Epidemiology of Food Systems, Climate Change and Malnutrition

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Outline

- Burden of Disease and Risk Factors affecting Human Health
- Sustainable Development Goals
- Food Systems and Planetary Health
  - Food systems and climate change
  - Climate change and food systems
  - Food systems, nutrition, and health
- Inter-relationships and Conclusion

- Why do food systems and climate change matter to you?

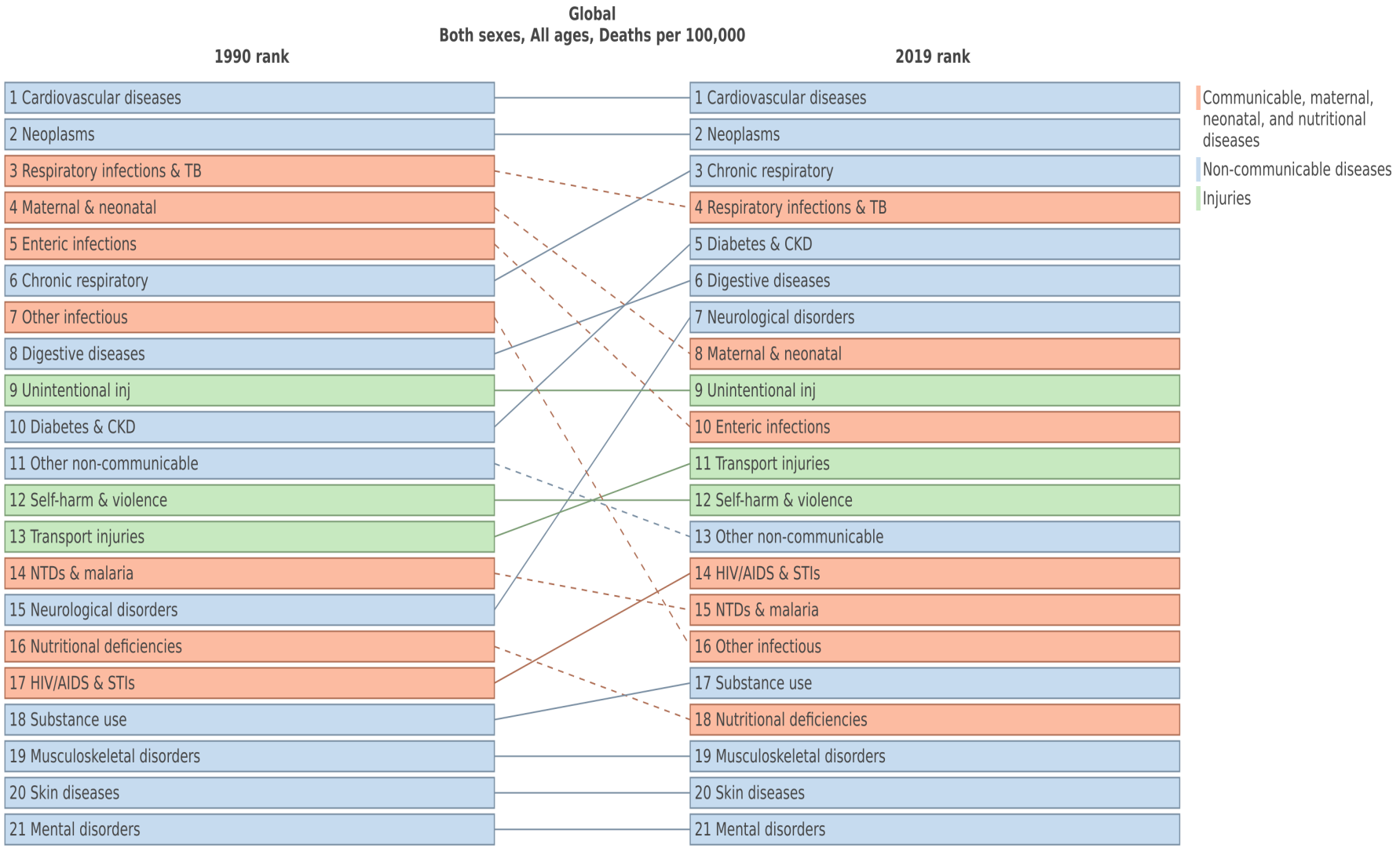
- Briefly state a problem that you are interested in and any population that is affected by that issue.

Impact of nutrition on disease

Malnutrition, encompassing both **over- and under-nutrition**, is a global problem with important consequences for **survival**, incidence of **acute and chronic diseases**, healthy **development**, and the economic **productivity** of individuals and societies.

Citations: Black 2013

Global causes of death



Citations: IHME 2019

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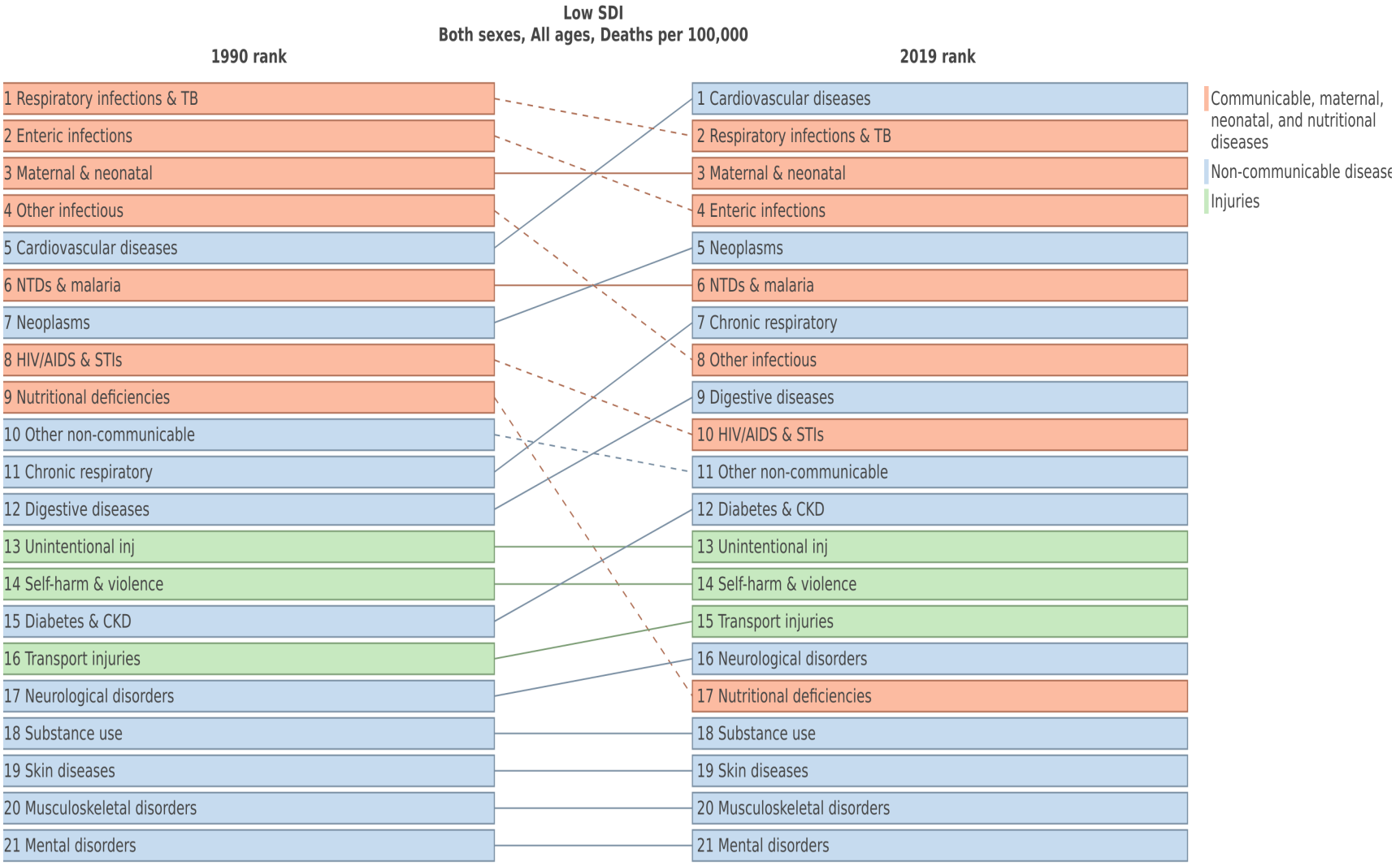
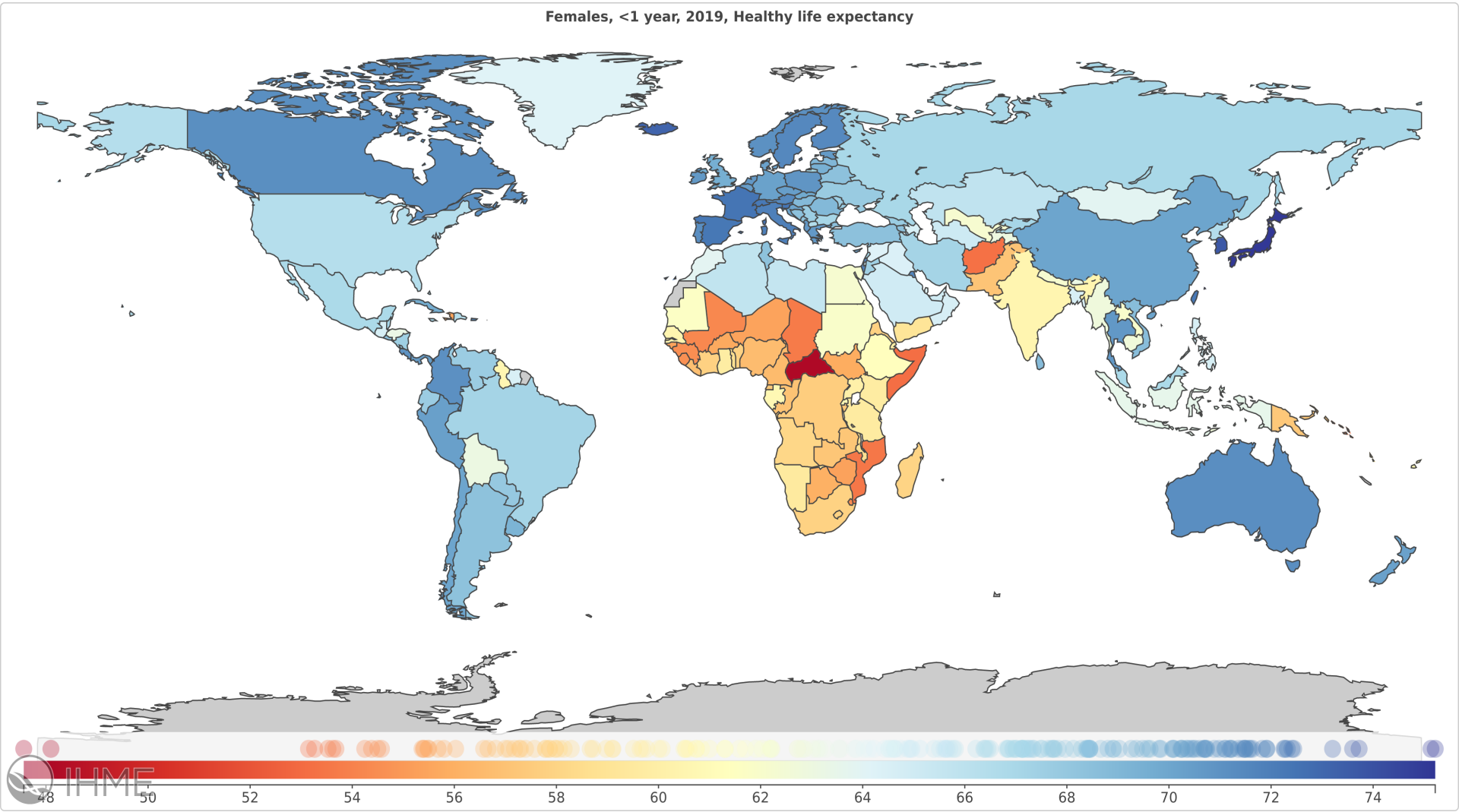
Global causes of death



Citations: IHME 2019

Global life expectancy (Females)



Citations: GBD 2019 Mortality Collaborators

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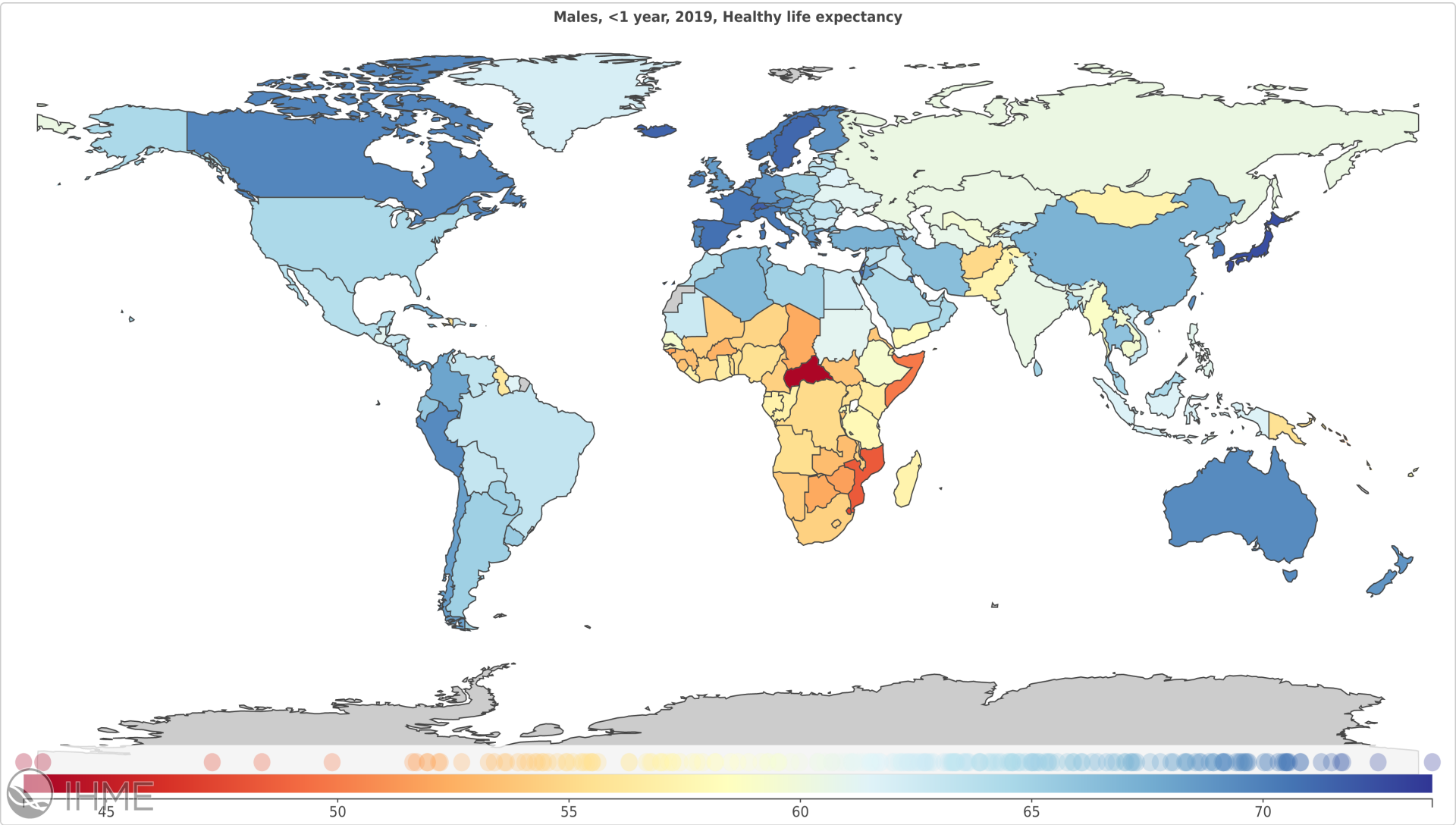
Global life expectancy (Males)



Citations: GBD 2019 Mortality Collaborators

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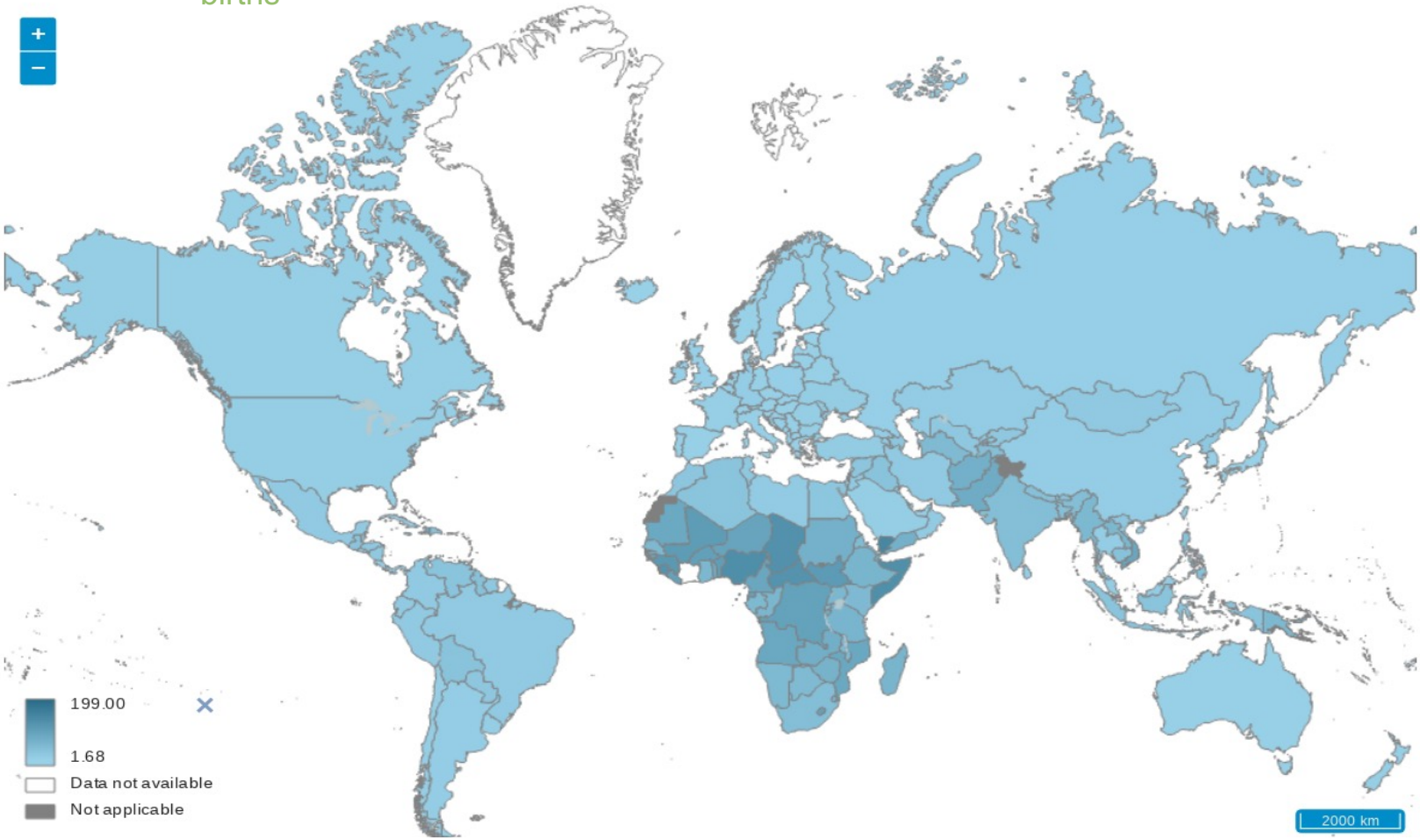
Global child mortality rate

Under-five mortality rate (probability of dying by age 5 per 1000 live births



Citations: WHO 2019

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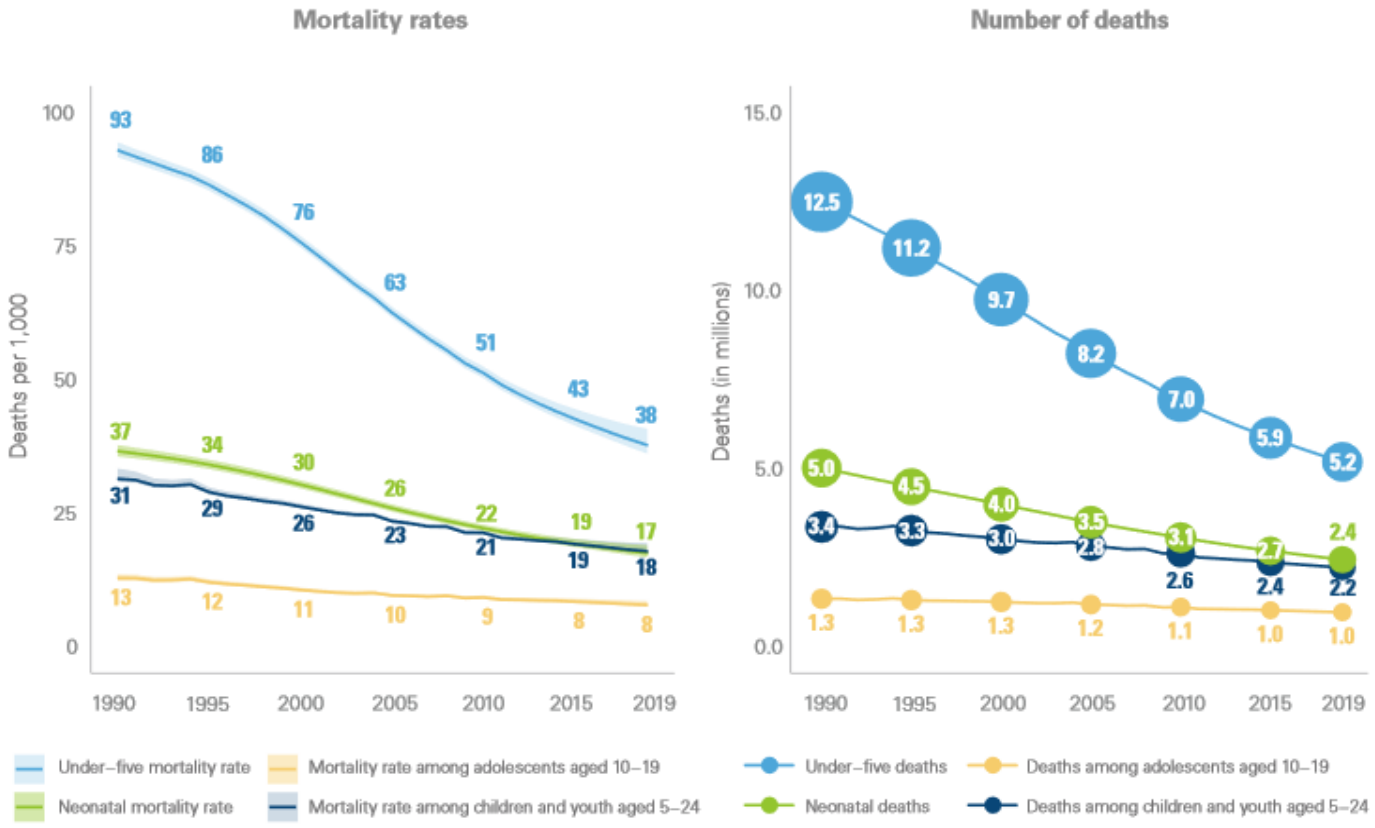
Mortality in early life

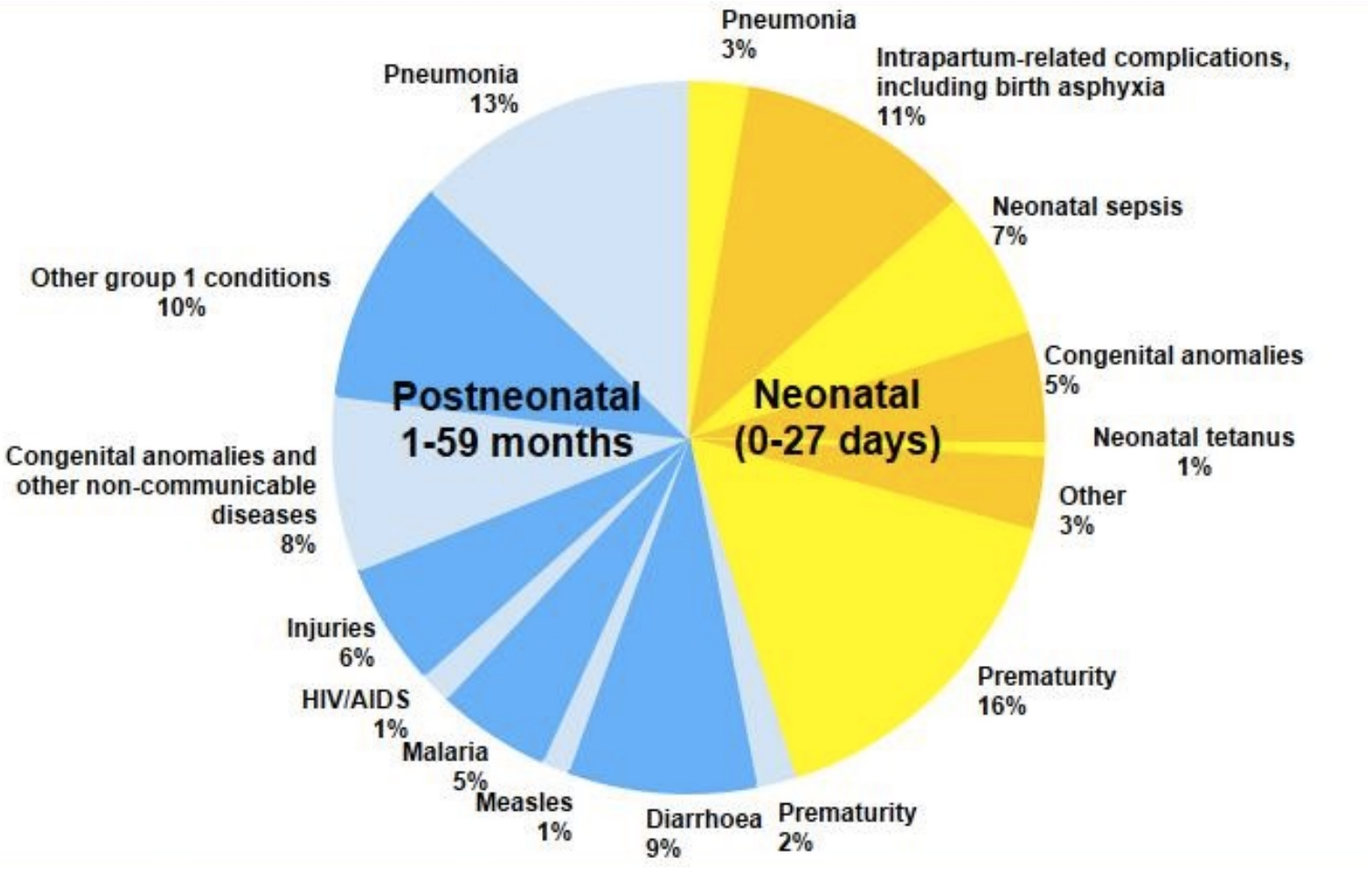
FIGURE 2 **Global mortality rates and number of deaths by age, 1990–2019**



Note: All figures are based on unrounded numbers. The solid line in the left panel represents the median estimate and the shaded area represents the 90 per cent uncertainty bound around the median value.

Citations: UNICEF 2020

Causes of child mortality



Citations: WHO 2016b

Nutrition and child mortality

	Attributable deaths with UN prevalences*	Proportion of total deaths of children younger than 5 years
Fetal growth restriction (<1 month)	817 000	11·8%
Stunting (1–59 months)	1 017 000*	14·7%
Underweight (1–59 months)	999 000*	14·4%
Wasting (1–59 months)	875 000*	12·6%
Severe wasting (1–59 months)	516 000*	7·4%
Zinc deficiency (12–59 months)	116 000	1·7%
Vitamin A deficiency (6–59 months)	157 000	2·3%
Suboptimum breastfeeding (0–23 months)	804 000	11·6%
Joint effects of fetal growth restriction and suboptimum breastfeeding in neonates	1 348 000	19·4%
Joint effects of fetal growth restriction, suboptimum breastfeeding, stunting, wasting, and vitamin A and zinc deficiencies (<5 years)	3 097 000	44·7%

Citations: Black 2013

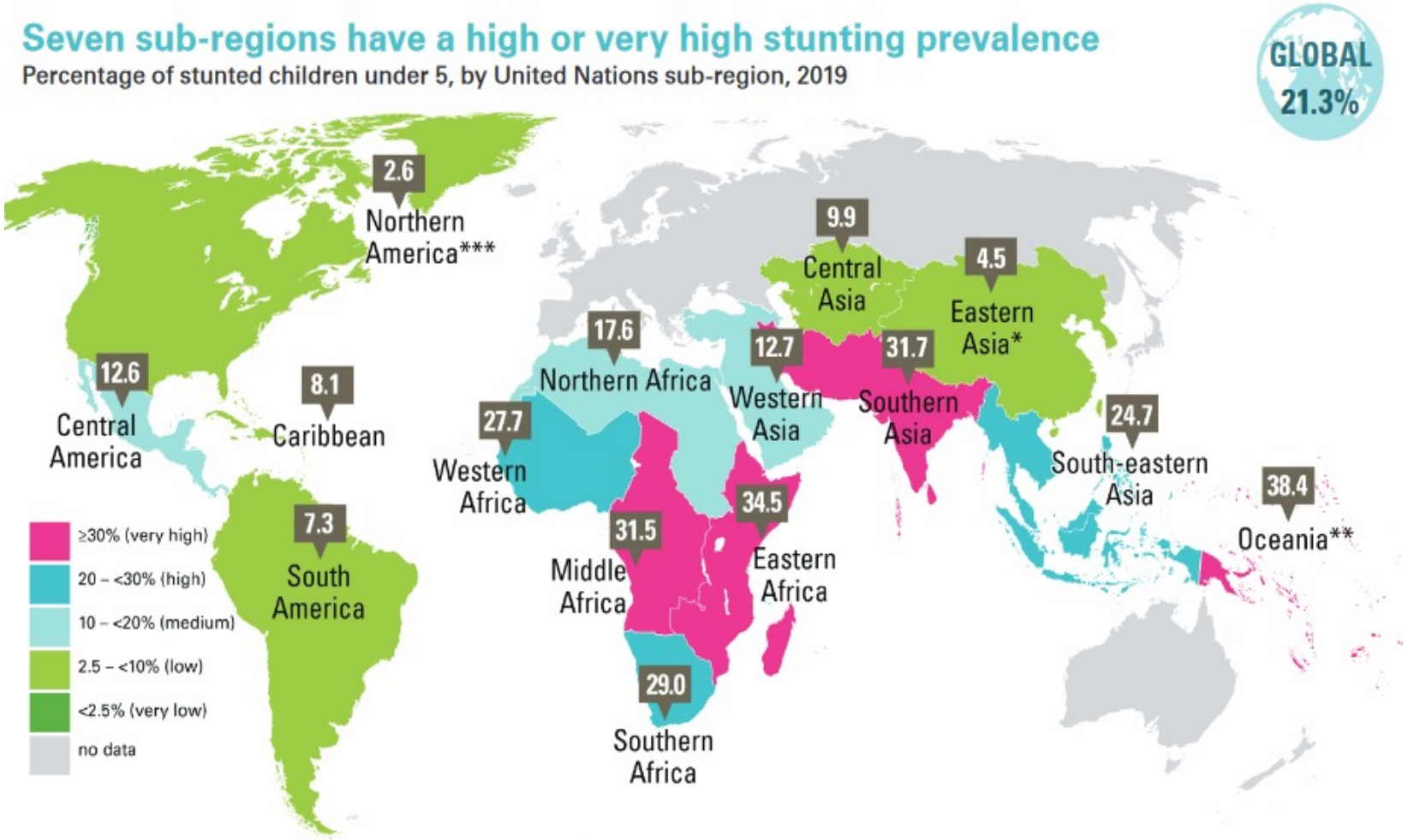
Question:

What is child stunting?

A. Low weight-for-height
B. Low height-for-age
C. Low weight-for-age
D. Low body mass index (BMI)

Stunting

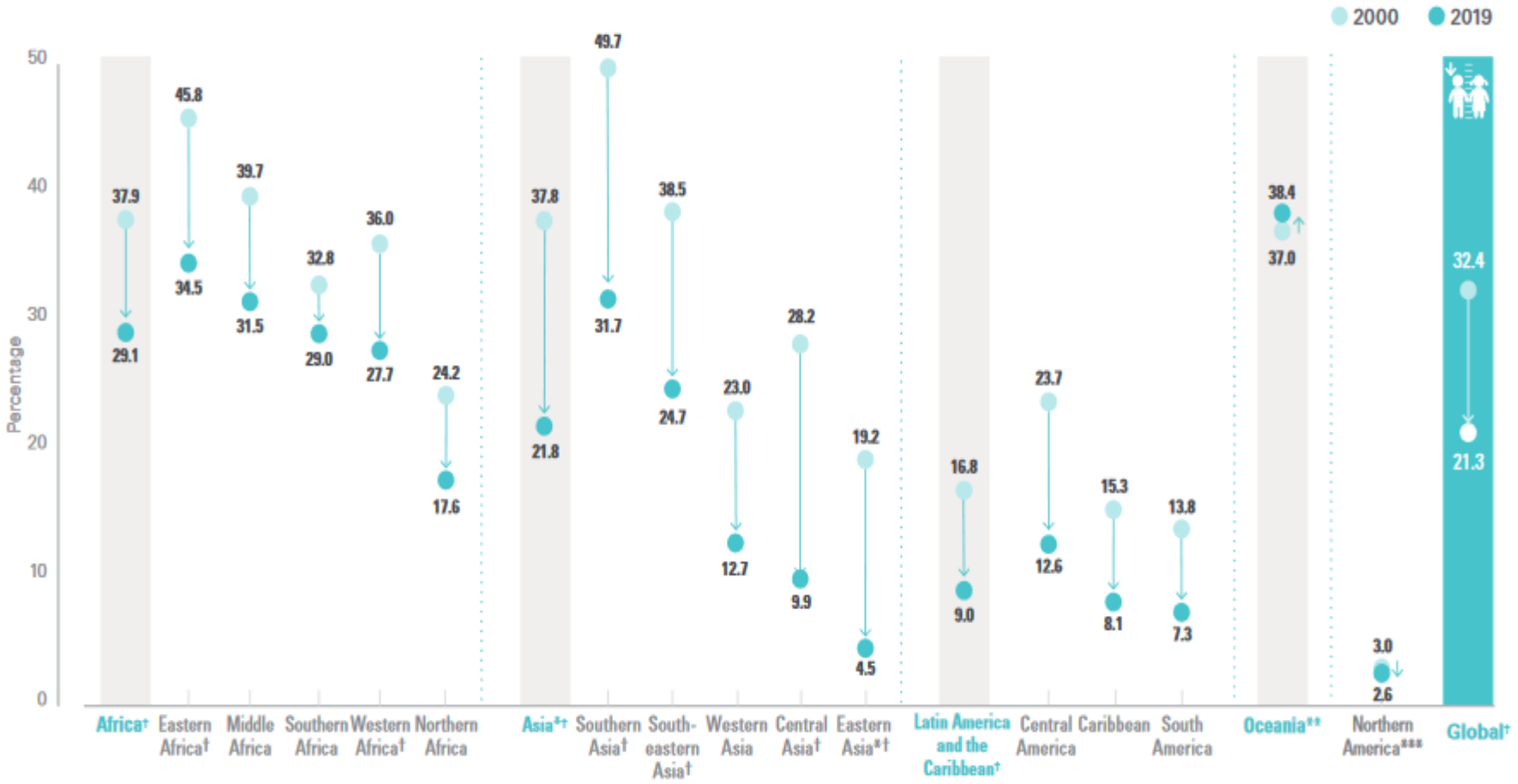
Global stunting burden (< 5y)



Source: UNICEF, WHO, World Bank Group joint malnutrition estimates, 2020 edition. Note: *Eastern Asia excluding Japan; **Oceania excluding Australia and New Zealand; ***Northern America sub-regional estimate based on United States data. There is no estimate available for the sub-regions of Europe or Australia and New Zealand due to insufficient population coverage. These maps are stylized and not to scale and do not reflect a position by UNICEF, WHO or World Bank Group on the legal status of any country or territory or the delimitation of any frontiers.

Citations: UNICEF/WHO/World Bank 2020

Global stunting burden (< 5y)

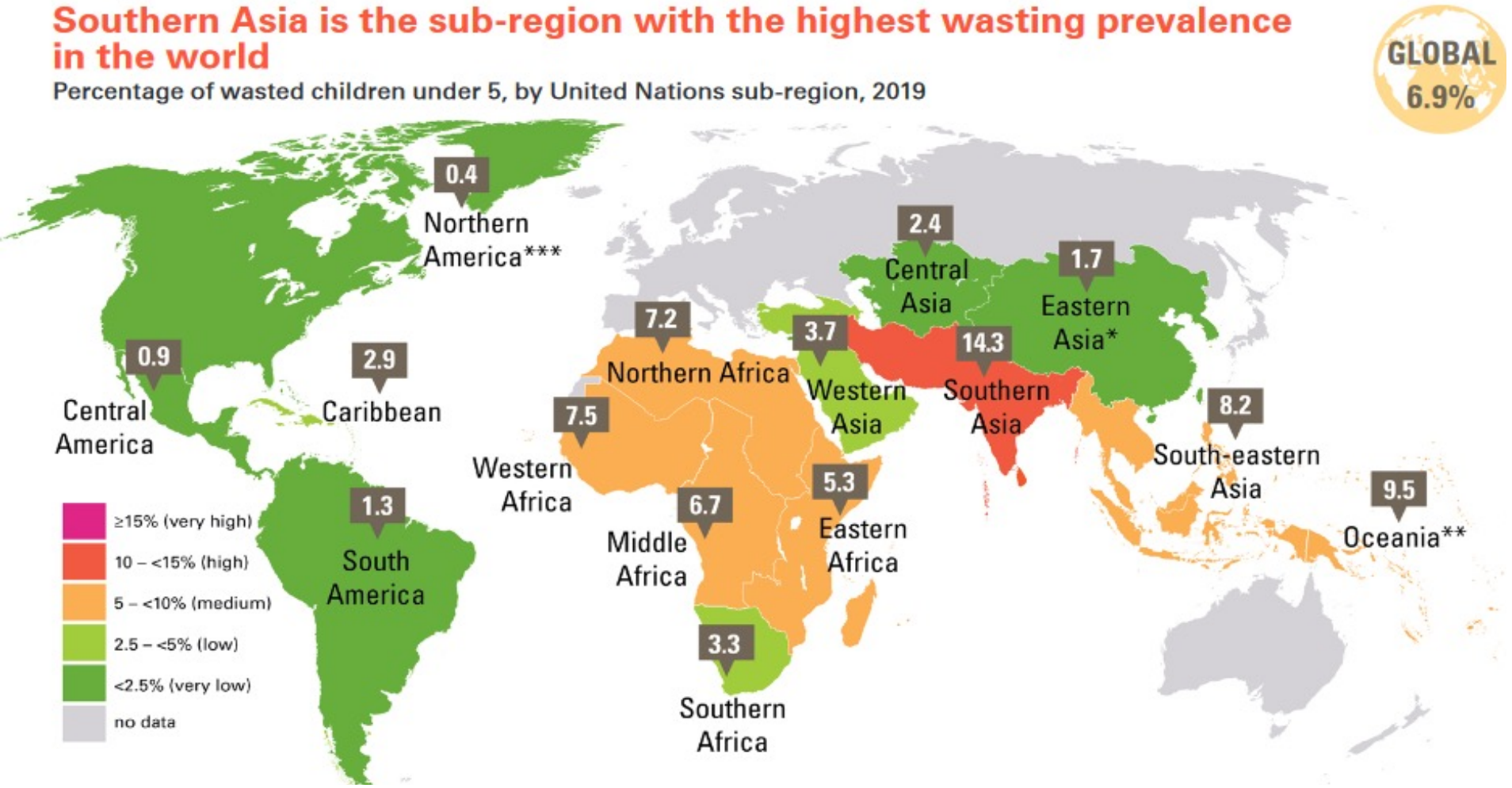


Source: UNICEF, WHO, World Bank Group joint malnutrition estimates, 2020 edition. Note: *Asia and Eastern Asia excluding Japan; **Oceania excluding Australia and New Zealand; ***Northern America sub-regional estimates based on United States data. There is no estimate available for the More Developed Region or for sub-regions of Europe or Australia and New Zealand due to insufficient population coverage. †represents regions/sub-regions where the change has been statistically significant; see page 12 for the 95% confidence intervals for graphed estimates.

Citations: UNICEF/WHO/World Bank 2020

Wasting

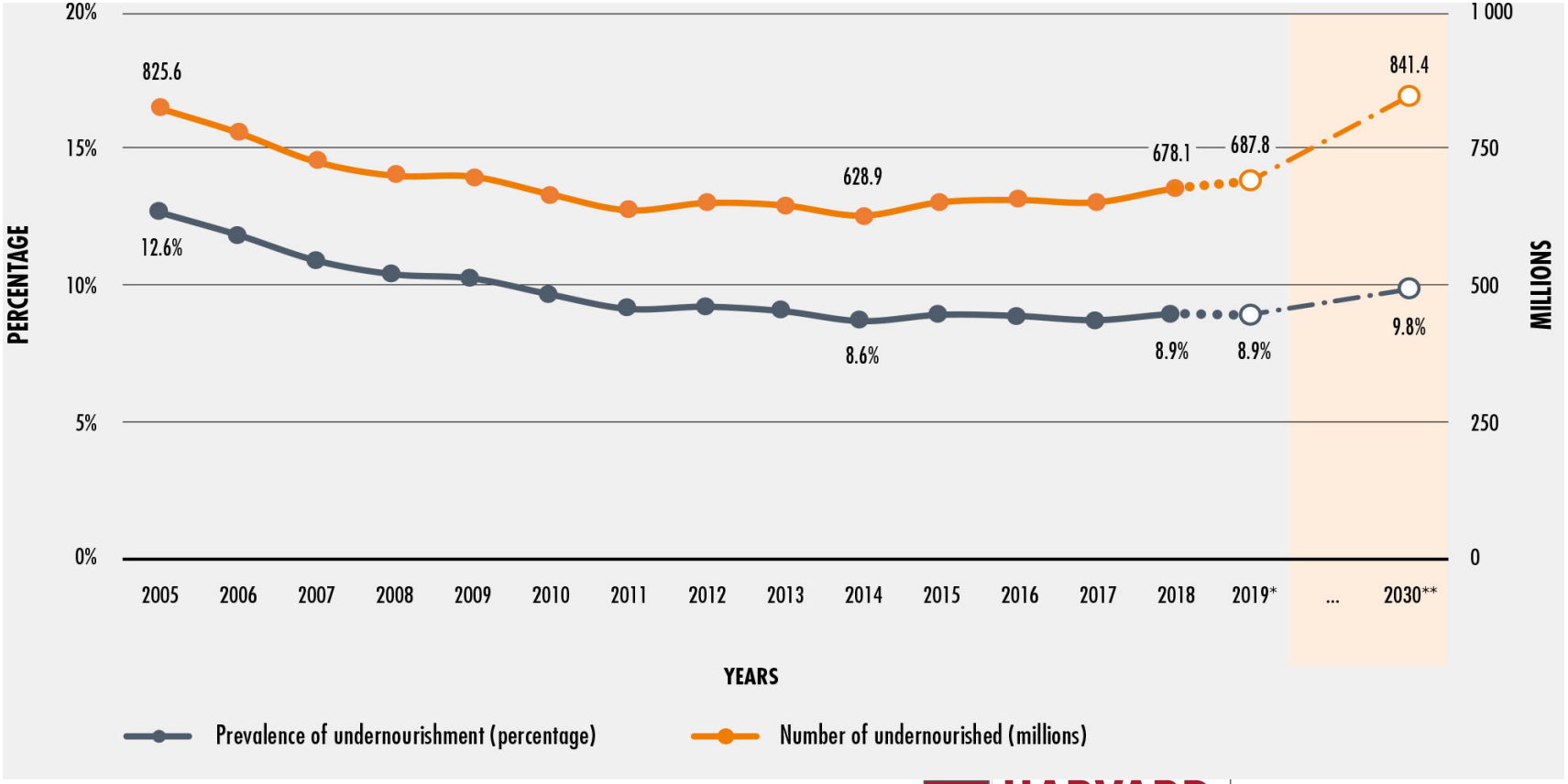
Global wasting burden (< 5y)



Citations: UNICEF/WHO/World Bank 2020

Undernourished population in the world

The number of undernourished people in the world CONTINUED to increase in 2019. If recent trends are not reversed, the SDG 2.1 Zero Hunger target will not be met



Citations: SOFI 2020

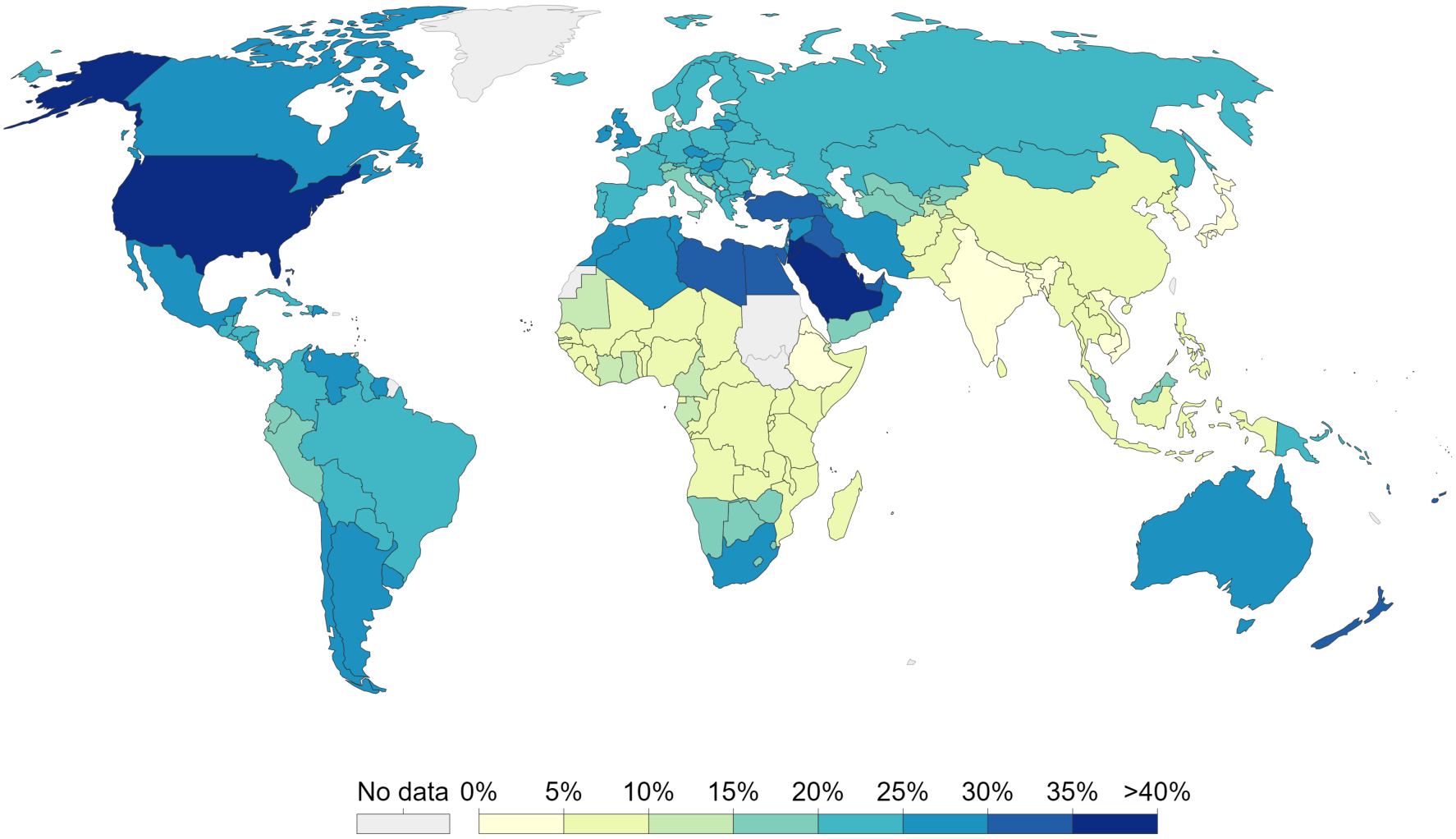
Undernourished population in the world

	Number of undernourished (millions)							
	2005	2010	2015	2016	2017	2018	2019*	2030**
WORLD	**825.6**	**668.2**	**653.3**	**657.6**	**653.2**	**678.1**	**687.8**	**841.4**
AFRICA	**192.6**	**196.1**	**216.9**	**224.9**	**231.7**	**236.8**	**250.3**	**433.2**
Northern Africa	18.3	17.8	13.8	14.4	15.5	15.0	15.6	21.4
Sub-Saharan Africa	174.3	178.3	203.0	210.5	216.3	221.8	234.7	411.8
Eastern Africa	95.0	98.1	104.9	108.4	110.4	112.9	117.9	191.6
Middle Africa	39.7	40.0	43.5	45.8	47.2	49.1	51.9	90.5
Southern Africa	2.7	3.2	4.4	5.1	4.5	5.2	5.6	11.0
Western Africa	36.9	37.0	50.3	51.2	54.2	54.7	59.4	118.8
ASIA	**574.7**	**423.8**	**388.8**	**381.7**	**369.7**	**385.3**	**381.1**	**329.2**
Central Asia	6.5	4.8	2.1	2.1	2.2	2.1	2.0	n.r.
Eastern Asia	118.6	60.6	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
South-eastern Asia	97.4	70.1	66.7	63.9	63.4	64.2	64.7	63.0
Southern Asia	328.0	264.0	263.1	256.2	245.7	261.0	257.3	203.6
Western Asia	24.3	24.2	27.6	29.2	29.5	30.4	30.8	42.1
Western Asia and Northern Africa	*42.6*	*42.0*	*41.4*	*43.6*	*45.0*	*45.4*	*46.4*	*63.5*
LATIN AMERICA AND THE CARIBBEAN	**48.6**	**39.6**	**38.8**	**42.4**	**43.5**	**46.6**	**47.7**	**66.9**
Caribbean	8.4	7.2	7.4	7.3	7.1	7.3	7.2	6.6
Latin America	40.1	32.4	31.4	35.1	36.3	39.3	40.5	60.3
Central America	11.8	12.4	13.4	14.7	14.4	14.7	16.6	24.5
South America	28.4	20.0	18.0	20.4	21.9	24.6	24.0	35.7
OCEANIA	**1.9**	**2.0**	**2.2**	**2.4**	**2.4**	**2.4**	**2.4**	**3.4**
NORTHERN AMERICA AND EUROPE	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**

Citations: SOFI 2020

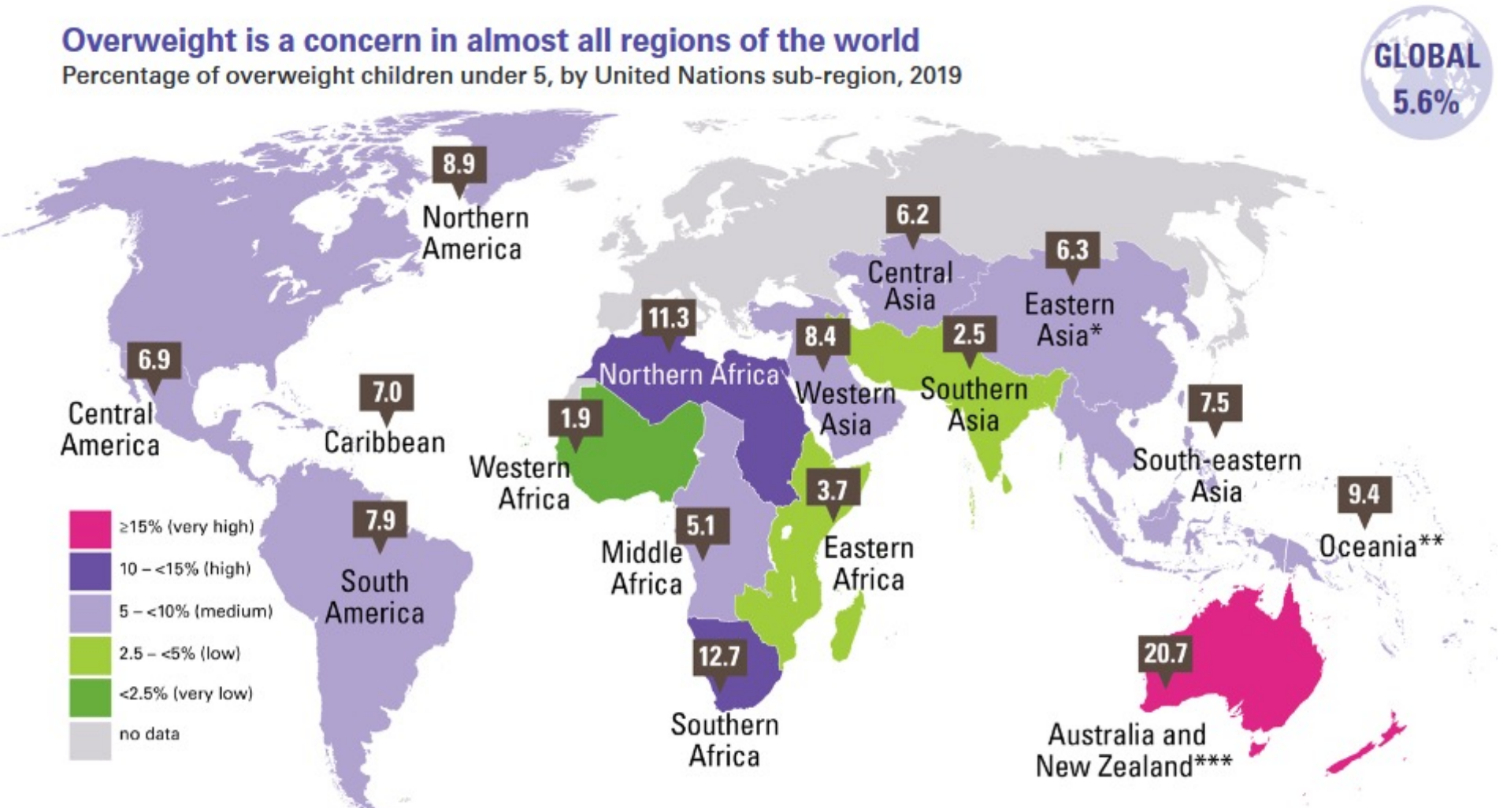
Overweight

Global obesity burden (adults)



Citations: WHO 2016

Global overweight burden (< 5y)



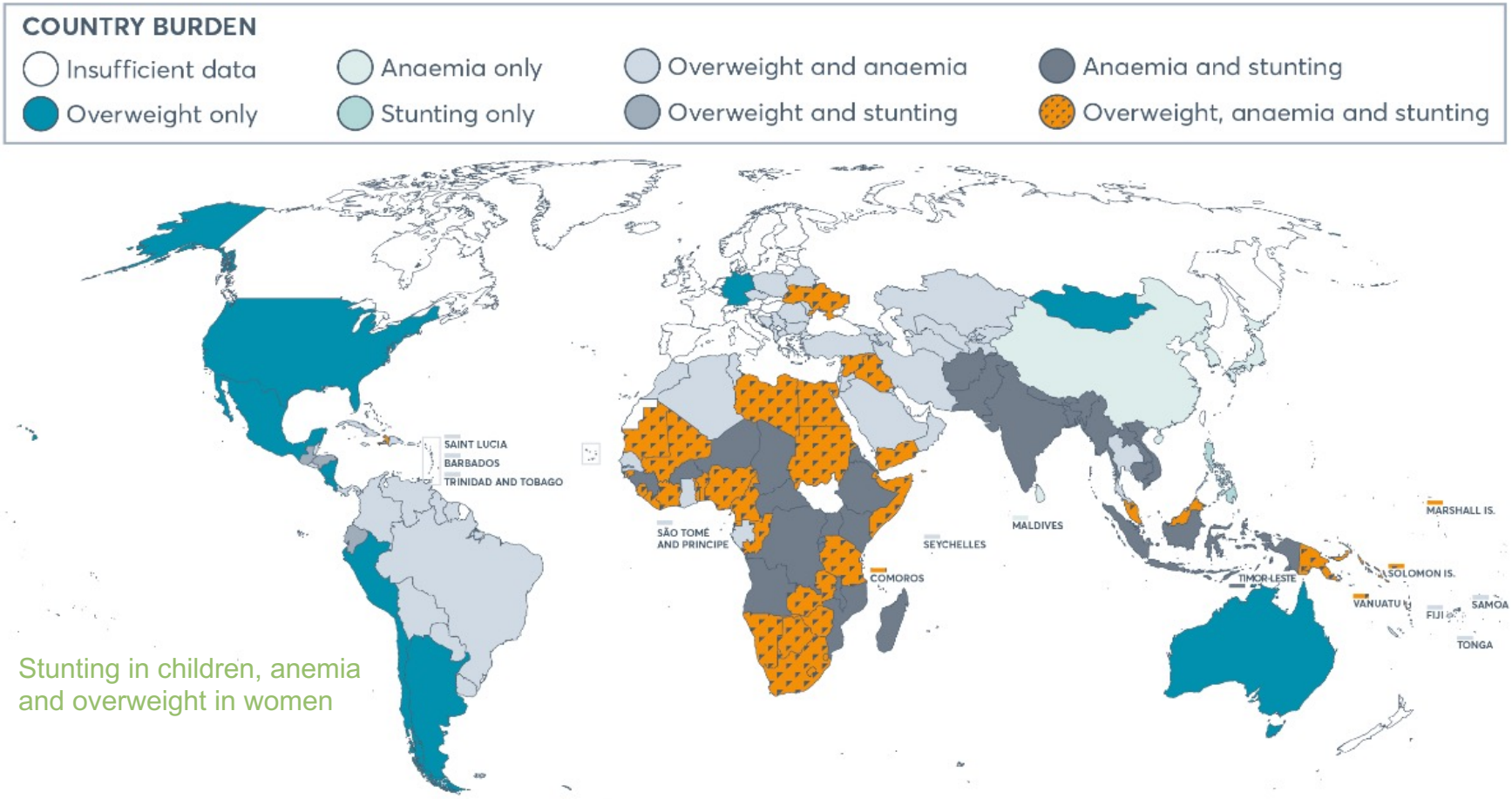
Citations: UNICEF/WHO/World Bank 2020

Multiple and coexisting forms of malnutrition

- Stunting and overweight can co-occur within a population, and even within an individual. The overlap of these conditions on a global level is not well-characterized.
- In particular, nutritional programs in developing countries must grapple with treating co-occurring conditions using population interventions.
- Numerous studies have observed both overweight among mothers and stunting among children in the same household, suggesting a nutrient-poor but calorie-dense environment.
- There is active research into whether early life under-nutrition creates physiological changes that cause adiposity later in life.

Citations: UNICEF/WHO/World Bank 2016; Andersen 2016

Multiple and coexisting forms of malnutrition



Stunting in children, anemia and overweight in women

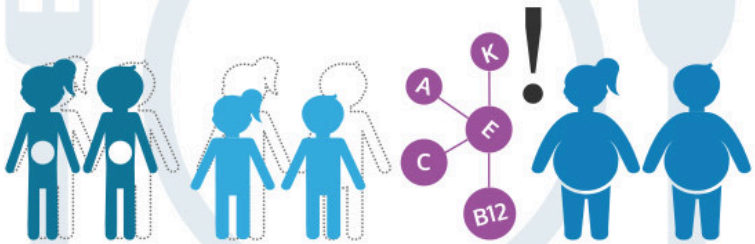
Source: UNICEF/WHO/World Bank Joint Child Malnutrition Estimates Expanded Database: Stunting, Wasting and Overweight, (March 2019, New York), NCD Risk Factor Collaboration 2019, WHO Global Health Observatory 2019.

Notes: Prevalence (%) thresholds used to determine whether a country is experiencing a high prevalence for a given form of malnutrition: stunting in children aged under 5 years: ≥20%; anaemia among women of reproductive age (15–49 years): ≥20%; overweight (including obesity) in adult women aged ≥18 years: body mass index of ≥25kg/m² ≥35%. Based on latest data available for 143 countries.

Citations: GNR 2020

Double Burden of Malnutrition

1



Undernutrition (wasting, stunting & micronutrient deficiencies) along with overweight and obesity

2

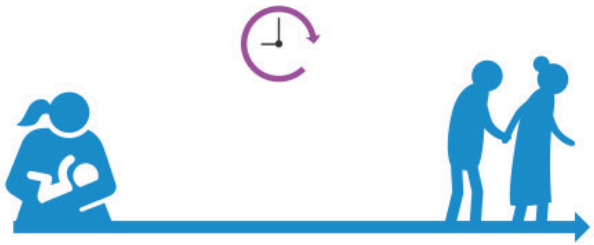
and diet-related noncommunicable diseases

3

within individuals, households and populations

4

throughout life



http://www.who.int

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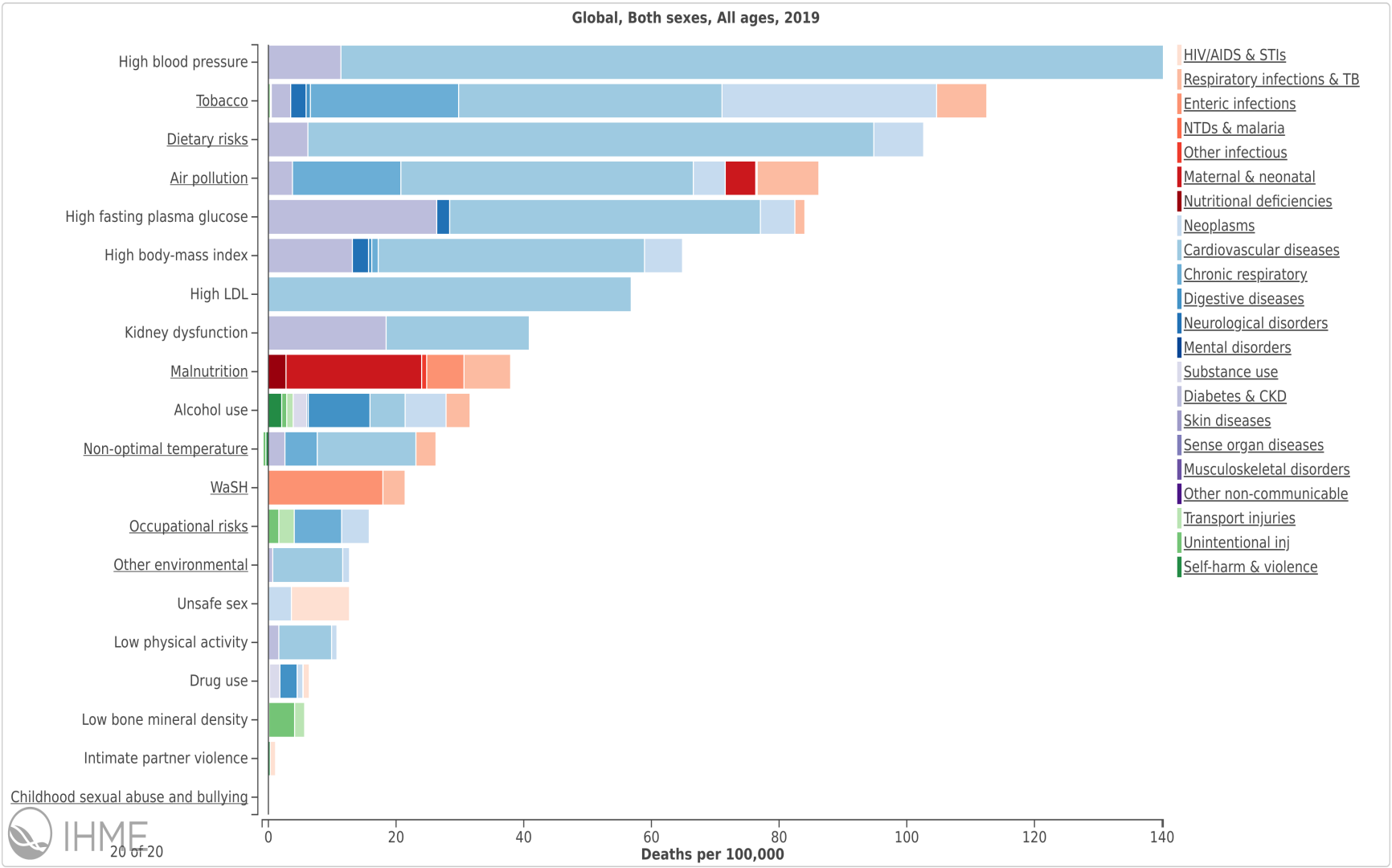
Global DALYs due to risk factors: 2019



Citations: IHME 2020

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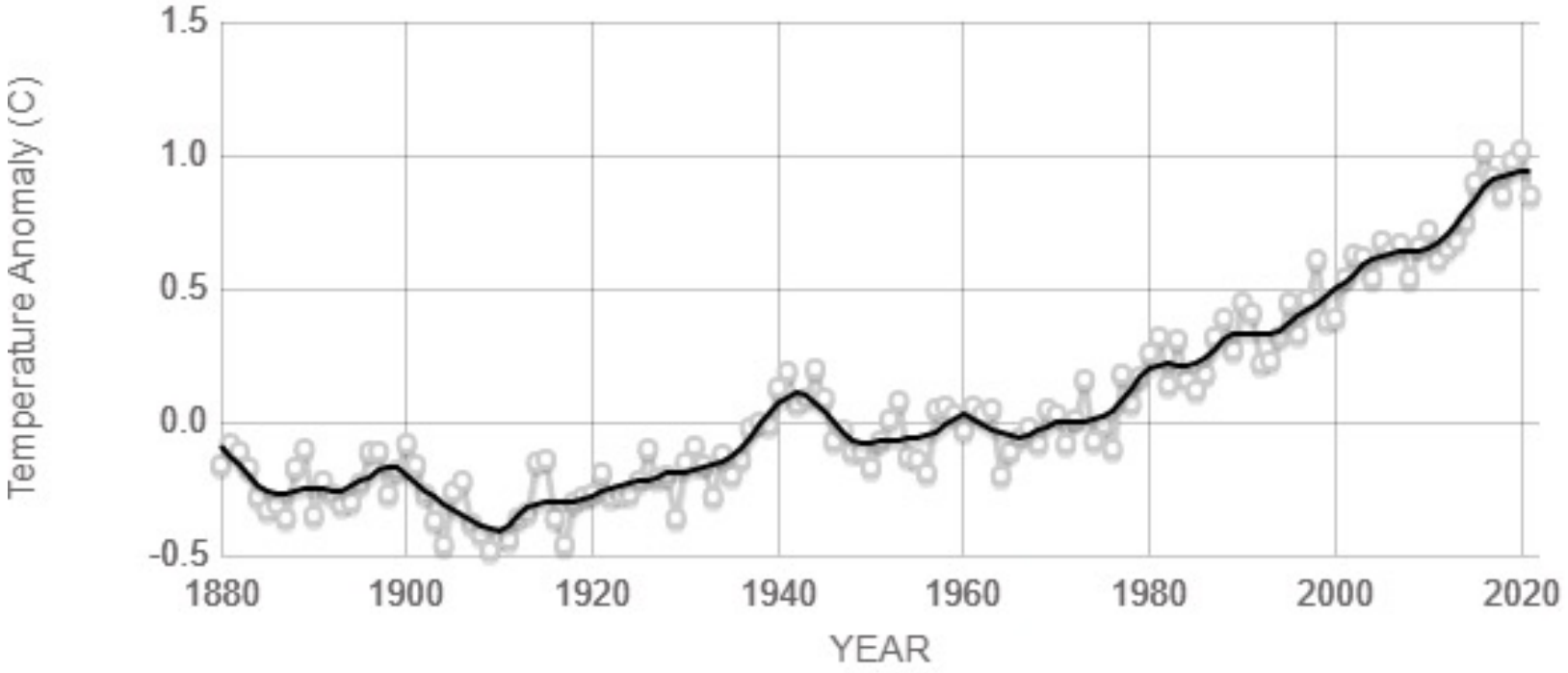
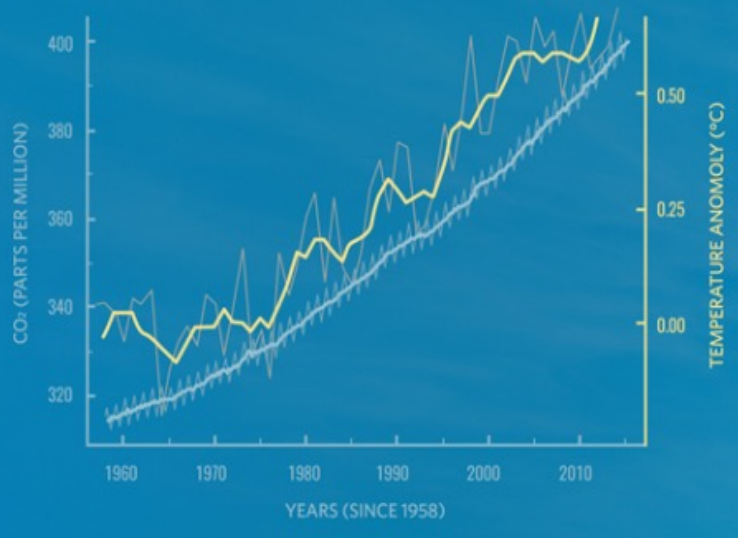
Earth's surface continues to warm, with recent global temperatures being the hottest in the past 2,000-plus years.



Source: climate.nasa.gov

ATMOSPHERE



THE RISE OF CARBON DIOXIDE (CO_2) IN EARTH'S ATMOSPHERE CORRESPONDS TO A WARMER PLANET AND RISING SEA LEVELS.

Each year, humans release nearly 40 billion tons of CO_2 into the atmosphere, driving changes in Earth's climate. That is an average of about 5.5 tons for every person on the planet. But that volume is not shared equally among nations. The top four emitters (China, the U.S., the European Union and India) are responsible for nearly 60% of carbon dioxide emissions.

Source: NASA

SDGs and Other Global Targets

Citations: IFPRI 2016

Sustainable Development Goals (SDGs)

- Enacted in January 2016 by the United Nations as a follow-on to the Millennium Development Goals (MDGs).
- Identifies 17 goals to end poverty, protect the planet, and ensure peace and prosperity for all. Measured with 169 targets and 230 indicators.

Citations: IFPRI 2016

Sustainable Development Goal #2

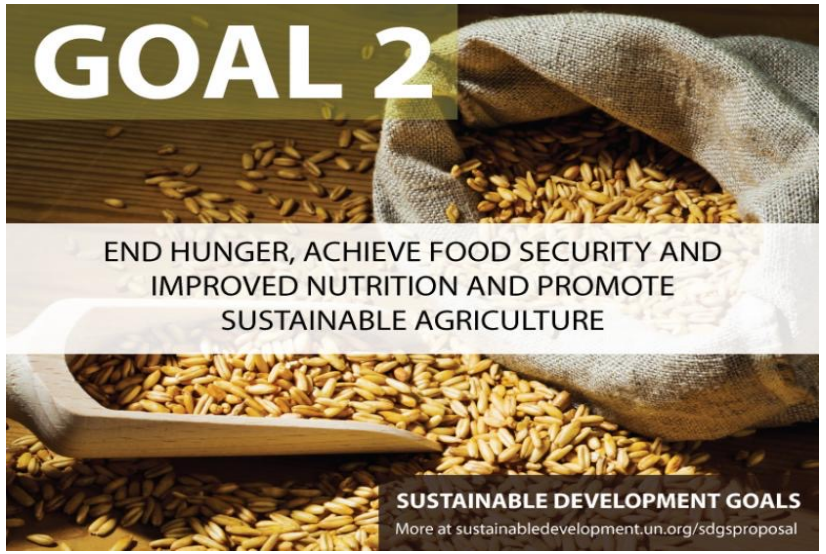
2.1: by 2030 end hunger and ensure access to safe, nutritious and sufficient food

2.2: by 2030 end all forms of malnutrition, including achieving global targets 2025 (address nutritional needs of adolescent girls, pregnant and lactating women, and older persons)

2.3: by 2030 double the agricultural productivity and the incomes of small-scale food farmers (especially women, family farmers, pastoralists)

2.4: by 2030 ensure sustainable food production systems and resilient agricultural practices (ecosystems, capacity for adaptation to climate change, soil quality)

2.5: by 2020 maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild



2 ZERO HUNGER

END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE

SUSTAINABLE DEVELOPMENT GOALS

THE GLOBAL PANDEMIC IS EXACERBATING WORLD HUNGER

WORLDWIDE, AN ADDITIONAL **70–161 MILLION PEOPLE** ARE LIKELY TO HAVE EXPERIENCED HUNGER AS A RESULT OF THE PANDEMIC IN 2020

NUMBER OF UNDERNOURISHED PEOPLE IN THE WORLD

PANDEMIC WILL WORSEN CHILD MALNUTRITION

22% (149.2 MILLION) OF CHILDREN UNDER 5 ARE STUNTED

6.7% (45.4 MILLION) OF CHILDREN UNDER 5 SUFFER FROM WASTING

5.7% (38.9 MILLION) OF CHILDREN UNDER 5 ARE OVERWEIGHT (2020*)

*THESE 2020 ESTIMATES DO NOT REFLECT IMPACT OF PANDEMIC

ALMOST ONE THIRD OF WOMEN OF REPRODUCTIVE AGE GLOBALLY SUFFER FROM ANAEMIA, IN PART DUE TO NUTRITION DEFICIENCIES

2.37 BILLION PEOPLE ARE WITHOUT FOOD OR UNABLE TO EAT A HEALTHY BALANCED DIET ON A REGULAR BASIS (2020)

THE SUSTAINABLE DEVELOPMENT GOALS REPORT 2021: UNSTATS.UN.ORG/SDGS/REPORT/2021/

https://sdgs.un.org/goals

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13 CLIMATE ACTION

TAKE URGENT ACTION TO COMBAT CLIMATE CHANGE AND ITS IMPACTS

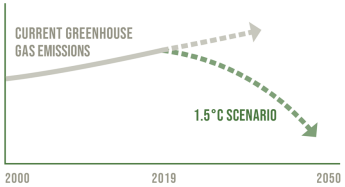
SUSTAINABLE DEVELOPMENT GOALS

THE CLIMATE CRISIS CONTINUES, LARGELY UNABATED

2020 GLOBAL AVERAGE TEMPERATURE AT 1.2°C ABOVE PRE-INDUSTRIAL BASELINE

WOEFULLY OFF TRACK TO STAY AT OR BELOW 1.5°C AS CALLED FOR IN THE PARIS AGREEMENT

RISING GREENHOUSE GAS EMISSIONS REQUIRE SHIFTING ECONOMIES TOWARDS CARBON NEUTRALITY



CLIMATE FINANCE INCREASED

BY 10% FROM 2015-2016 TO 2017-2018, REACHING AN ANNUAL AVERAGE OF $48.7 BILLION

125 OF 154 DEVELOPING COUNTRIES ARE FORMULATING AND IMPLEMENTING NATIONAL CLIMATE ADAPTATION PLANS

HIGHEST PRIORITY AREAS INCLUDE

THE SUSTAINABLE DEVELOPMENT GOALS REPORT 2021: UNSTATS.UN.ORG/SDGS/REPORT/2021/

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https://sdgs.un.org/goals

Food Systems and Planetary Health

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Social and economic determinants of nutrition

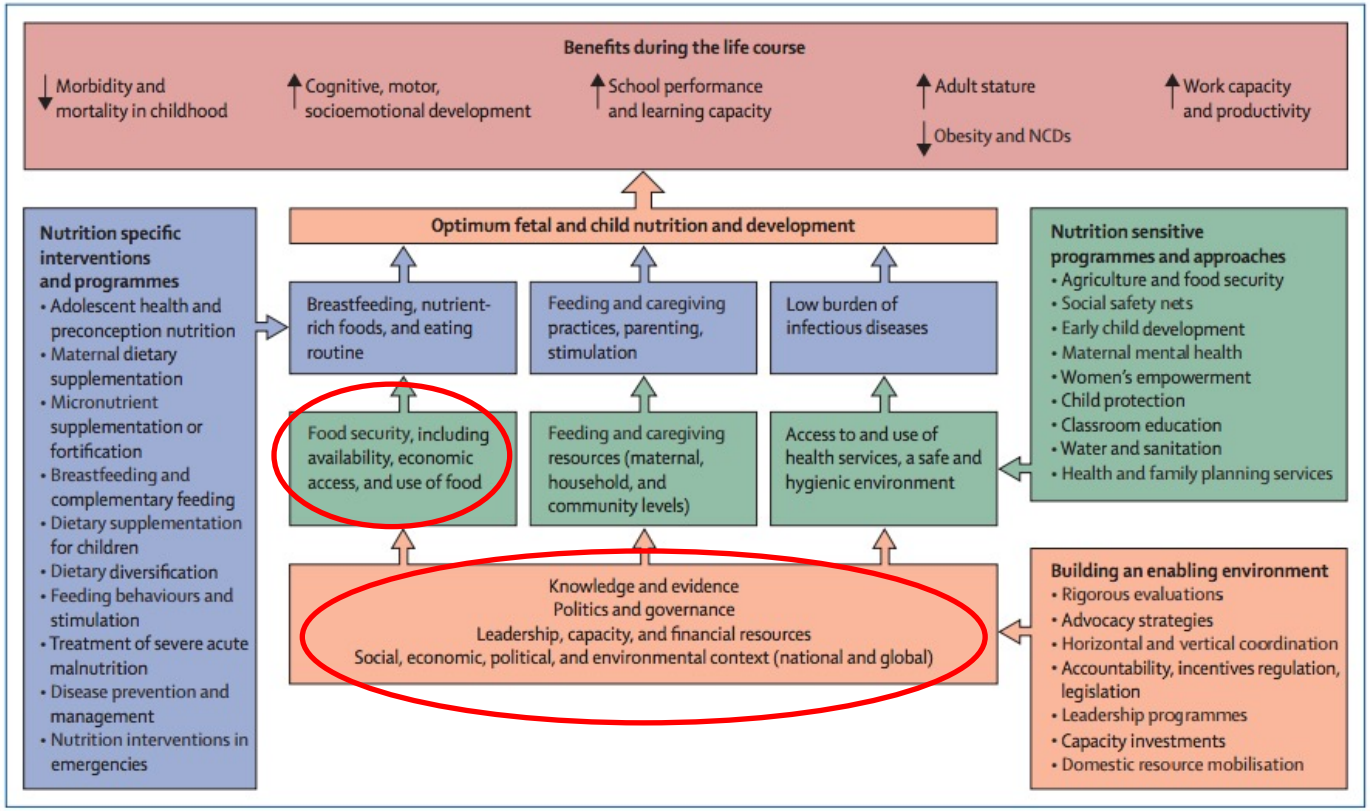


Figure 1: Framework for actions to achieve optimum fetal and child nutrition and development

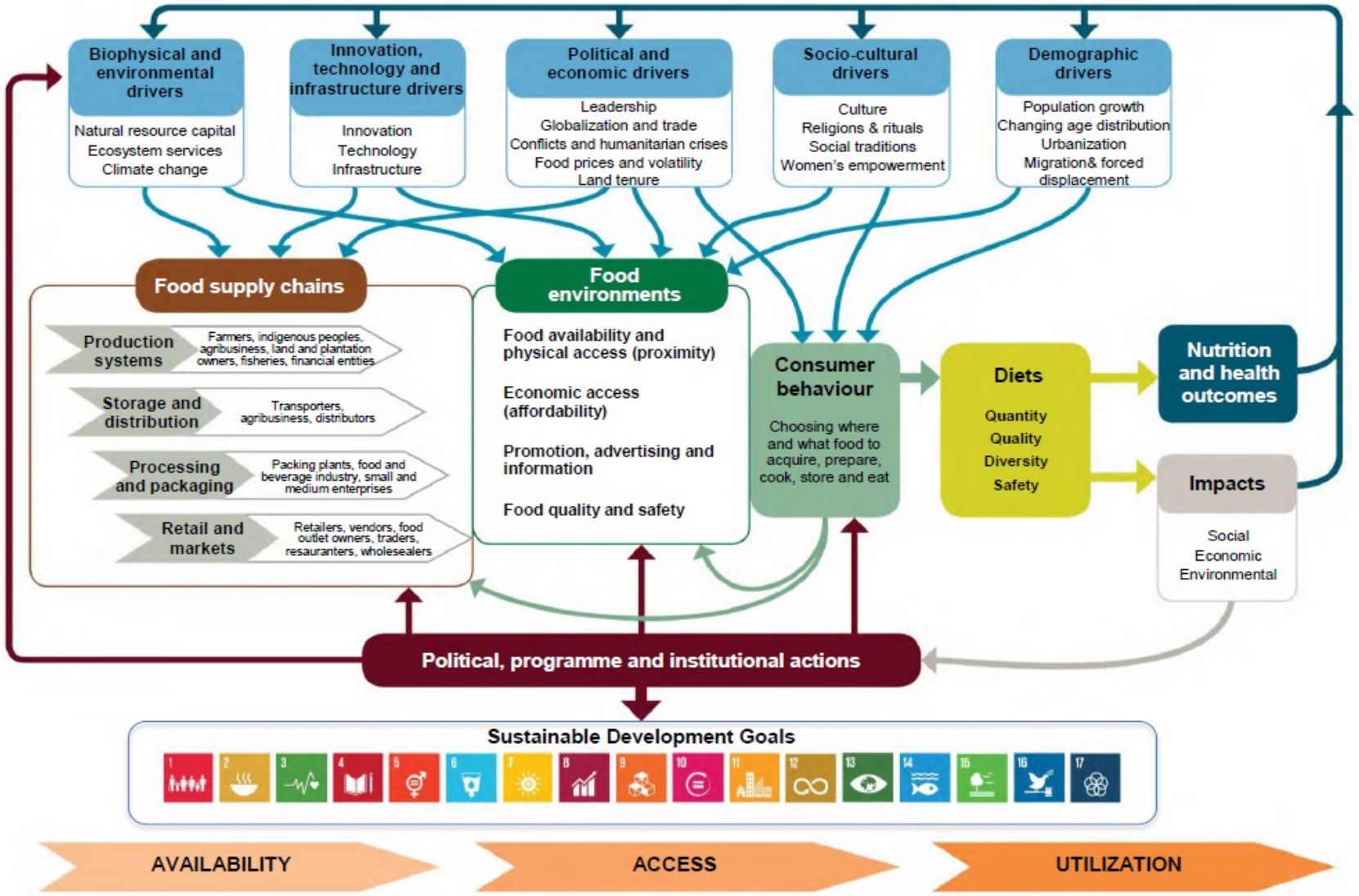
Citations: Black 2013

Definition

- “A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes.”

- (HLPE 2017)

Framework


Biophysical and environmental drivers
Natural resource capital
Ecosystem services
Climate change
Innovation, technology and infrastructure drivers
Innovation
Technology
Infrastructure
Political and economic drivers
Leadership
Globalization and trade
Conflicts and humanitarian crises
Food prices and volatility
Land tenure
Socio-cultural drivers
Culture
Religions & rituals
Social traditions
Women's empowerment
Demographic drivers
Population growth
Changing age distribution
Urbanization
Migration& forced displacement
Food supply chains
Production systems
Farmers, indigenous peoples, agribusiness, land and plantation owners, fisheries, financial entities
Storage and distribution
Transporters, agribusiness, distributors
Processing and packaging
Packing plants, food and beverage industry, small and medium enterprises
Retail and markets
Retailers, vendors, food outlet owners, traders, resauranters, wholesealers
Food environments
Food availability and physical access (proximity)
Economic access (affordability)
Promotion, advertising and information
Food quality and safety
Consumer behaviour
Choosing where and what food to acquire, prepare, cook, store and eat
Diets
Quantity
Quality
Diversity
Safety
Nutrition and health outcomes
Impacts
Social
Economic
Environmental
Political, programme and institutional actions
Sustainable Development Goals
AVAILABILITY
ACCESS
UTILIZATION

Food is the single strongest lever to optimize human health and environmental sustainability on Earth.

Figure 1

An integrated agenda for food in the Anthropocene recognizes that food forms an inextricable link between human health and environmental sustainability. The global food system must operate within boundaries for human health and food production to ensure healthy diets from sustainable food systems for nearly 10 billion people by 2050.

Willett et al, EAT Lancet Commission Report 2019.

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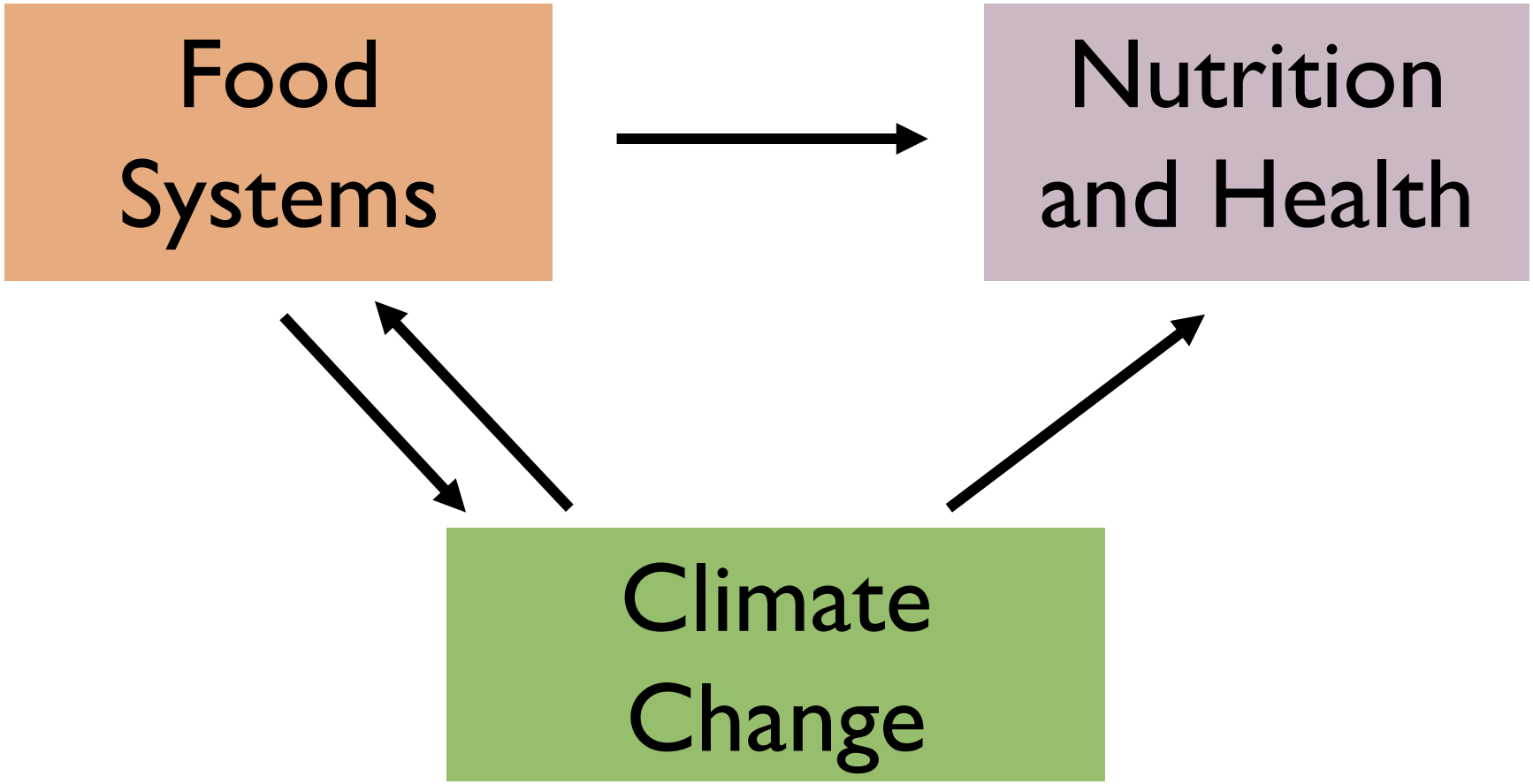
Food Systems
Nutrition and Health
Climate Change

Outline

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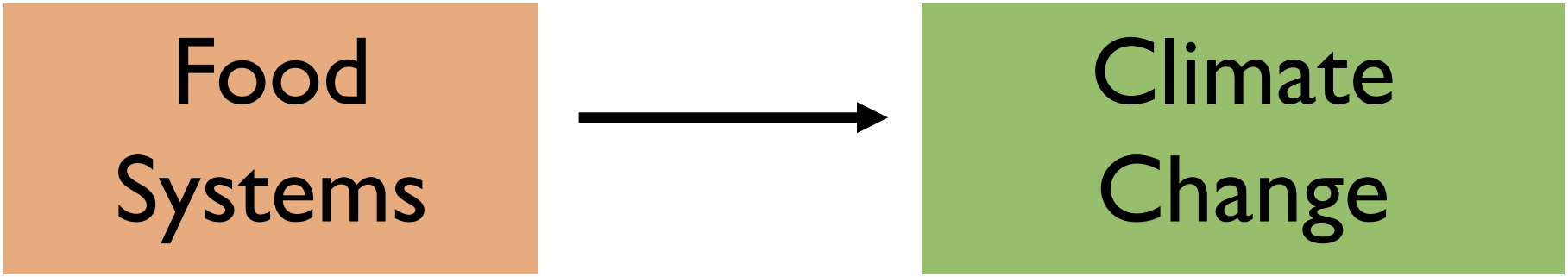

Food Systems
Climate Change

RELATIVE GREENHOUSE-GAS EMISSIONS ASSOCIATED WITH SEVERAL COMMON PROTEIN SOURCES

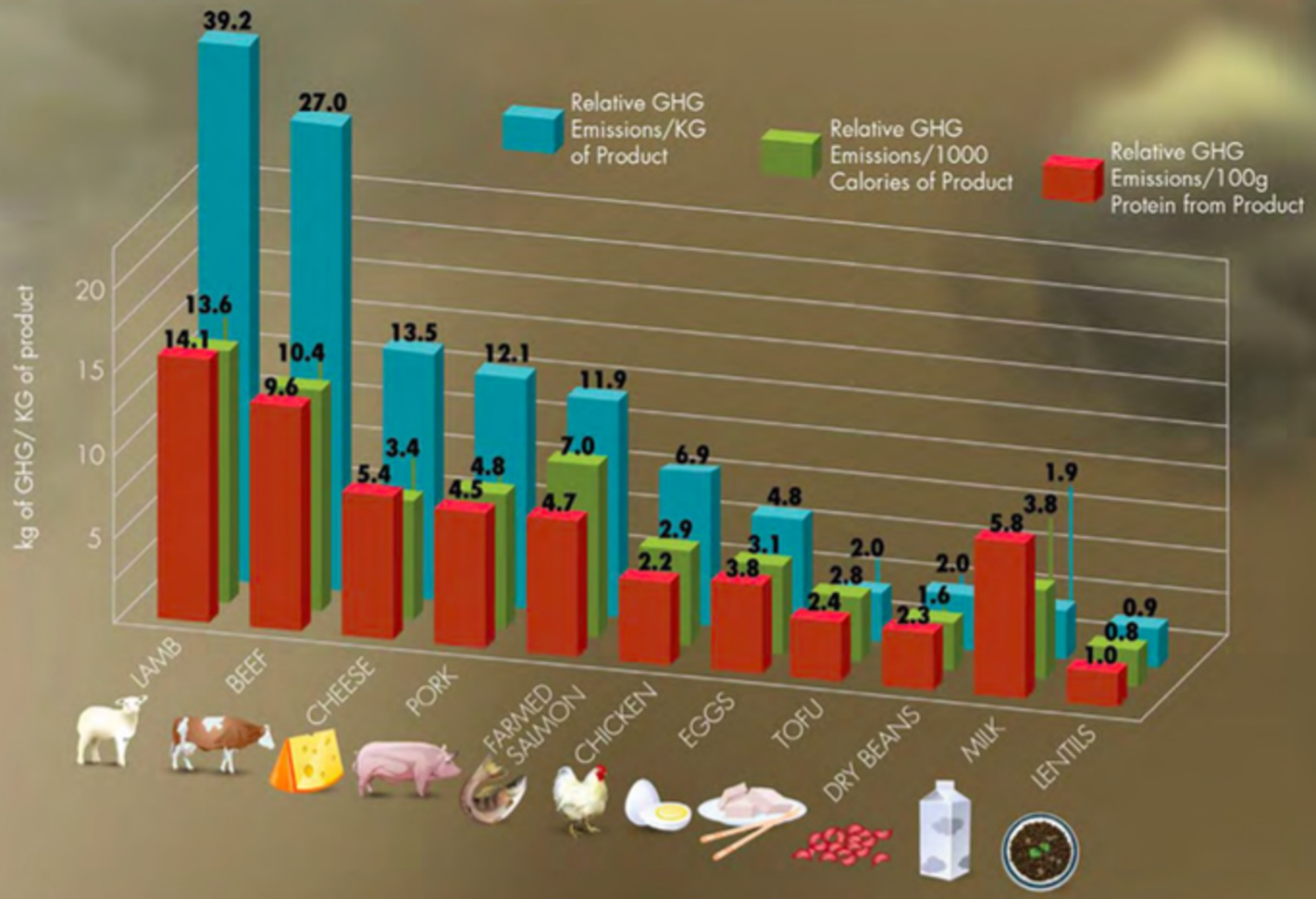
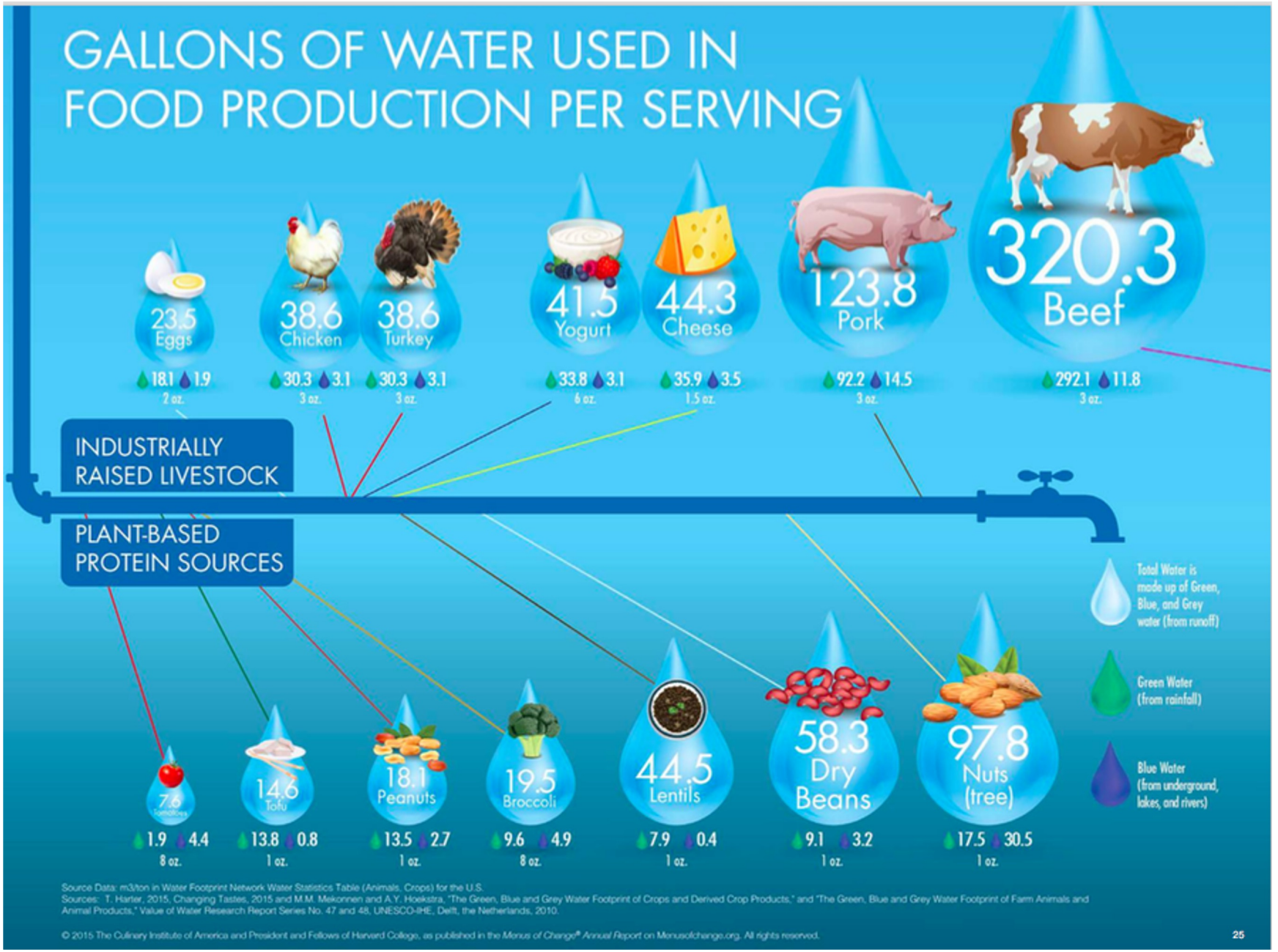


Table 1 illustrates the greenhouse-gas emissions associated with several common protein sources and is a good indicator of environmental impact including energy and chemical use, soil management, and mechanical irrigation. Both public health and the environment will improve if restaurants decrease the amount of red meat on menus and replace it with alternative protein sources.

www.menusofchange.org

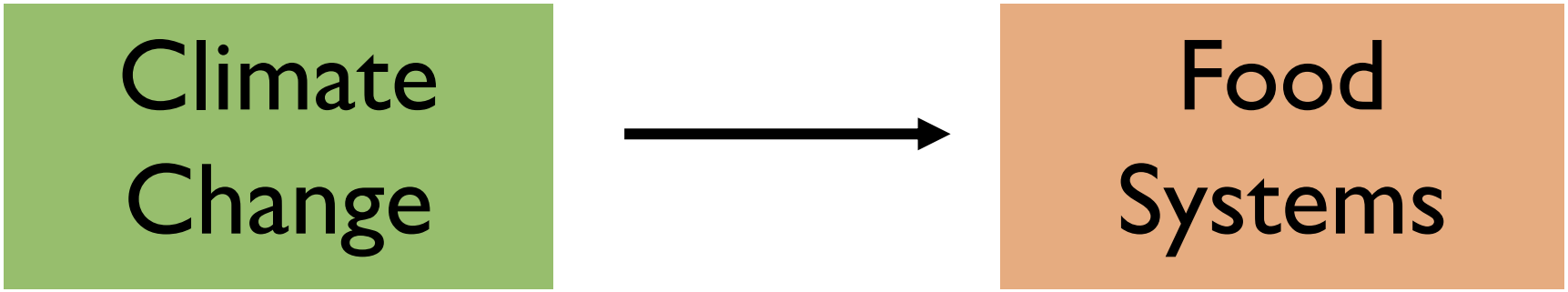


www.menusofchange.org

Current food systems drive climate change and environmental degradation

- Poor crop production practices cause degradation of land and deterioration of soil quality, leading to poor agricultural productivity
- Agriculture production, fertilizer production, and postharvest processes contribute up to 29% anthropogenic greenhouse gas (GHG) emissions globally
- Agricultural practices contribute to pollution of rivers and water bodies through excessive nitrogen and phosphorus inputs, leading to the pollution of aquatic and terrestrial ecosystems and decreasing fish populations
- Livestock production is a significant contributor to GHG emissions, with beef and cattle milk production accounting for the majority of emissions

Vermuelen et al, 2021; Gomiero T, 2016; Springmann et al, 2018; Gerber et al, 2013


Climate Change
Food Systems

Consequences of increased greenhouse gas emissions

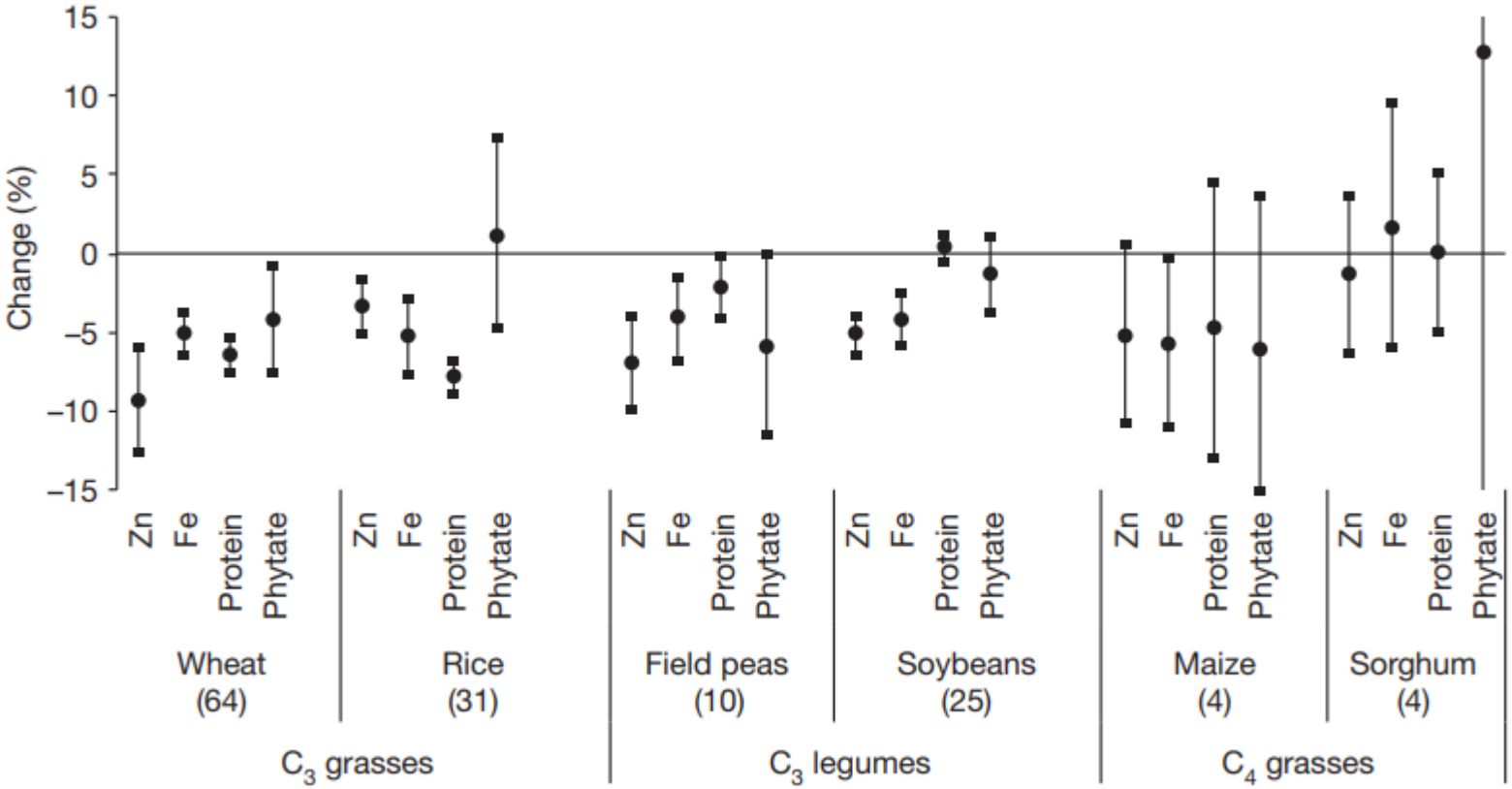
- Reduces crop yields
- More pests, pathogens, weeds and other pressures
- Pollinator declines
- Lower human labor capacity
- Poorer crop nutrient content
- Greater postharvest losses
- Coral reef degradation and shellfish declines
- Altered fish nutrient composition
- Degradation of ecosystems which leads to greater risk of zoonotic diseases and pandemics

Image source: US EPA

Meyers et al. Annual review of public health, 2017.

Rising CO^2 levels lead to less nutritious foods

When wheat, corn, rice and soy are exposed to CO^2 at levels predicted for 2050, they lose as much as 10% of zinc, 5% iron, and 8% of protein



Percentage change in nutrients at elevated CO^2 relative to ambient CO^2

Meyers et al. Nature, 2014.

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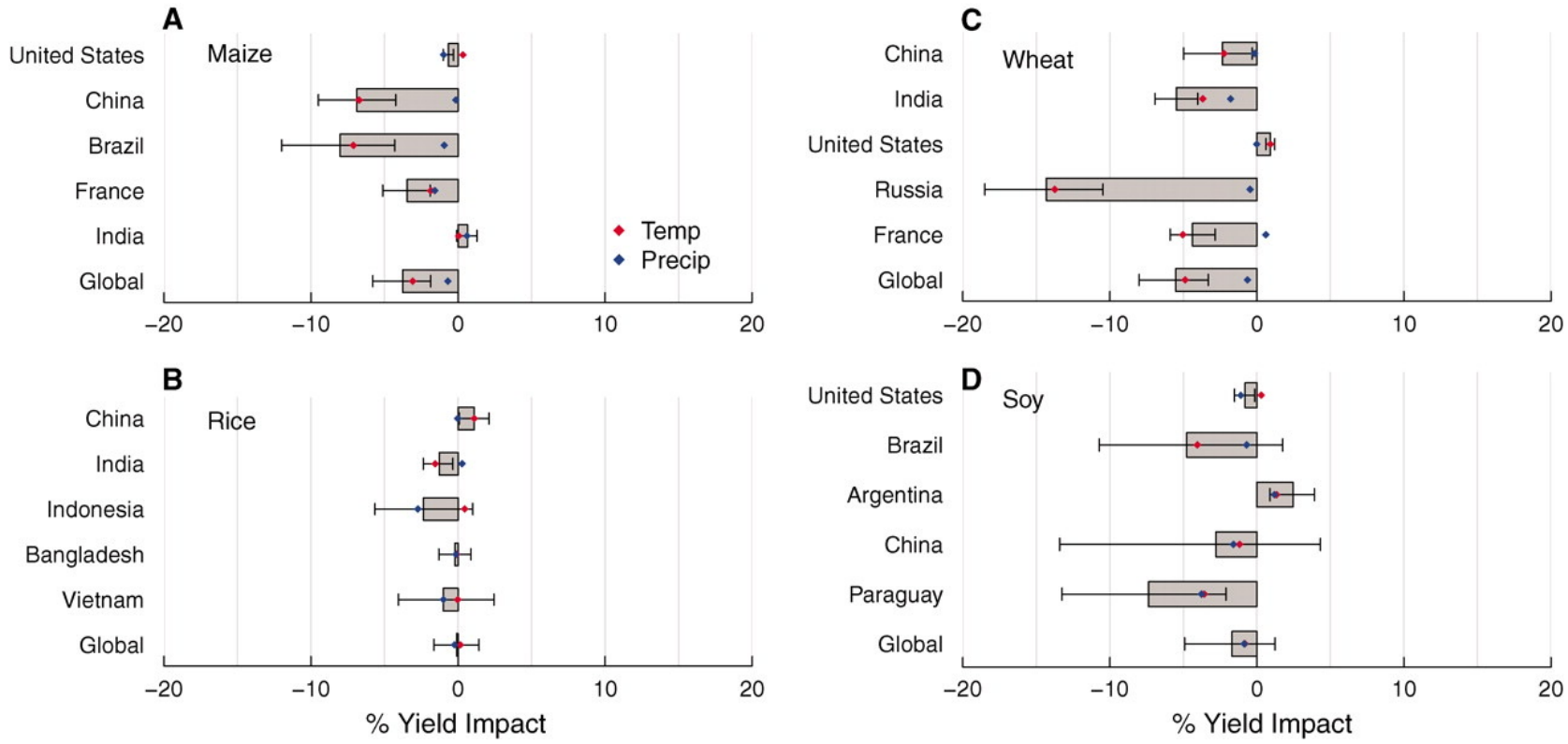
Greenhouse gas emissions → changes in temperature and precipitation → lower crop yields



Estimated net impact of climate trends for 1980–2008 on crop yields for major producers and for global production. Values expressed as percent of average yield. Red and blue dots show median estimate of impact for T trend and P trend, respectively.

Lobell et al. Science, 2011.

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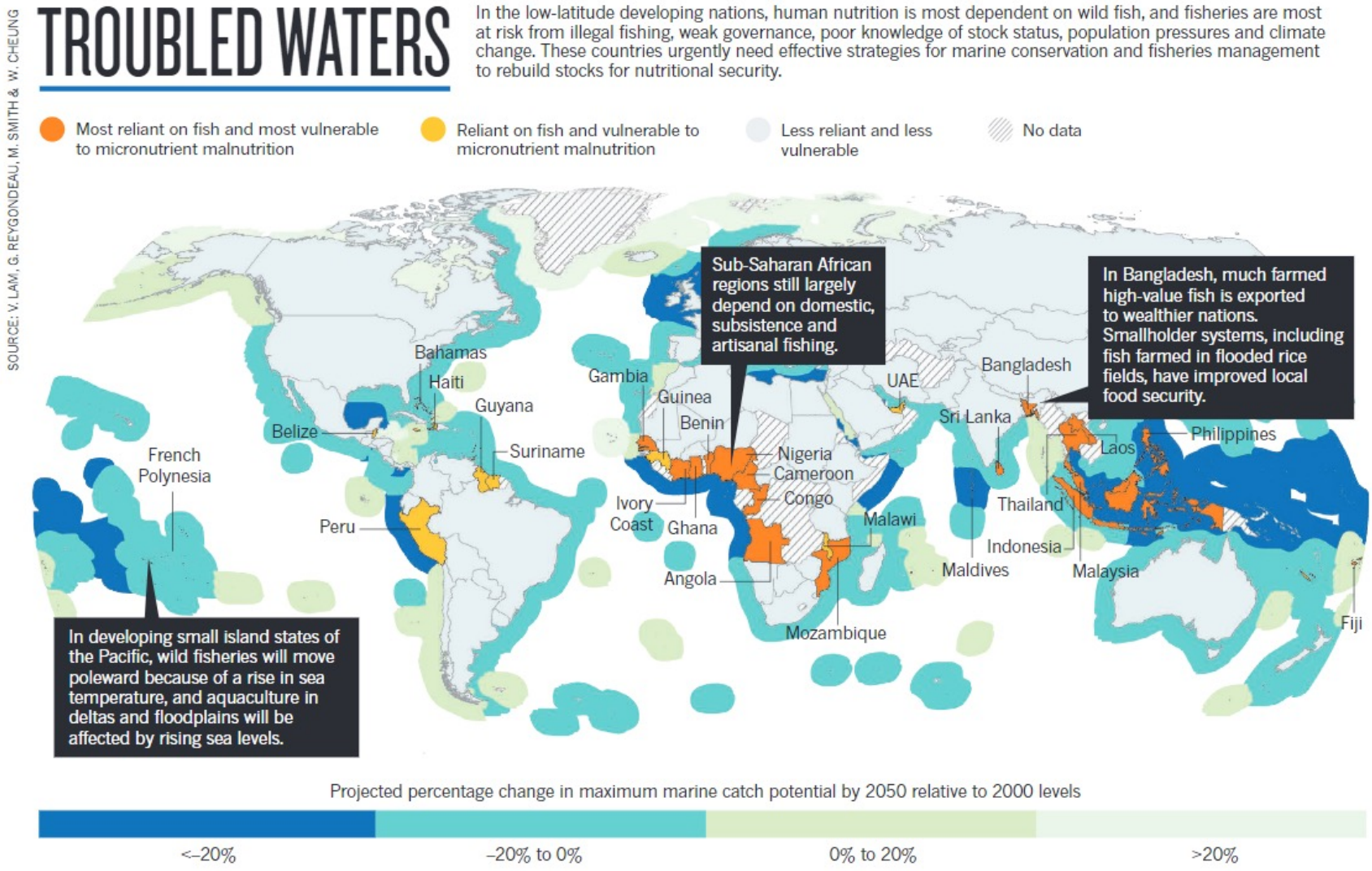
Rising CO^2 levels lead to altered fish catch and nutrient content



Golden et al. Nature, 2016.

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Pollinator declines → reduced crop yield and altered nutrient content

- Animal pollinators declining globally
- Action of pollinators greatly benefits foodcrops and nutrients important in diets (fruits, vegetables, nuts and seeds, vitamin A, folate)
- Pollinators contribute to agricultural yield for 35% of global food production and are directly responsible for up to 40% of worlds supply of certain micronutrients, such as vitamin A

Image source: https://www.pollinator.org/

Smith MR et al Lancet. 2015

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Contribution of pollination to human health through diet

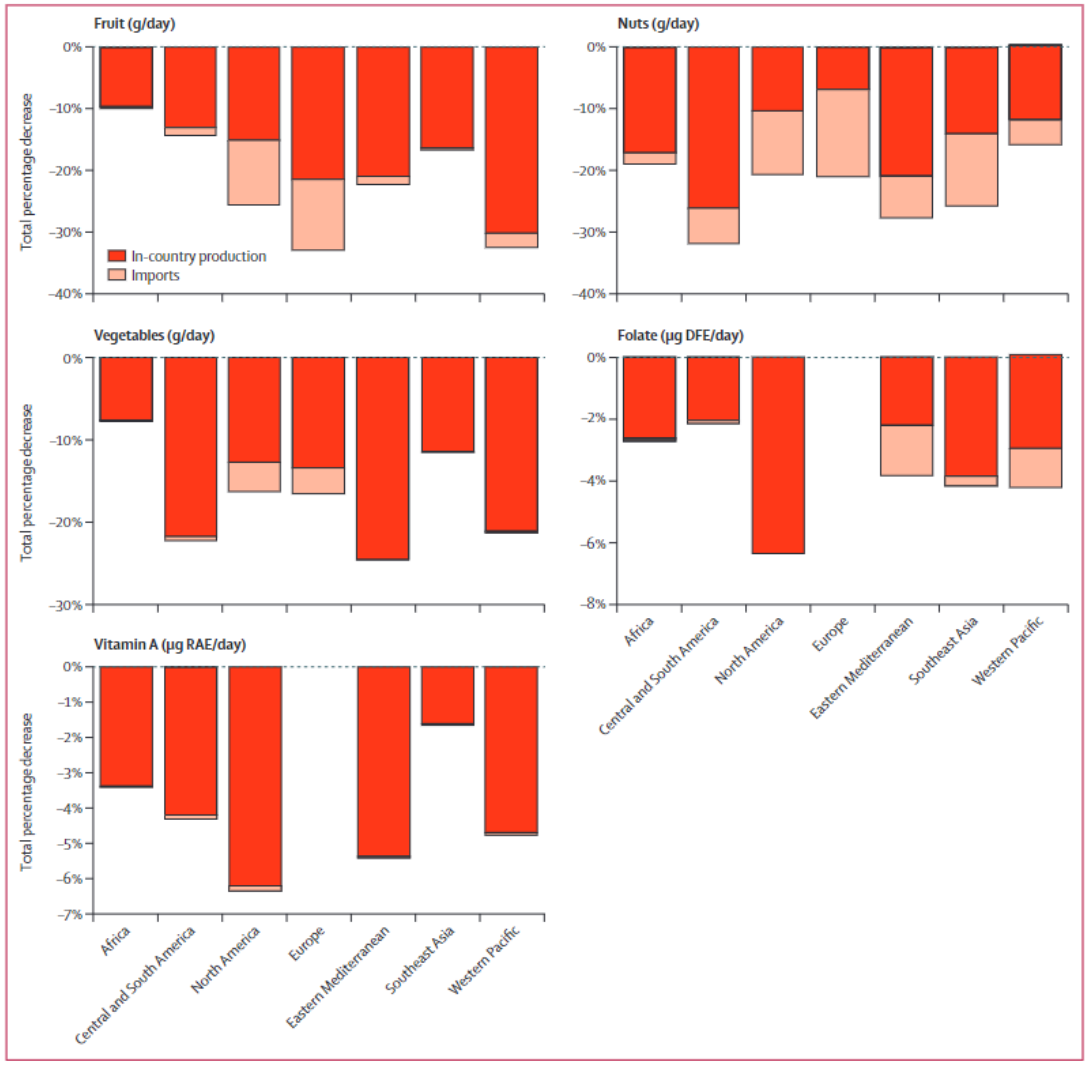

Figure 3: Decreases in food and nutritional intake with full pollinator removal
RAE=retinol activity equivalent. DFE=dietary folate equivalent.

Smith MR et al Lancet. 2015

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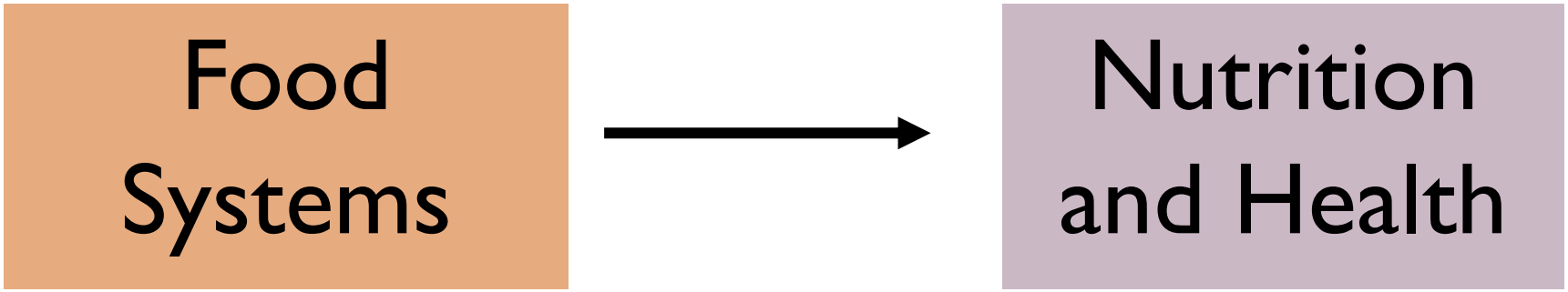
Ecosystem degradation → pandemics → food system disruption

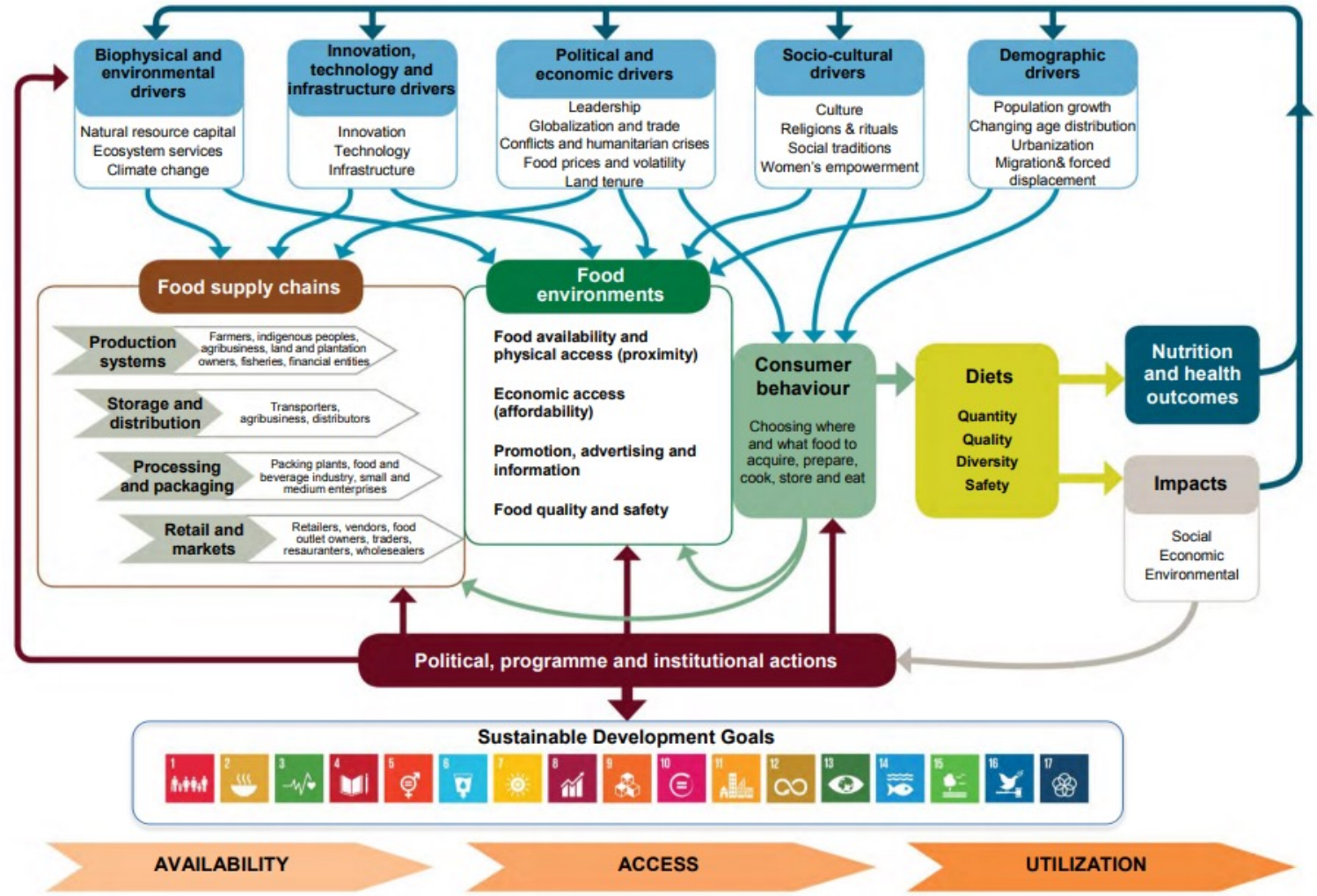
- Emerging infectious diseases driven by growing human populations increasingly disrupting natural ecosystems and driving pandemics
- Forests provide habitats for 80% of amphibians, 75% of birds, and 68% of mammals but are being cleared at a rate of 100 000 km^2 per year
- Brings people into closer contact with species that are hosts of potentially zoonotic pathogens like COVID-19
- COVID-19 and other pandemics lead to supply chain challenges and disruption of markets and food production

McNeely JA. *Ambio* 202.


Food Systems
Nutrition and Health

Food Systems Conceptual Framework

Figure 1 Conceptual framework of food systems for diets and nutrition



HLPE, 2017

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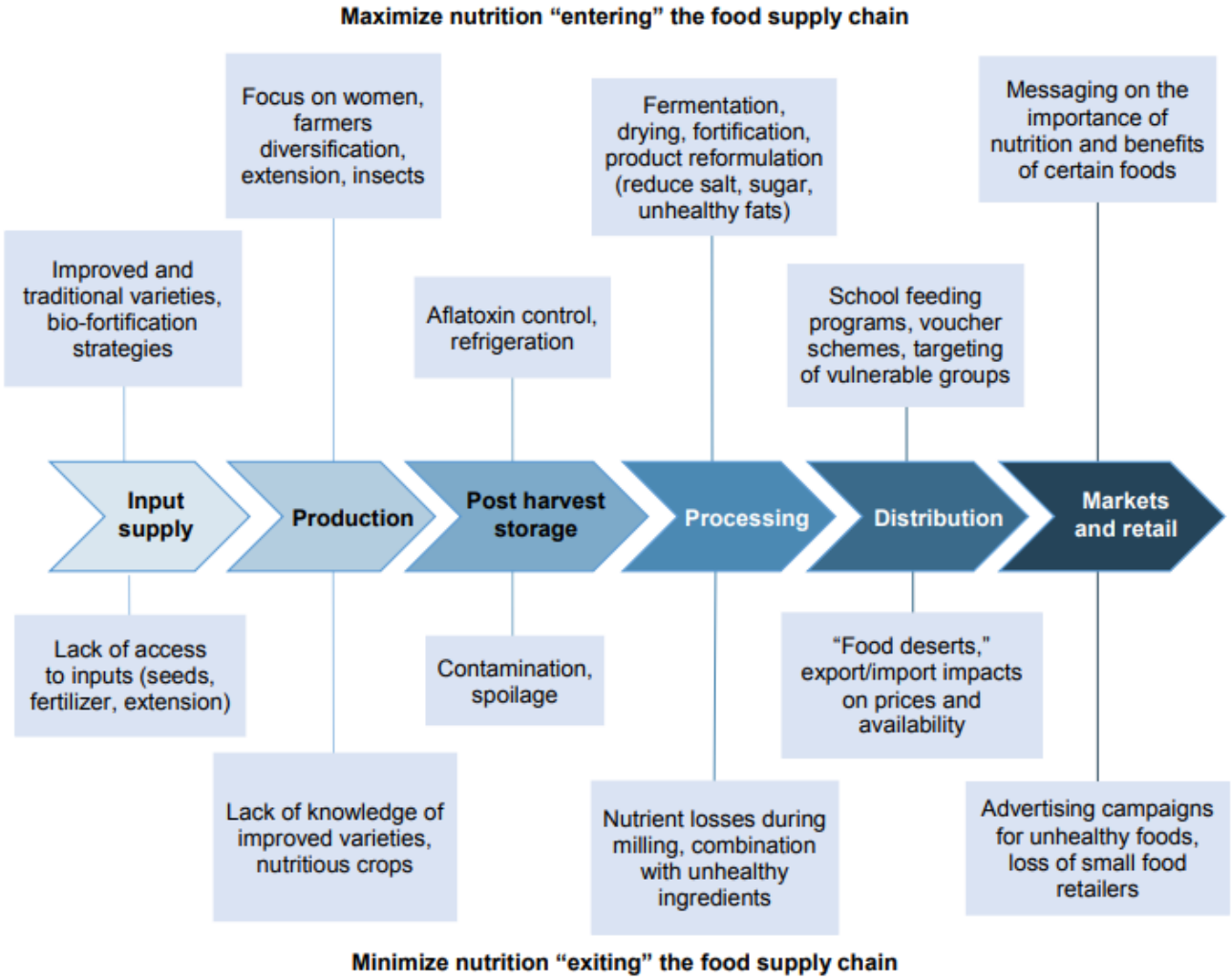
Key points for interventions across food supply chains

Figure 14 Exit and entry points along the nutrition value chain



Source: Fanzo *et al.* (2017b).

HLPE, 2017

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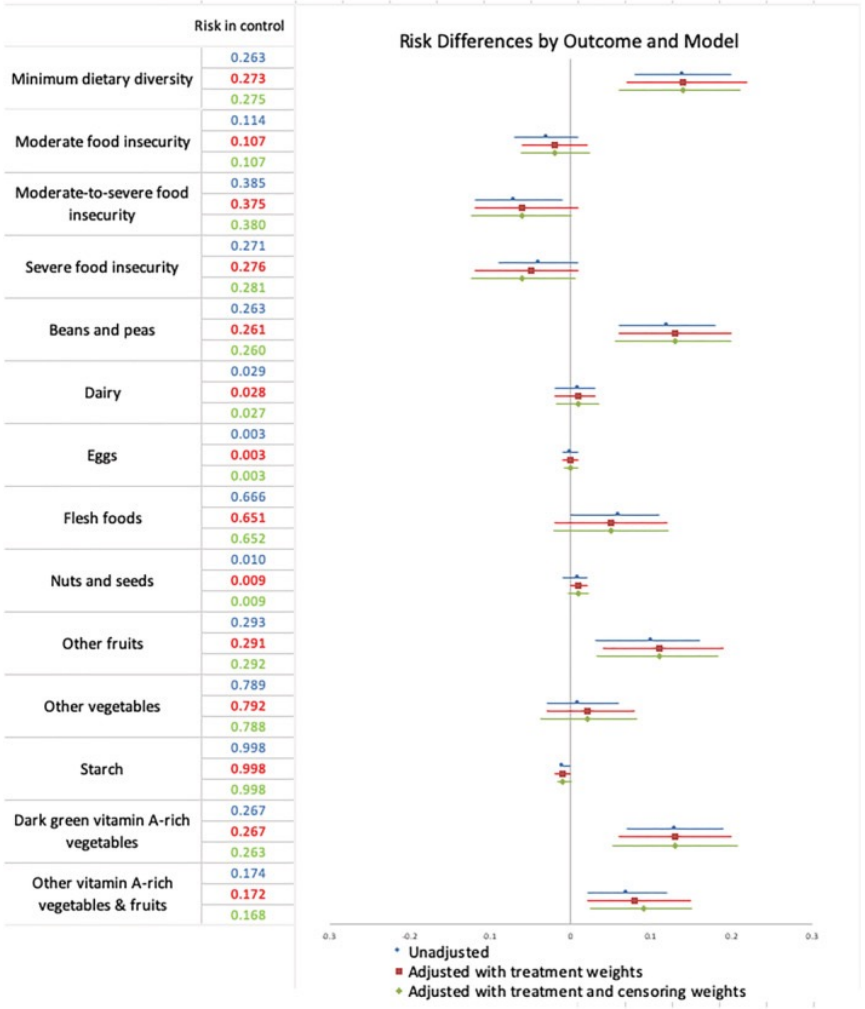
Homestead Agriculture and Nutrition (HANU) project



Risk differences between intervention (INT) and control (CON) households after 12 months of follow up. Adjusted models show difference in risk of outcome expressed as a probability of outcome in INT compared with CON group

- Evaluated integrated homestead food production intervention to improve maternal and child health and nutrition outcomes in a rural community in Tanzania
- Homestead agriculture was associated with increased dietary diversity and food security for women of reproductive age after 1 year
- Evidence of spill-over benefits of the homestead intervention to households that did not participate in the intervention, with improved dietary diversity for women

Blakstad et al. Matern Child Nutr, 2021;

Blakstad et al. Public Health Nutr, 2019.

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Homestead Agriculture and Nutrition (HANU) project

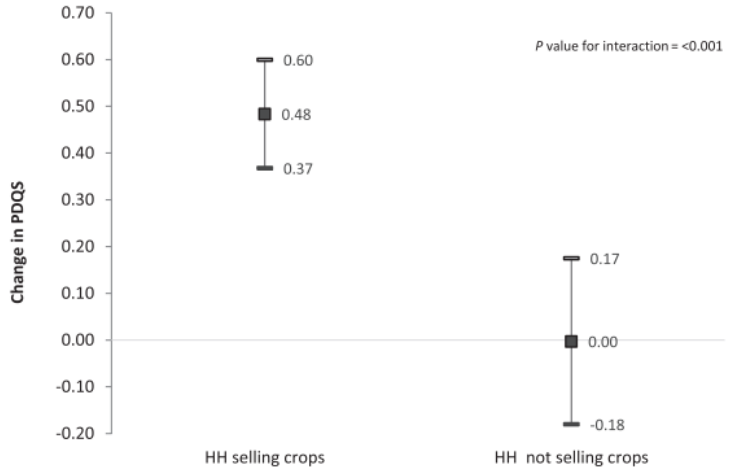

FIGURE 4 Association of crop species richness with PDQS among women in rural Tanzania, stratified by sale of food crops. Error bars are 95% CIs. GEE linear models with exchangeable correlation, controlling for clustering by village pair, were used to evaluate the association of crop species richness with maternal diet quality. Stratified models were restricted to women whose households sold at least 1 food crop or households that did not sell food crops in the previous year. The models control for treatment (HANU/control), maternal age (years), maternal education (none, primary, secondary, and higher), parity (0–2, ≥3), wealth index (quintiles), land size (acres), livestock diversity score, women's participation in nonfarm economic activities, receiving wages or salary, maternal BMI categories, market food diversity score, and distance to market. The association of crop species richness with PDQS is stronger among women from households that sold food crops. Abbreviations: GEE, generalized estimating equation; HH, household; PDQS, prime diet quality score.

- Diversification of food crop production and access to non-farm income associated with women's diet quality and dietary diversity in rural Tanzania
- Food production may interact with access to markets for sales and purchases to influence women's diet quality in rural Tanzania.

Madzorera et al. J Nutr, 2021.

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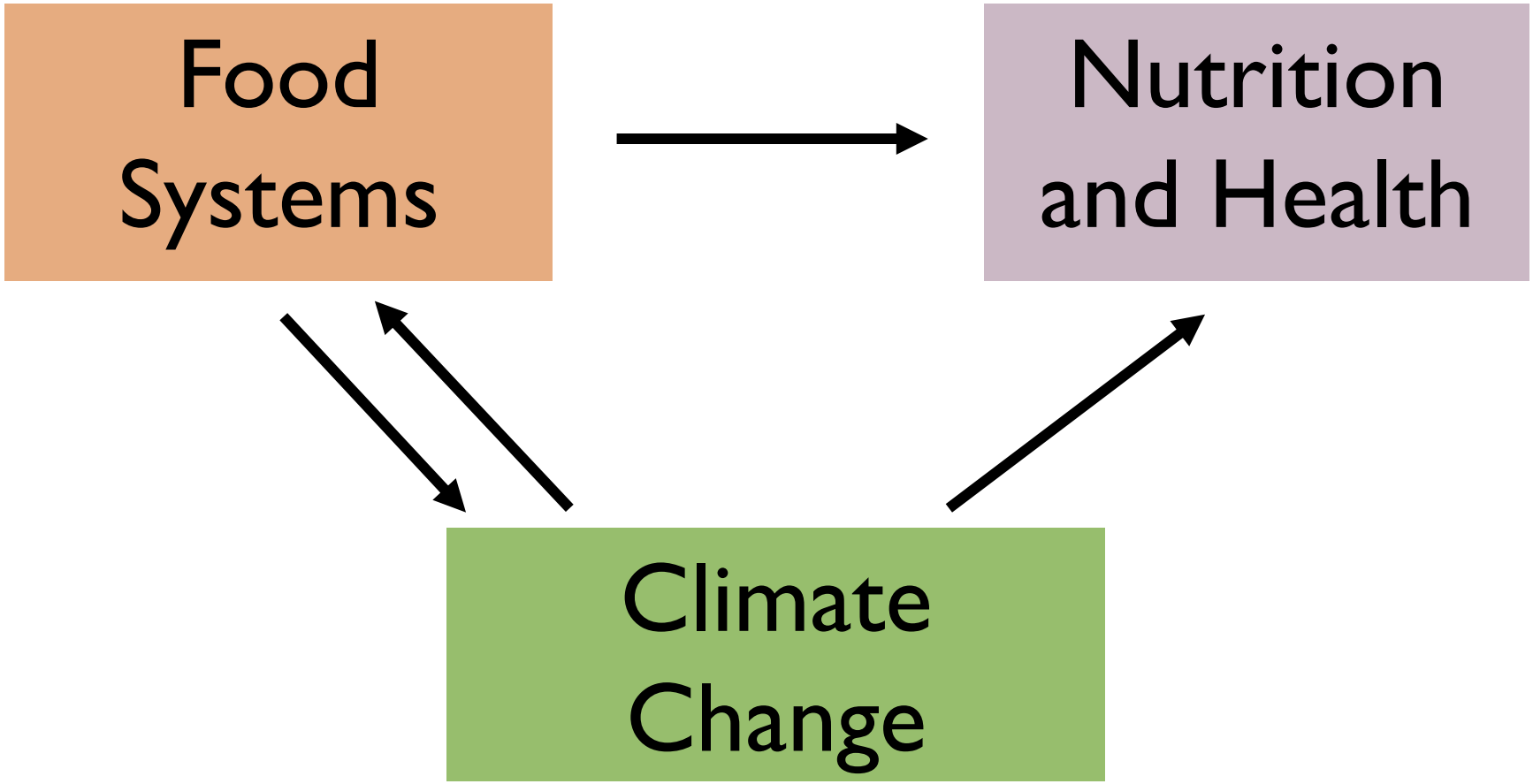
Food Systems
Nutrition and Health
Climate Change

Life expectancy and agricultural environmental impacts can be improved through optimized plant and animal protein consumption

Framework of comparative risk assessment, local dietary surveys and relative risks from large observational studies used to quantify health and environmental impacts of meeting adult and child recommended daily protein intakes in urban Addis Ababa.

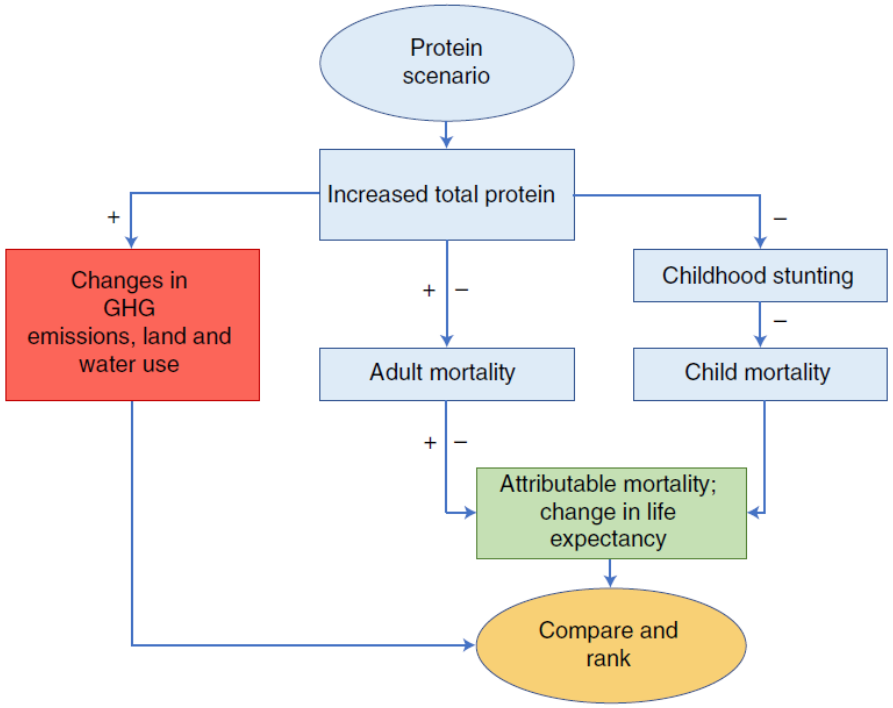

Fig. 1 | Conceptual framework. Analysis flowchart for quantifying the planetary health effects of dietary strategies to meet the protein RDA.

Blakstad et al. Nature Food 2021.

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Life expectancy and agricultural environmental impacts can be improved through optimized plant and animal protein consumption

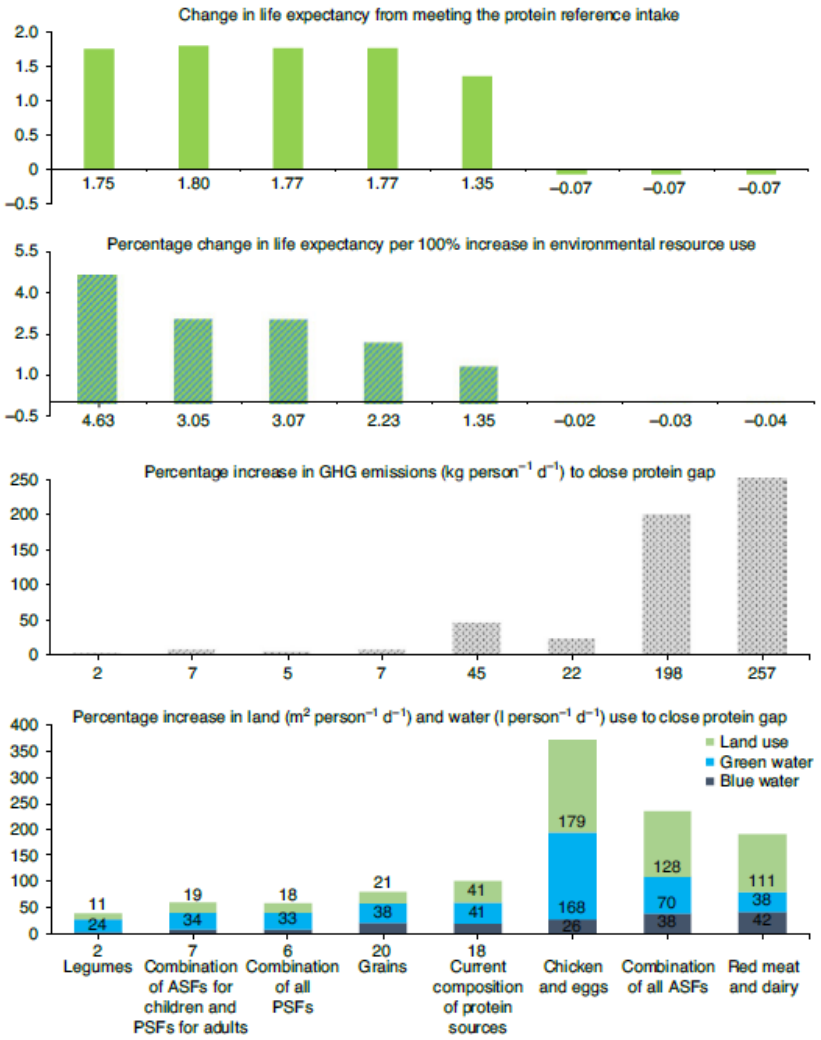

Fig. 2 | Life expectancy and environmental impacts of meeting protein reference intake. Results reflect intakes of children aged between 6 months and 5 yr, and adults aged between 20 and 60 yr in Addis Ababa. ASF, animal-source food; PSF, plant-source food.

- Animal-source protein for children and plant-source protein for adults had largest absolute health gain: life expectancy at birth was estimated to increase by 1.19 yr
- Legumes strategy had the lowest environmental impact with a 65% increase in land and water use and a 2% increase in GHG emissions relative to the environmental impacts associated with the status quo diet

Blakstad et al. Nature Food 2021.

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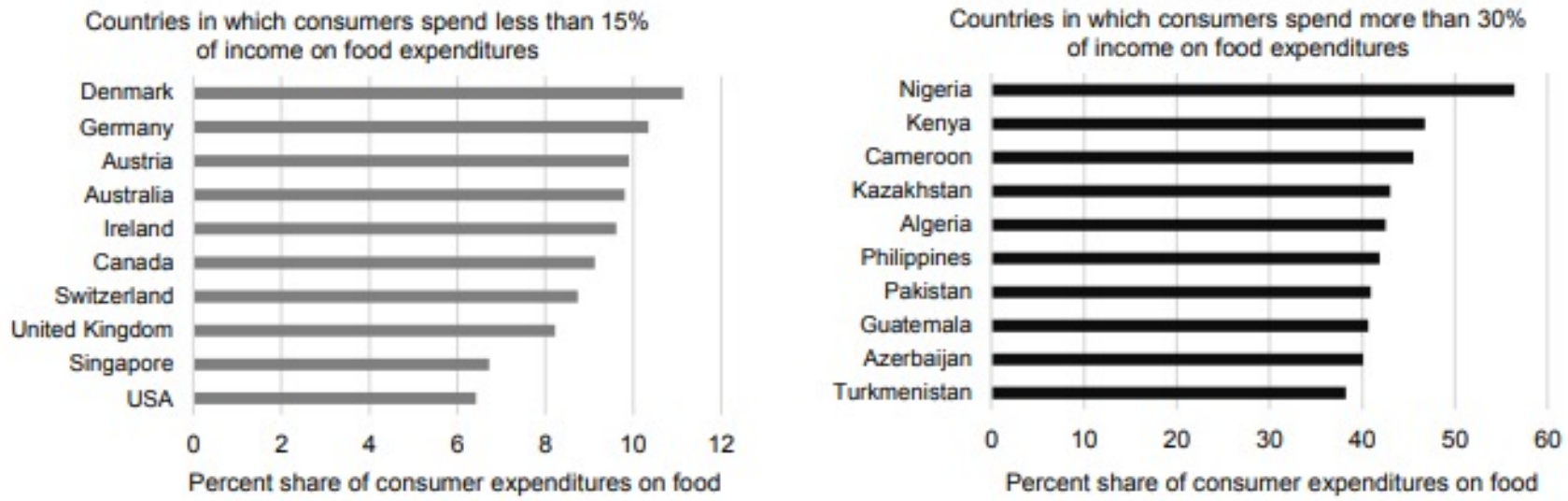
Current food systems are not producing equitable, affordable diets

Figure 2 Proportion of household budgets spent on food in different countries (2015)



Source: USDA ERS Food Expenditure Series 2016 "Percent of consumer expenditures spent on food, alcoholic beverages, and tobacco that were consumed at home, by selected countries, 2015" available at: https://www.ers.usda.gov/data-products/food-expenditures.aspx

HLPE, 2017

Conclusion

Addressing challenges in food systems is key to meeting the health and environmental SDGs in Africa and South Asia, where undernutrition and micronutrient deficiencies persist alongside overweight and obesity and related chronic diseases



Madzorera et al. Curr Dev Nutr, 2021.

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Africa Research Implementation Science and Education (ARISE) Network

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Comprehensive Nutrition and School Garden Project

- Assess the impact of a community-based school intervention package on improving adolescent nutrition, health, and school attendance, as well as community agriculture productivity and food security

  1. School Garden and Meal Program
  2. Agriculture, Nutrition, and WASH Education
  3. Community Education and Fertilizer/Seed Distribution

- 6 schools in Dodoma, Tanzania (3 intervention and 3 control)

Key challenges in food systems in LMICs and proposed solutions

Challenges in food systems	Proposed solutions
1. Complexity of food systems	• Refinement of concepts and definitions through research and across specializations • Tools and metrics can be refined, simplified and standardized, and approaches developed to allow the collection of data at national and subnational levels
2. Scarcity of data on food systems	• Collection on data in systematic and simplified approaches across countries • Development of dashboards and other resources tracking progress in food systems
3. Lack of appropriate tools and indicators for the measurement of food systems, including diet quality, food affordability, and drivers of food choices in LMICs	• Development and validation of tools and indices for measuring diet quality, assessing both micronutrient adequacy and consumption of healthy and unhealthy foods • Development and validation of tools for assessing affordability • Increased research to determine the drivers of food choices

Madzorera et al. Curr Dev Nutr, 2021.

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Key challenges in food systems in LMICs and proposed solutions

4. Knowledge gaps: Which food systems interventions are effective in improving diets and addressing suboptimal nutrition in LMICs	• Technology to increase the production of nutrient-dense food and small livestock production • Improvements in genetics and market linkages for nutrient-rich food crops, biofortification, small livestock production • Interventions to evaluate the effectiveness of agriculture and food systems approaches to improving nutrition, considering intermediary outcomes • Innovative approaches for scale-up of effective interventions
5. Environmental risks to nutrition	• Research on new technology in management practices and pest control, and actions taken to prevent natural resource degradation • Innovation in farm management practices
6. Interdisciplinary training and skills are lacking	• Interdisciplinary approaches in research and groups undertaking work on food systems • Nutrition training for agriculture, health, food science, and other groups • Cross-disciplinary and multisector training through short courses, joint training, and learning approaches across various sectors

Madzorera et al. Curr Dev Nutr, 2021.

Harnessing University Strengths in Multisectoral Collaborations for Planetary Health

- Poor dietary intake, over-and undernutrition, and chronic diseases are persistent health challenges in sub-Saharan Africa.

- A planetary health approach to addressing these challenges offers a unique opportunity to advance solutions for environmental and social factors that influence agriculture, nutrition, and overall health in the larger context of rapid population growth and transitions in food systems and livelihoods.

- Universities can promote planetary health approaches through: 1) new research to assess complex relations between people and the environment; 2) development of novel interventions and study designs; and 3) the advancement of multidisciplinary training programs.

Passarelli et al. Curr Dev Nutr, 2018.

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Vitamin A fortification of sugar

- In Guatemala and other Central American countries, vitamin A has been added to sugar since 1974.
- A longitudinal evaluation of children (5 surveys enumerated 6 months apart) observed changes in serum vitamin A levels after the intervention was implemented.
- After 1 year of fortification, 76% of children experienced an elevation of retinol, and all those with initial values <20 µg/dl showed improvement.
- Significant improvements were observed for those with baseline serum retinol <20 µg/dl (increase from 16.2 to 30.2) and among those with baseline values of 20-29 µg/dl (increase from 24.9 to 30.1).
- Natural dietary vitamin A remained unchanged throughout.

Vitamin A supplementation

- A meta analysis of 43 vitamin A supplementation trials including 215,633 children aged 6-59 months found:
  - 24% reduction in all-cause mortality
  - 28% reduction in diarrhea-related mortality
  - 15% reduction in diarrhea incidence
  - 50% reduction in measles
  - 68% reduction in night blindness
  - 69% reduction in xerophthalmia
  - Three trials reported an increased risk of vomiting in the 48 hours following supplementation (RR=2.75; 95% CI: 1.81, 4.19)
- The authors conclude that further **placebo controlled** trials of vitamin A among children 6-59 months are not required. However, studies comparing dose and delivery are useful.

Citations: Mayo-Wilson 2011

TABLE 2. Risk of Stunting and Wasting at 18 Months by Quintile of Dietary Vitamin A Intake among Children Who Had Normal Anthropometric Status at Baseline

	Quintile of Total Vitamin A Intake					*P*-Value for Linear Trend*
	1	2	3	4	5	
Stunting						
No. at risk	2,412	1,680	2,305	2,466	2,684	
No. of cases	176	141	135	133	117	
Multivariate RR† (95% CL)‡	1.0	0.9 (0.7, 1.2)	0.7 (0.6, 1.0)	0.8 (0.6, 1.0)	0.7 (0.5, 0.9)	0.03
Wasting						
No. at risk	2,412	1,680	2,305	2,466	2,684	
No. of cases	116	70	102	108	107	
Multivariate RR† (95% CL)‡	1.0	0.8 (0.6, 1.1)	0.8 (0.6, 1.1)	0.8 (0.6, 1.1)	0.7 (0.5, 0.9)	0.04

* Test for trend was obtained by modeling diet as a continuous variable and assigning the median value of each quintile to all members of the quintile.
† From logistic regression models that included age, gender, wealth, availability of water in the house, maternal literacy, region of residence, morbidity status, capsule, and quintiles of dietary vitamin A intake (4 dummy variables).
‡ CL = confidence limits.

Fawzi et al. 1997

Relative risk of death according to frequency of tomato consumption by Sudanese children

	Consumption of tomato, *d*				
	0	1	2	3	*P* for trend[2]
Cases	158	55	17	2	
Child periods	34,335	27,960	12,774	5010	
Age- and sex-adjusted RR (95% CI)[3]	1.00	0.46 (0.34–0.63)	0.39 (0.23–0.64)	0.13 (0.03–0.53)	<0.0001
Multivariate RR 1 (95% CI)[3]	1.00	0.57 (0.40–0.81)	0.52 (0.30–0.91)	0.17 (0.04–0.72)	0.0002
Multivariate RR 2 (95% CI)[3]	1.00	0.62 (0.43–0.89)	0.60 (0.34–1.05)	0.20 (0.05–0.84)	0.0002

[1] Child periods between rounds 1 and 2 were allocated to groups according to consumption of tomatoes assessed at round 1 (0 or 1 time); those between rounds 2 and 3 were allocated according to consumption of tomatoes assessed at rounds 1 and 2, respectively (0, 1, or 2 times); and those between rounds 3 and 4 were allocated according to consumption of tomatoes assessed at rounds 1, 2, and 3, respectively (0, 1, 2, or 3 times).

[2] Test for trend was obtained with frequency of tomato consumption as a continuous variable.

[3] Relative risk (RR) and confidence interval (CI) are derived from logistic models. The model for multivariate RR 1 included age (six-level ordinal), sex, and (in multivariate model 1) capsule (vitamin A or placebo), wealth (four-level ordinal variable), maternal literacy (yes/no), water in house (yes/no), and region (four dummy variables). In addition to these variables, multivariate model 2 included morbidity in the previous round (four dummy variables: diarrhea with or without fever, cough, cough with fever, measles with "no signs" as reference), nutritional status (four dummy variables: wasted, stunted, wasted and stunted, not known with "normal" as reference), and seasonality (five dummy variables for six 2-mo periods).

Fawzi et al. 2000

Comparing supplementation, fortification, and diet diversity

Intervention	Benefits	Challenges
Supplementation	• High dose can lead to faster repletion • Can be targeted to specific populations	• Requires a continual delivery mechanism • Relies on patient behavior
Fortification	• Less reliant on patient compliance • Mass coverage and easier delivery • Inexpensive (eventually)	• Input from Industry • Requires staple food • Not targeted • Requires monitoring
Diet diversification	• Health benefits of foods extend beyond individual nutrients	• Depends on access to food (financial,

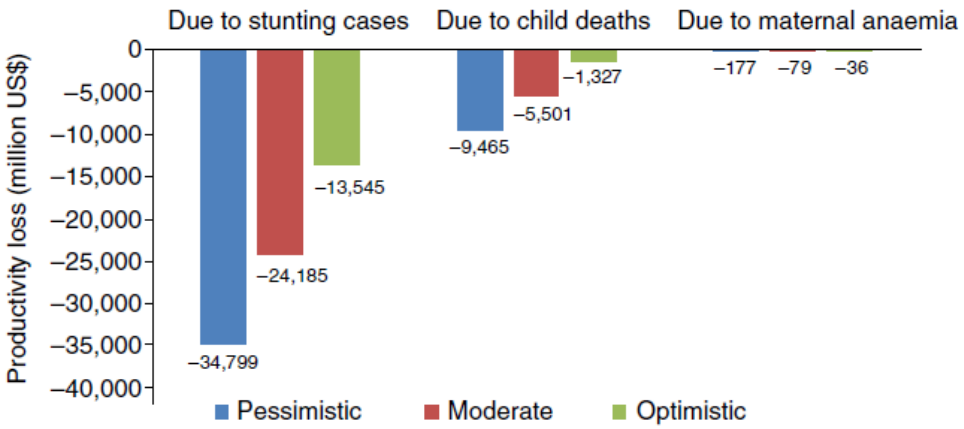
Climate change undermining infectious disease eradication efforts

- Increasing suitability for transmission of water-borne, air-borne, food-borne, and vector-borne pathogens.
    - Number of months with environmentally suitable conditions for the transmission of malaria (*Plasmodium falciparum*) rose by 39% from 1950–59 to 2010–19 in areas with low human development index
- Extreme weather events, infectious disease transmission, and food, water, and financial insecurity are overburdening the most vulnerable populations.

Romanello et al. Lancet, 2021.

COVID-19 will exacerbate maternal and child undernutrition and child mortality in low- and middle-income countries

- By 2022, COVID-19-related disruptions could result in an additional:
  - 9.3 million wasted children
  - 2.6 million stunted children
  - 168,000 child deaths
  - 2.1 million maternal anemia cases
  - 2.1 million children born to women with a low BMI
  - US$29.7 billion in future productivity losses



Future productivity losses due to additional cases of child stunting, mortality and maternal anemia.

Additional US$1.2 billion per year will be needed to mitigate these effects by scaling up nutrition interventions

Osendarp et al. Nature Food, 2021.

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ARISE COVID-19 Survey

Nutrition and Food Security during the COVID-19 Pandemic in Ethiopia, Burkina Faso, Nigeria

- Participants reported increased prices of staples, pulses, fruits, vegetables and animal source foods
- ≥40% reported decreased consumption of staples, legumes, some vegetables and fruit
- Diet diversity and diet quality were lower during the COVID-19 pandemic
- Lower crop production was associated with lower diet diversity

Madzorera et al. AJTMH 2021.

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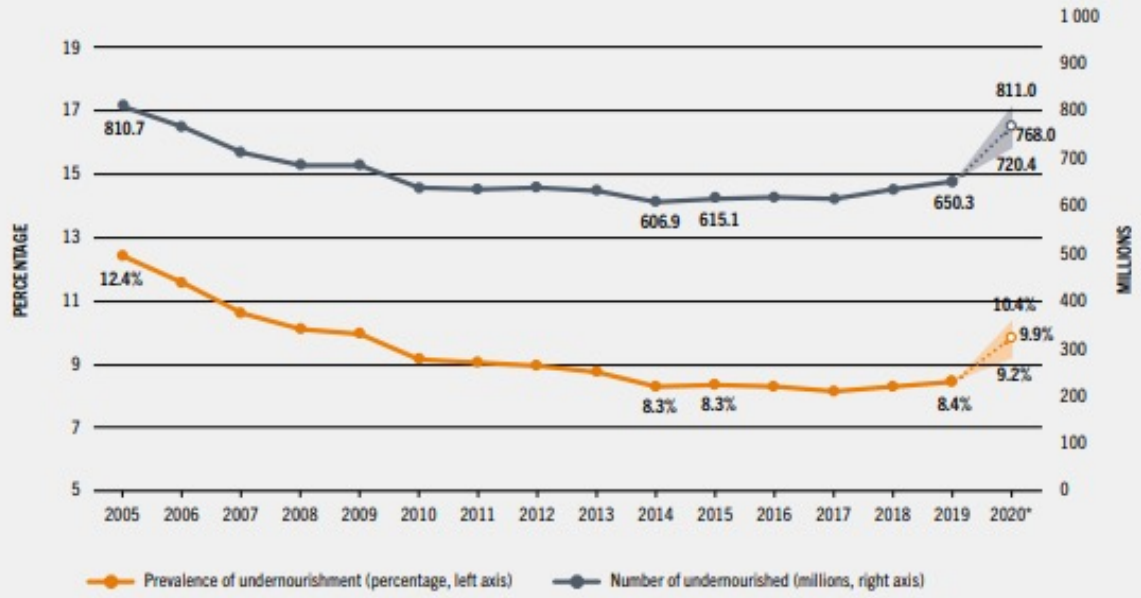
Food insecurity and hunger are rising worldwide

FIGURE 1 THE NUMBER OF UNDERNOURISHED PEOPLE IN THE WORLD CONTINUED TO RISE IN 2020. BETWEEN 720 AND 811 MILLION PEOPLE IN THE WORLD FACED HUNGER IN 2020. CONSIDERING THE MIDDLE OF THE PROJECTED RANGE (768 MILLION), 118 MILLION MORE PEOPLE WERE FACING HUNGER IN 2020 THAN IN 2019 – OR AS MANY AS 161 MILLION, CONSIDERING THE UPPER BOUND OF THE RANGE



NOTES: * Projected values for 2020 in the figure are illustrated by dotted lines. Shaded areas show lower and upper bounds of the estimated range.
SOURCE: FAO.

FAO, IFAD, UNICEF, WFP and WHO. 2020

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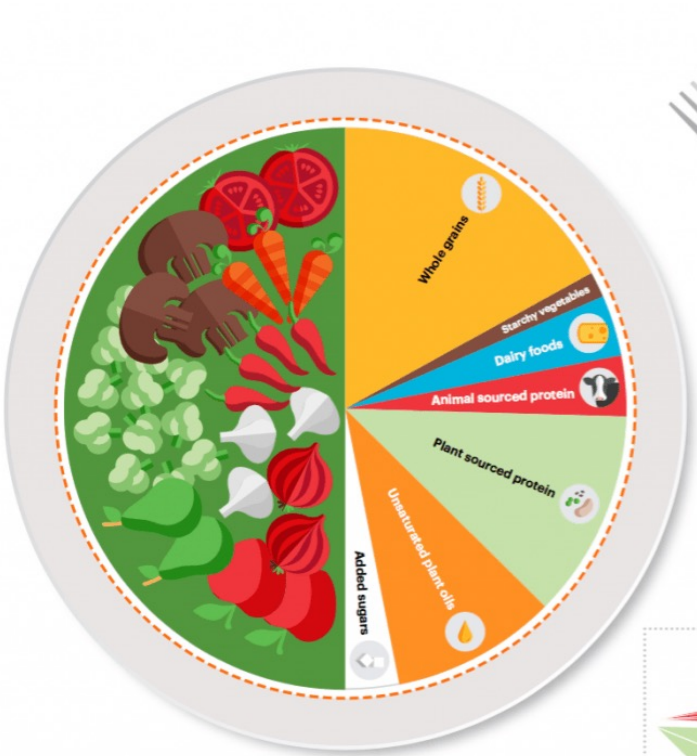
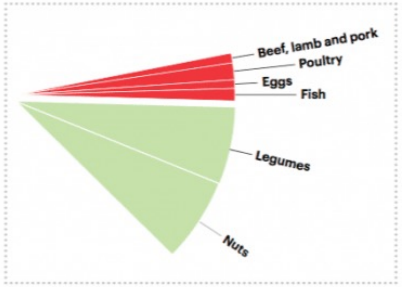
Planetary Health Diet

- Designed to improve human and planetary health
- Abundant vegetables, fruits, whole grains, legumes, nuts, and unsaturated oils
- Moderate seafood, poultry and dairy (optional)
- Limits red meat, processed meat, added sugar, refined grains, starchy vegetables and highly processed foods
- Appropriate calorie intake

Willett et al, EAT Lancet Commission Report 2019.





- Compared with current diets, this shift will require global consumption of foods such as red meat and sugar to decrease by 50%, while consumption of fruits, nuts, vegetables, and legumes must double.
- It is important to tailor these targets to local situations. For example, while North American countries currently consume almost 6.5 times the recommended amount of red meat, countries in South Asia eat only half the recommended amount.

Affordability of EAT Lancet Diet

- Most affordable EAT–Lancet diets cost a global median of US$2·84 per day in 2011

- Cost of an EAT–Lancet diet exceeded household per capita income for at least 1·58 billion people

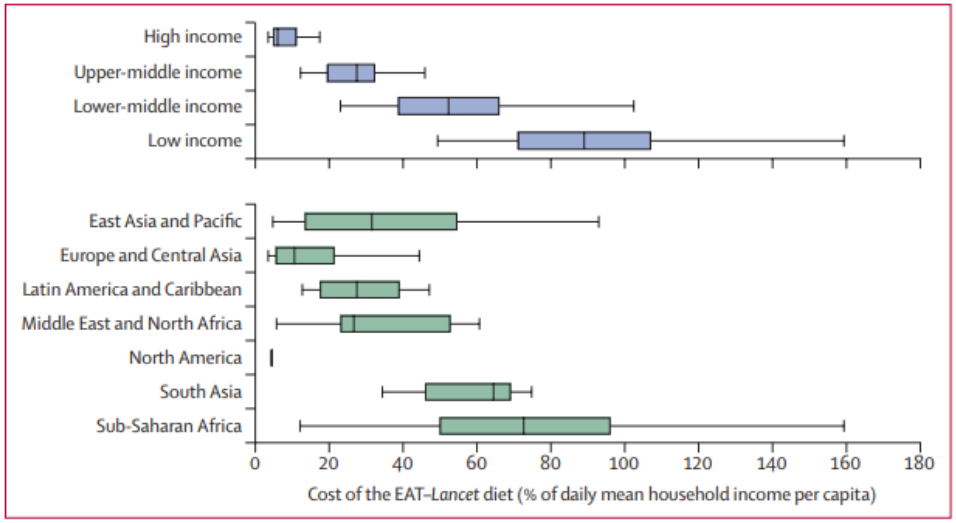


Figure 2: **Cost of the EAT–*Lancet* reference diet relative to mean daily per capita household income by country income levels and major regions**
We used price data from the International Comparison Program to estimate the cost of the EAT–*Lancet* diet and compared these estimates to mean daily per capita household income. The size of the box indicates the IQR. The bottom and top rule marks the bottom fifth and top fifth percentiles, respectively. The vertical bar rule inside the box shows the median value for the income group or geographical region. N=141 countries.

- Current diets differ greatly from EAT–Lancet targets. Improving diets is affordable in many countries but for many people would require some combination of higher income, nutritional assistance, and lower prices

Women empowerment is central to addressing the double burden of malnutrition

- Important for enhancing infant and young child feeding, household caloric availability and dietary diversity
- Women provide 50% or higher of agricultural labor in smallholder farms yet own 5–30% of the agricultural land in LMICs
- Women farmers need empowerment through increased control of production resources and land, improved seeds, technology for planting and harvesting, credit, training and extension services.
- Women need decision-making power over productive assets and the use of income from agriculture and off-farm employment in order to act on nutrition knowledge.

Madzorera et al. EClinicalMedicine, 2020.

Conclusions

- **Key areas of intervention:**
  - Optimizing food systems and increasing agricultural productivity beyond calories, to nutrient-rich vegetables and fruits, legumes, and livestock, and sustainable fishing.
  - Strengthening of research around food systems—on pathways, value chains, and development and validation of metrics of diet quality.
  - Development of new technology in crop management and pest control and addressing natural resource degradation.
  - Engaging with the public and private sectors, outreach to donors and policymakers, and strengthening cross-disciplinary collaborations are imperative to improving food systems.

Madzorera et al. Curr Dev Nutr, 2021.

Source: NASA

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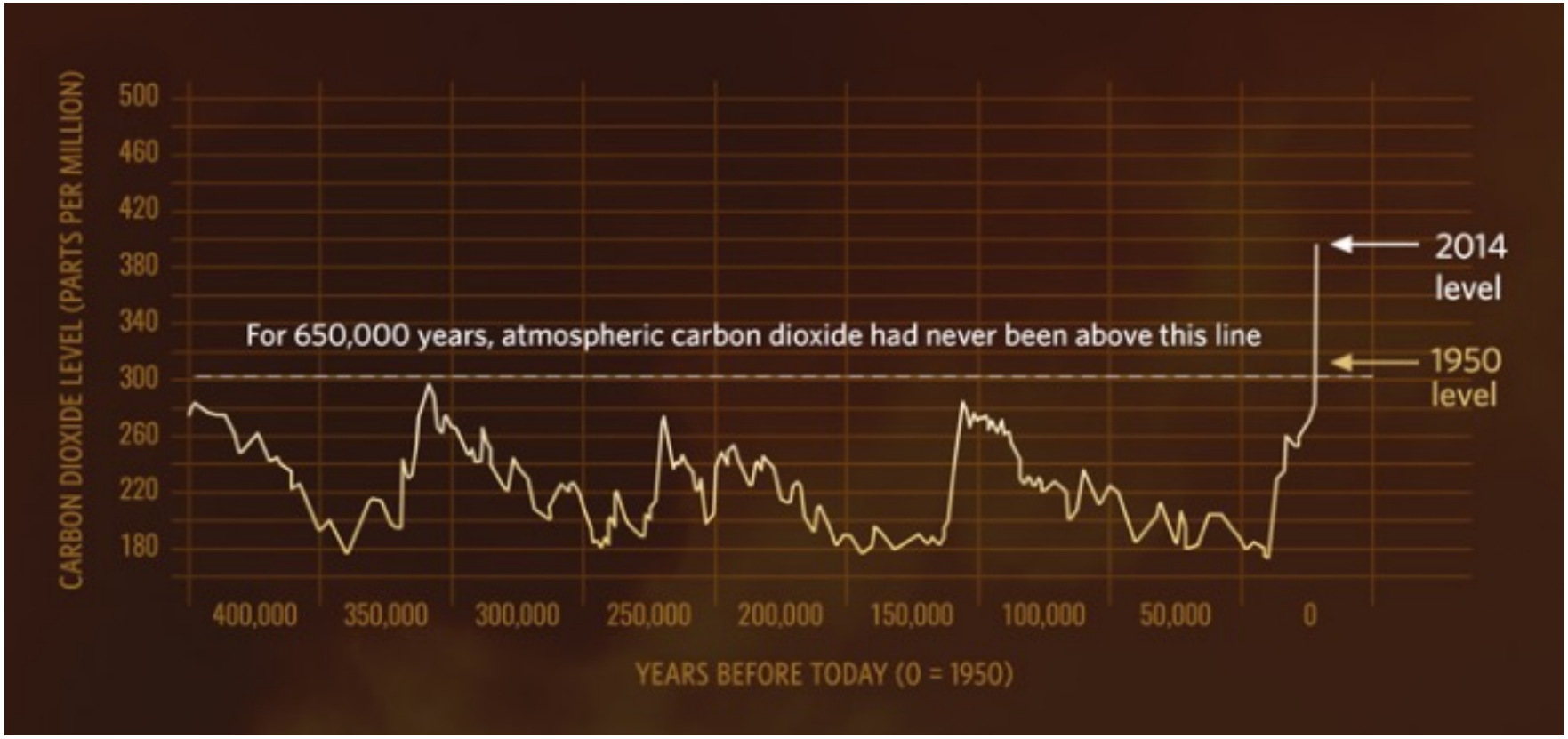
Atmospheric carbon dioxide levels are increasing



Source: NASA

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The world is facing triple threats of obesity, undernutrition and climate change

And the world population will grow to 10 billion in 2-3 decades

Food and Agriculture Organization of the United Nations

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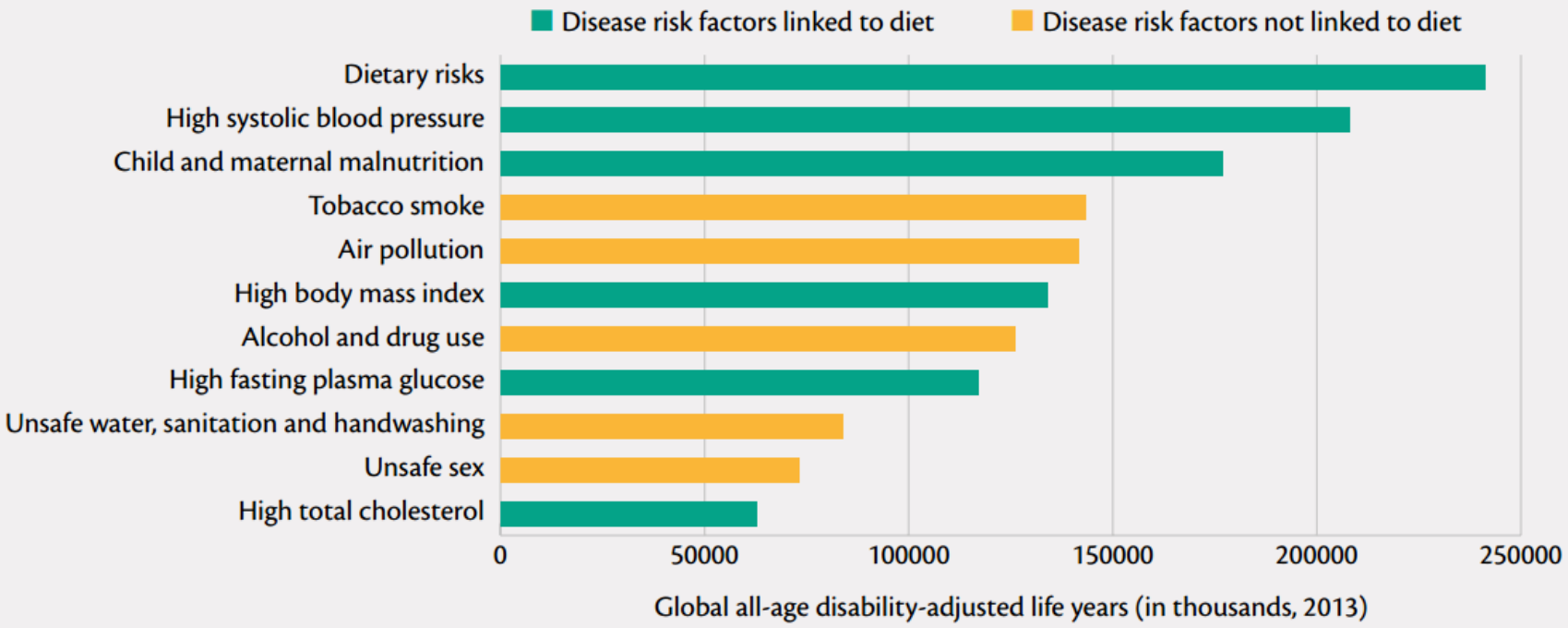
Sustainable Development Goals (SDGs)

- 12 of the 17 goals include indicators that are highly relevant for nutrition. For example:
  - **Indicator 3.2.2 – Neonatal mortality.** Nutrition plays an important role in infant survival.
  - **Indicator 5.3.1 – Early marriage rates.** Early marriage and early pregnancy are associated with poor nutritional outcomes.
  - **Indicator 6.1.1 – Access to improved drinking water.** Improved drinking water reduces enteric infections, which results in better nutritional absorption.
  - **Indicator 10.2.1 – Proportion of people living below 50% of the median income.** Reductions in extreme poverty are strongly associated with reductions in stunting.
  - **Indicator 16.1.2 – Number of conflict-related deaths.** Conflict is a cause of acute food shortages and malnutrition.

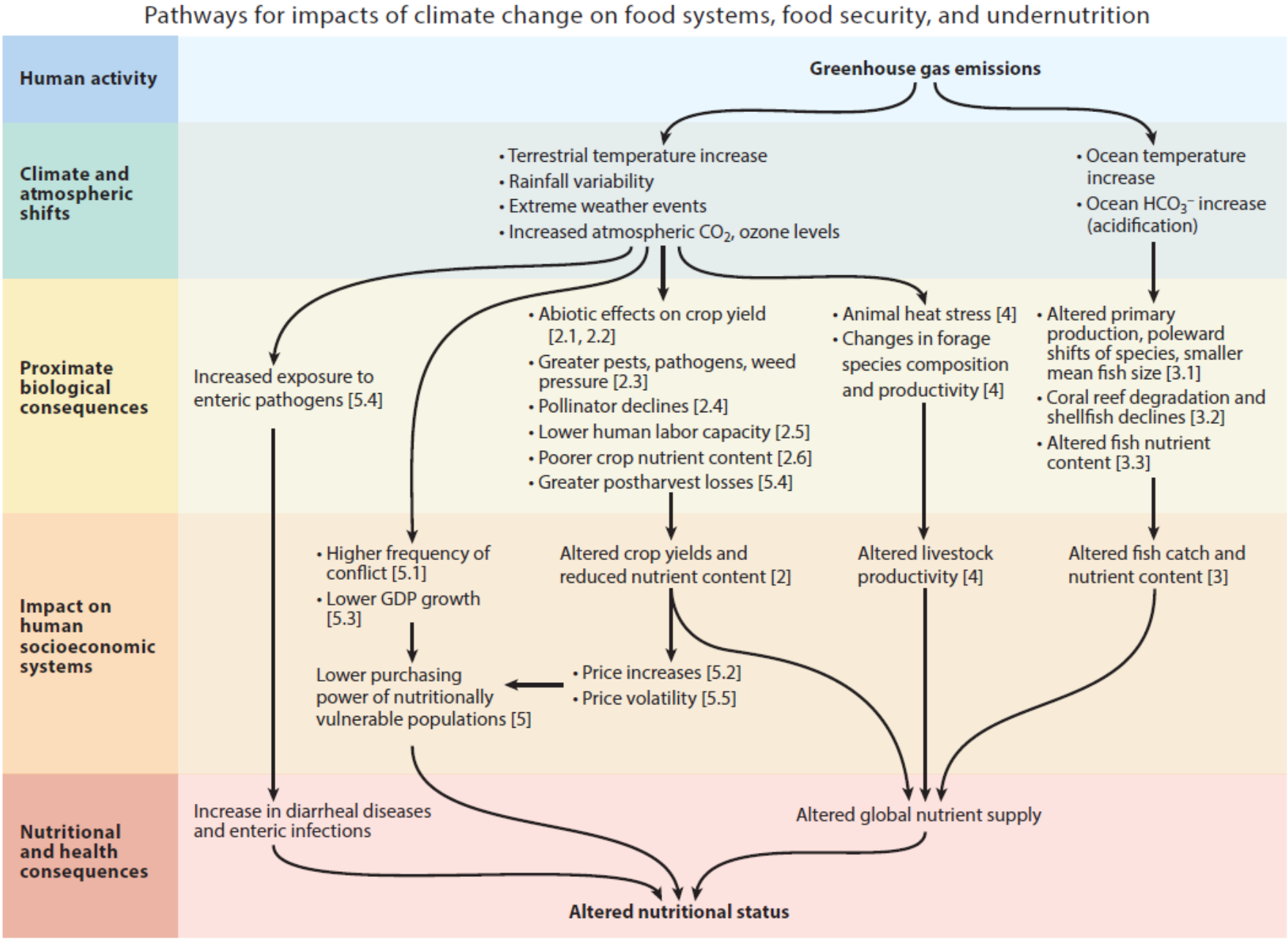
Citations: IFPRI 2016

FIGURE 1: Six of the top 11 risk factors driving the global burden of disease are related to diet



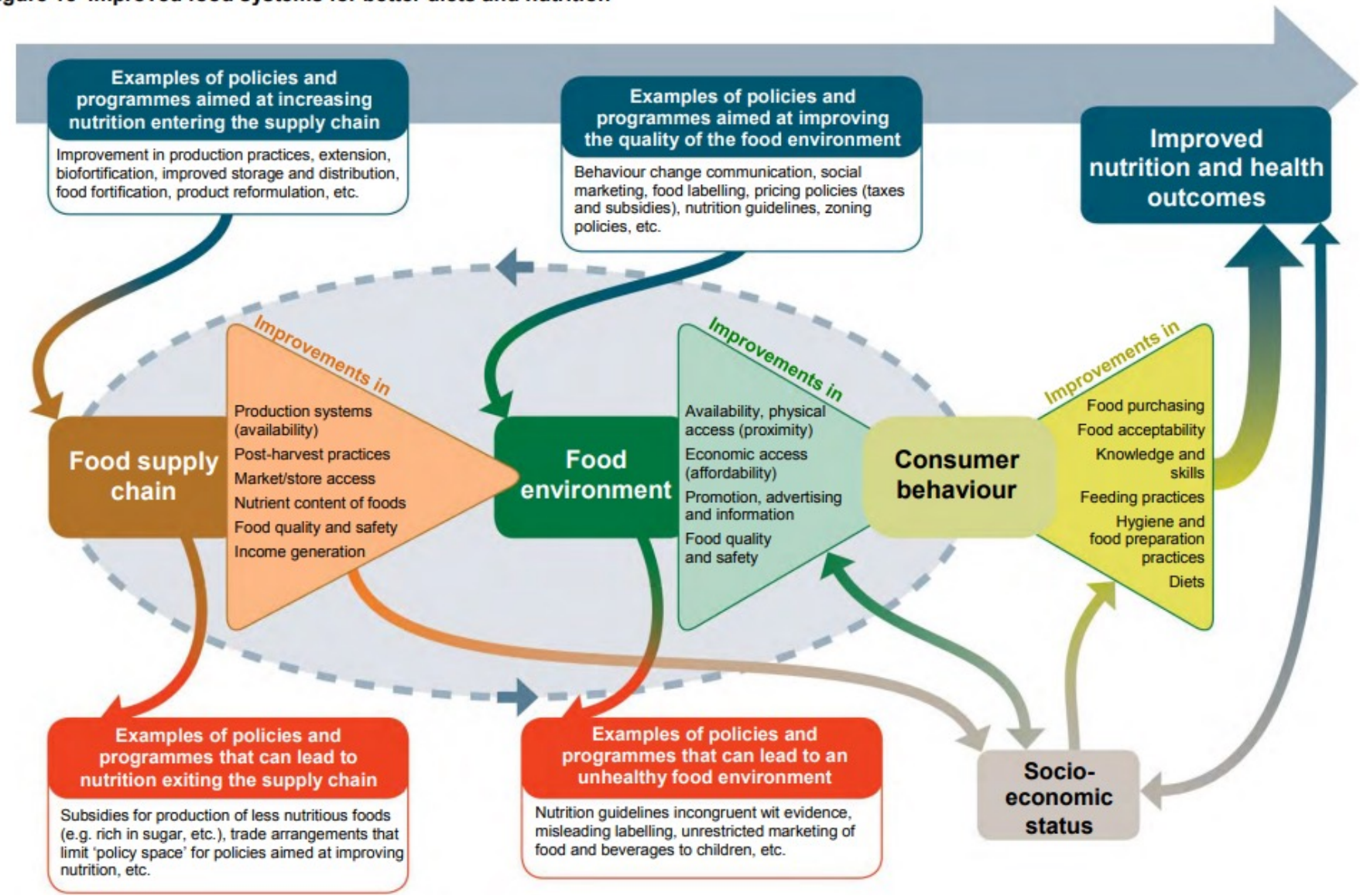
Source: Global Burden of Disease Study 2013 Collaborators (2015), Figure 5

Note: The graph shows global disability-adjusted life years (DALYs) attributed to level 2 risk factors in 2013 for both sexes combined.



Meyers et al. Annual review of public health, 2017.

Figure 15 Improved food systems for better diets and nutrition



HLPE, 2017

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Questions?