	0.89 (f)		0.4 (f)	
AFG1	1.76 (f)		0.4 (f), 1.8 (m)[2]	
AFG2	100.2 (m), 1.77 (f)[2]		0.4 (f)	1.9 (m)
FB1	260.5 (m)	39.4 (m)	53.8 (m)	40.3 (m)
FB2	5.1 (m)	39 (m)	19.2 (m)	1.4 (m)
AOH	184.4 (m; a)	11.3 (m)	5.6 (m)	
AME	207.5 (m; a)	5.4 (m)	2.1 (m)	0.34 (m)
TEN	10.2 (m)		5.2 (m)	3.1 (m)
ZEN	214 (pp)			
OTA	8.6 (m),2.26 (pp)[2]	4.9 (m)	7.9 (m)	
DON	367.5 (m)			
ENA	323.81 (m; a)			
T2	251.3 (f), 32 (pp)			
HT2	11 (pp)			
STO	25 (f)			
MAS	19.5 (pp)			
DAS	21 (pp)			

Abbreviations: a, average content; AFB1, AFB2, AFG1, AFG2, aflatoxin B1, B2, G1, G2; AME, alternariol monomethyl ether; AOH, alternariol; DAS, diacetoxyscirpenol; DON, deoxynivalenol; ENA, enniatin A; f, flour; FB1, FB2, fumonisin B1, B2; m, meat analogues; MAS, monoacetoxyscirpenol; OTA, ochratoxin A; pp, protein products (i.e., textured, concentrate, and isolate); STO, scirpentriol; T2, HT2, toxin T2, HT2; TEN, tentoxin; ZEN, zearalenone.
Source: References: Mihalache et al., 2023, 2022.

Milana et al., 2024. The chemical and microbiological safety of emerging alternative protein sources and derived analogues: A review. *Comprehensive Reviews in Food Science and Food Safety*, 23, e13377. https://doi.org/10.1111/1541-4337.13377

Edible insects

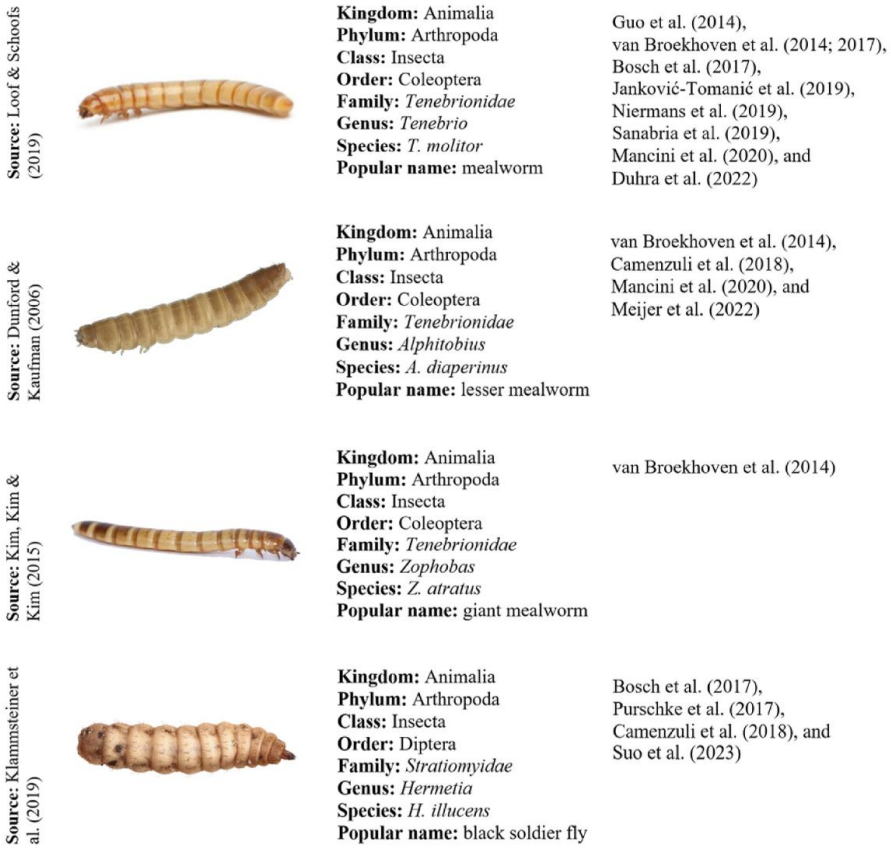


Fig. 3. Edible insect species (larvae) investigated for mycotoxin contamination.

- Tend to be contaminated by the **substrate used** for their breeding and development or by **improper processing and storage** operations

Insect	Mycotoxins	Contamination levels	Reference
T. molitor	Alternariol (AOH)	< 15 µg/Kg	Paepe et al. (2019)
	HT-2	> 15 µg/Kg	
	Roquefortine C	< 30 µg/Kg	
H. illucens	ZEN	60 µg/Kg	
L. migratoria	Nicarbazin	> 100 µg/Kg	
	NIV	3–6 µg/Kg	
Caterpillars	AF	3–25 µg/Kg	Kachapulula et al. (2018)
Termites	AF	16–37 µg/Kg	

Bisconsin-Junior et al., 2023. Mycotoxins on edible insects: Should we be worried? *Food and Chemical Toxicology*, *177*, 113845. https://doi.org/10.1016/j.fct.2023.113845

InsectERA

AGENDA MOBILIZADORA

Insectera

Novo setor bioindustrial

- Alternative food/nutritional solutions
  - Increase in the world's population
  - Climate change
  - Food waste
  - Environmental sustainability ↔ circular economy

https://www.insectera.pt/english/

InsectERA

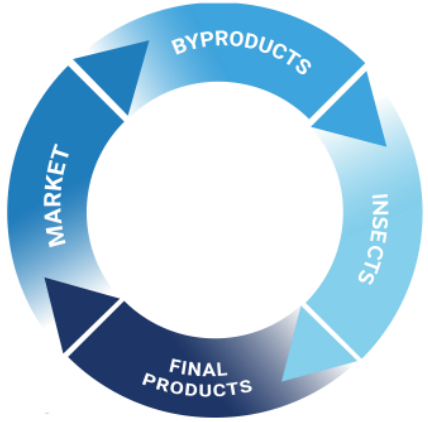
AGENDA MOBILIZADORA

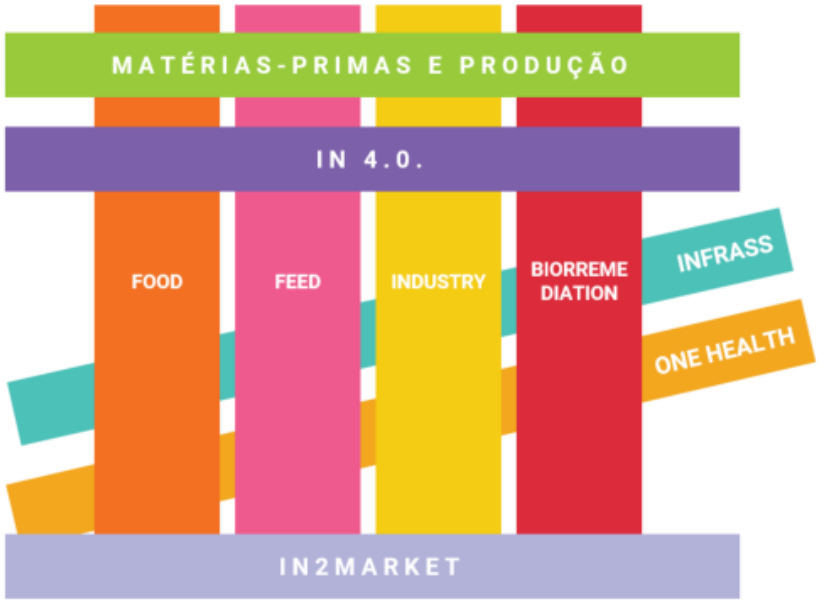
Insectera

Novo setor bioindustrial

- Assessing the impact of insects (new foods, feeds) in health and sustainability

MYCOTOXINS





https://www.insectera.pt/english/

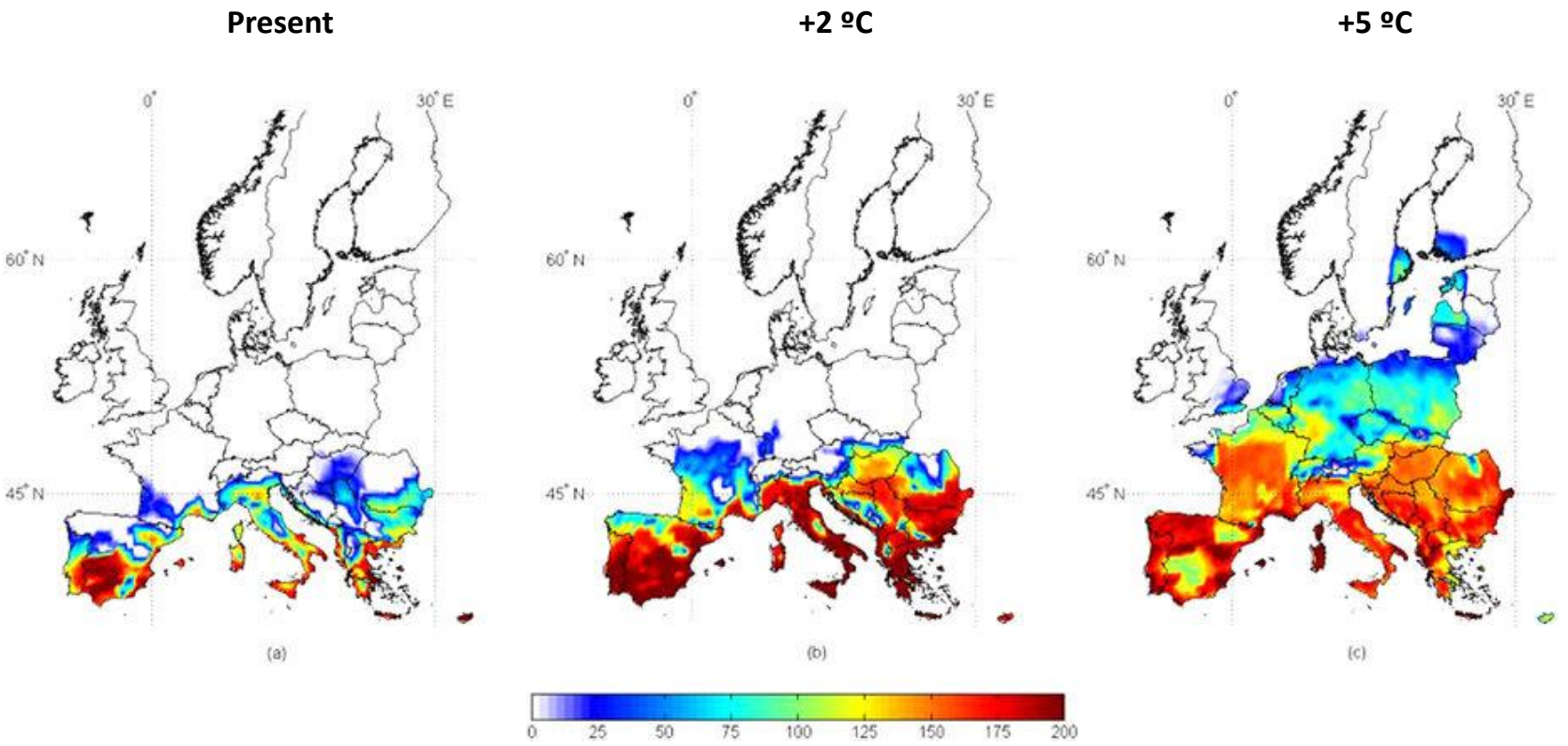
What about the impact of Climate Change?

Climate change – different health impacts

- Climate change → possible food safety impacts
- Foodborne Disease Agents (Bacteria, Viruses and Parasitic)

- Zoonosis and animal diseases
- **Toxigenic Fungi and Mycotoxin Contamination**
  - Naturally occurring toxins produced by fungi, affecting humans and animals
  - Food & feed are considered the main exposure sources

AFB_1 contamination in maize, within next 100 years, in Europe



Batilani et al., 2016, *Scientific Reports* **6**, 24328. doi:10.1038/srep24328

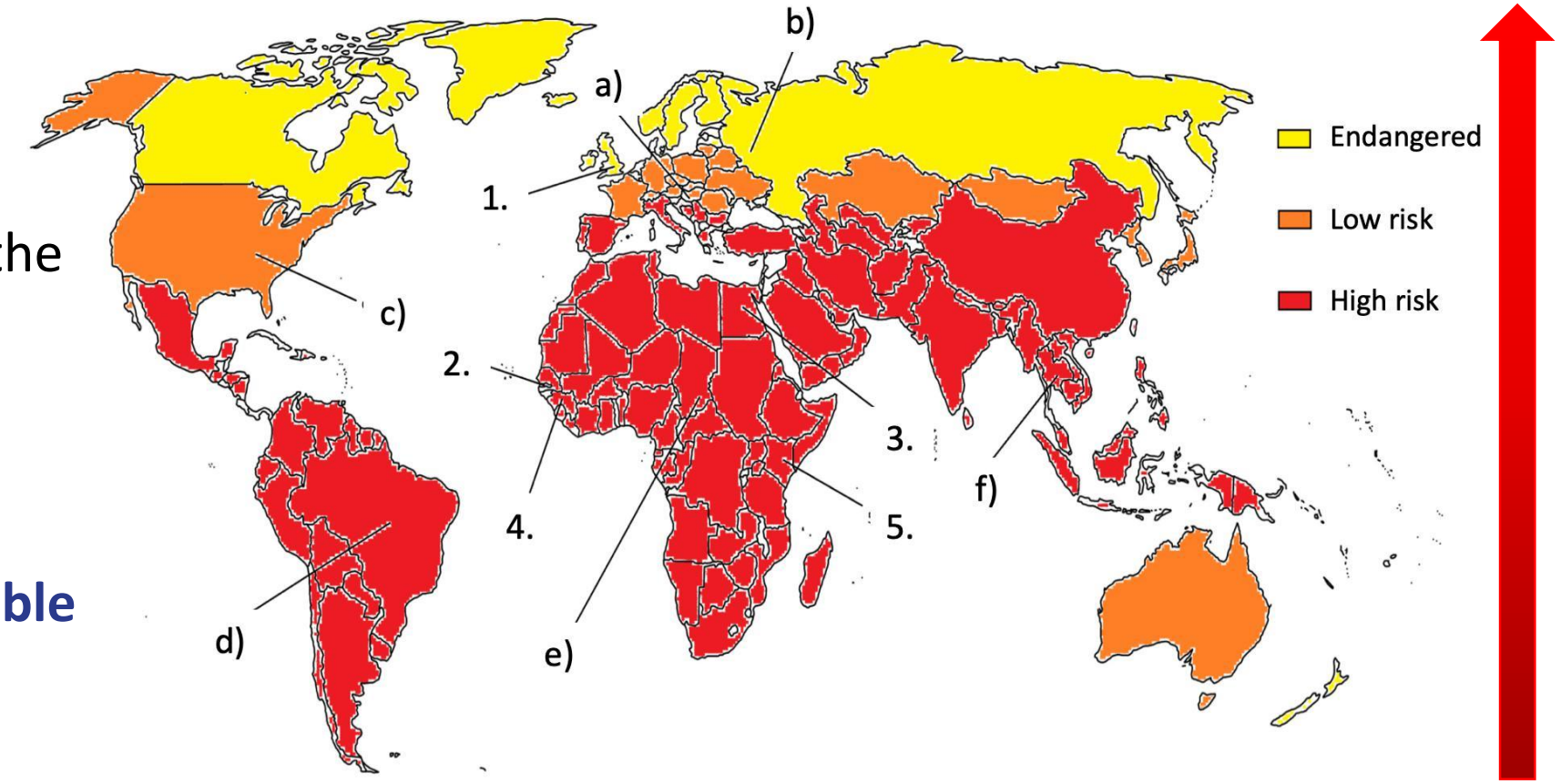
Risk maps for aflatoxin contamination in maize at harvest in 3 different climate scenarios, present, +2 °C, +5 °C.
Mean daily data used as input result from 100-year run of the predictive model AFLA-maize in 2254 geo-referenced points throughout Europe, in the 3 scenarios.

AFB_1 contamination in maize, within next 100 years, in Europe

What about the **alternative protein sources**?

And **Sustainable diets**?

Risks? **Benefits**?



Ráduly et al., 2020

Key aspects & Conclusions

- Various aspects of **food systems**, particularly those related to animal-derived proteins, exert significant **pressure on the environment**
- Food systems are both major contributors to **climate change** and highly vulnerable to its impacts
- Transitioning to **sustainable food systems** is essential for addressing climate change and mitigating environmental degradation
- Sustainable diets and alternative protein sources, such as insects and legumes, are vital for supporting the transition to sustainable food systems. However, they also pose potential risks, such as **mycotoxin contamination**
- While few studies have characterized mycotoxin contamination in alternative protein sources, these contaminants can still be **present in these food matrices**
- Climate change may increase the risk of mycotoxin exposure, highlighting the need for effective **risk-benefit assessment and management strategies**

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Thank you!

Dziękuję

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