NEXUS Gains:
Realizing Multiple Benefits
Across Water, Energy, Food
and Ecosystems

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

Climate change and food security

(Food-land-water-energy nexus)

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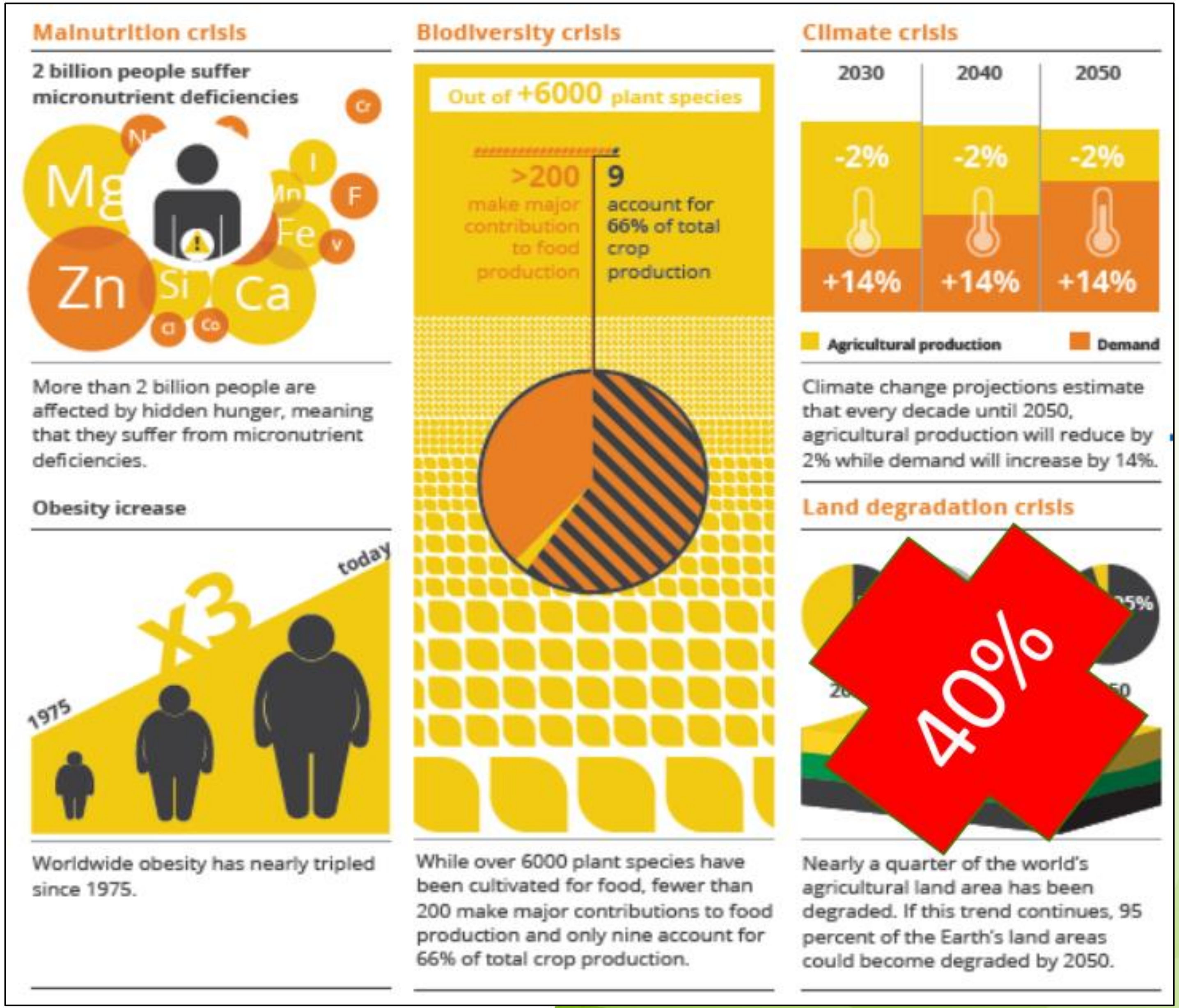
Presentation Plan

- ❖ Context of food security and climate change and their relationship
- ❖ Frameworks for assessment
- ❖ Adaptation and mitigation options
- ❖ Current research and tools (FABLE Consortium)
- ❖ Our ongoing research in India (using case studies)

The challenge



Source: Nature+ Initiative of OneCGIAR

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What are some of the ways in which climate change affects food security?

ⓘ Start presenting to display the poll results on this slide.

Focus on FOOD SYSTEMS

Factors affecting agriculture and food security –

- arable land, available fresh water, and skilled labor, given constant physical assets of farming, suitable climate conditions, including rainfall, and soil quality, landscape and geographic location, and species of crops and livestock

ALL of these things will be affected by climate change!

Will affect

- Food availability
- Access
- Food utilization
- Stability

IPCC Special Report

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People currently use one quarter to one third of **land's** potential net primary production for food, feed, fiber, timber and energy.

Agriculture currently accounts for ca. 70% of global **fresh-water** use

Data available since 1961 shows the per capita supply of vegetable oils and meat has more than doubled and the supply of **food calories** per capita has increased by about one third

Currently, 25–30% of total food produced is lost or **wasted** - estimated 821 million people are still **undernourished**

Frequency and intensity of **droughts** has increased in some regions (including the Mediterranean, west Asia, many parts of South America, much of Africa, and north-eastern Asia) and there has been an increase in the intensity of heavy **precipitation** events at a global scale

Rising sea levels, CO2–induced ocean acidification, and changes in water temperature have also impacted the health and sustainability of marine and freshwater **fisheries** crucial to regional dietary diversity and **livelihoods**

High confidence

- contributions arising from **unsustainable energy use, land use and land-use change**, lifestyles and **patterns of consumption and production** across regions, between and within countries, and among individuals

Adverse impacts on **agricultural production**

Adverse and positive impacts attributed to climate change

- Physical **water** availability
- Animal and **livestock health** and productivity

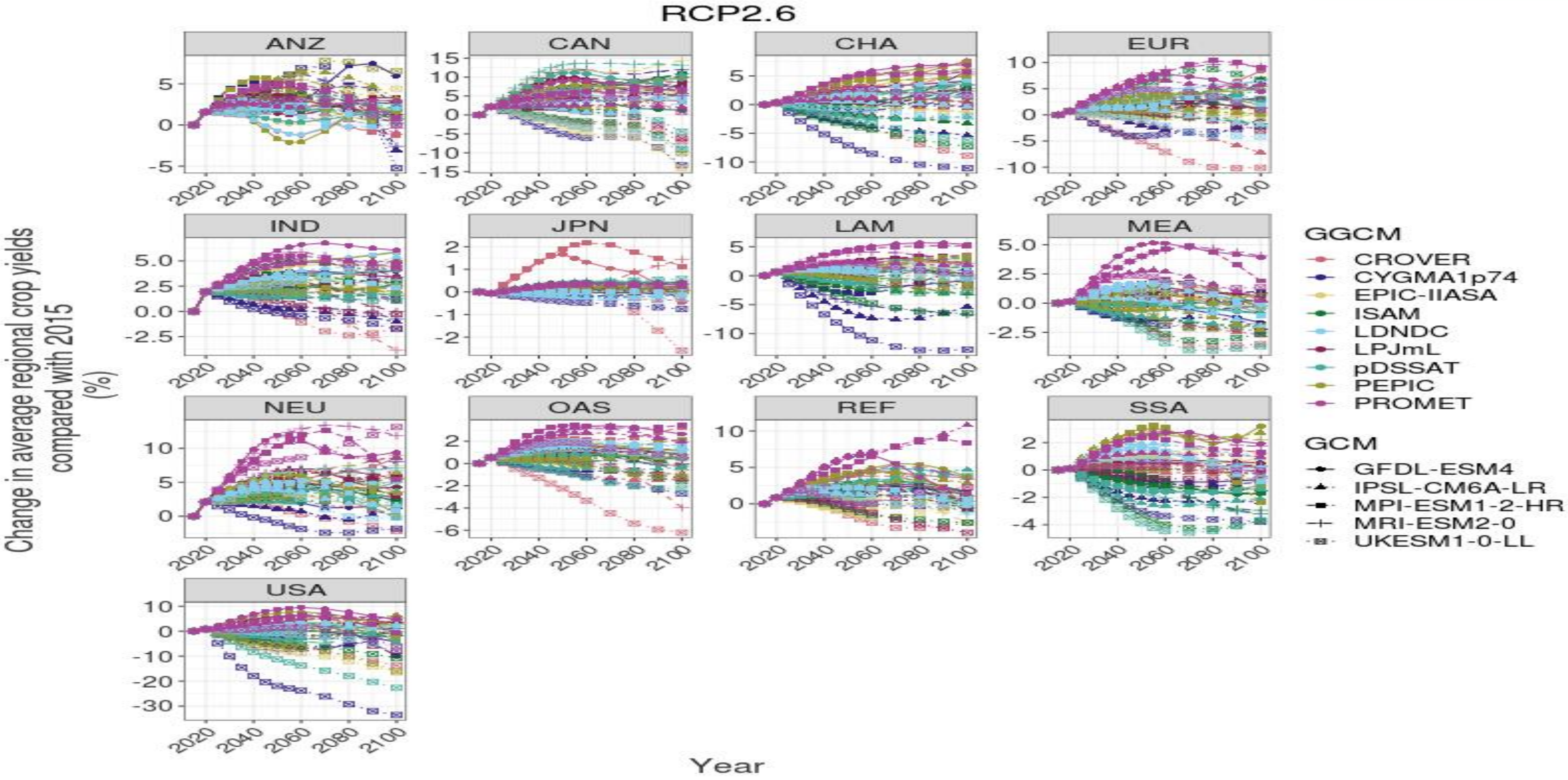
Impacts of climate change

- increased probability of crop failure (IPCC 2019)
- Increased incidences of droughts and floods
- Increased food-borne and other infectious diseases
- Reduction in biodiversity
- Increase all forms of malnutrition and obesity

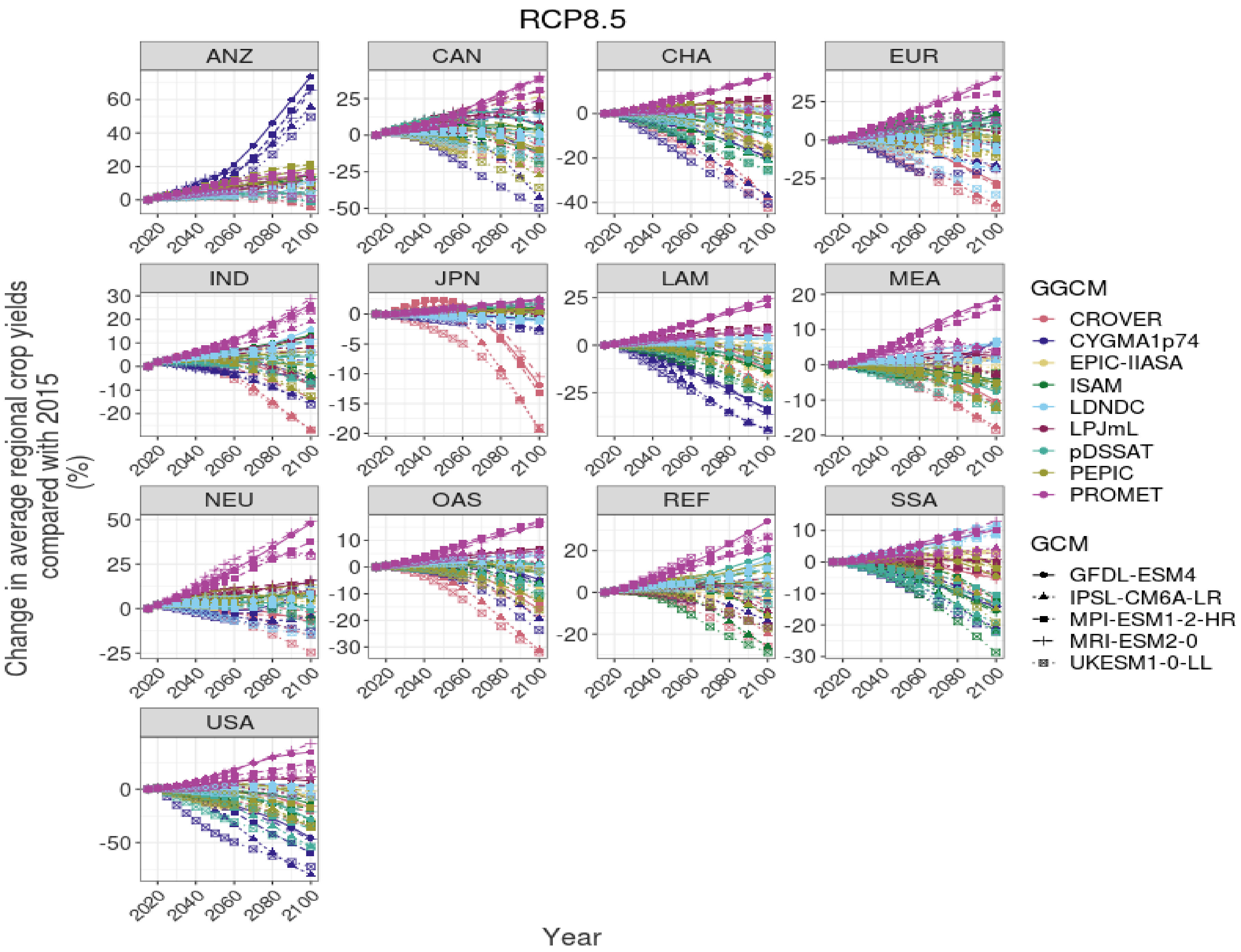
In India specifically,

- Food systems strongly dependent on the agricultural sector
- most of the population is employed
- food demand, employment, and incomes as well as livestock feed requirements
- 39% of India's population (472 million people) is under-nourished, rise in NCD's
- Healthy diets not affordable for over 2/3rds of the population
- Agriculture sector (including livestock) emits 18% of Greenhouse Gas Emissions (causing global warming)
- 80% of freshwater used for production of cereal crops (rice and wheat)

Potential impacts on yields (low emissions scenarios)



Source: Molina Bacca, E.J., at.al., 2023



High emissions scenario

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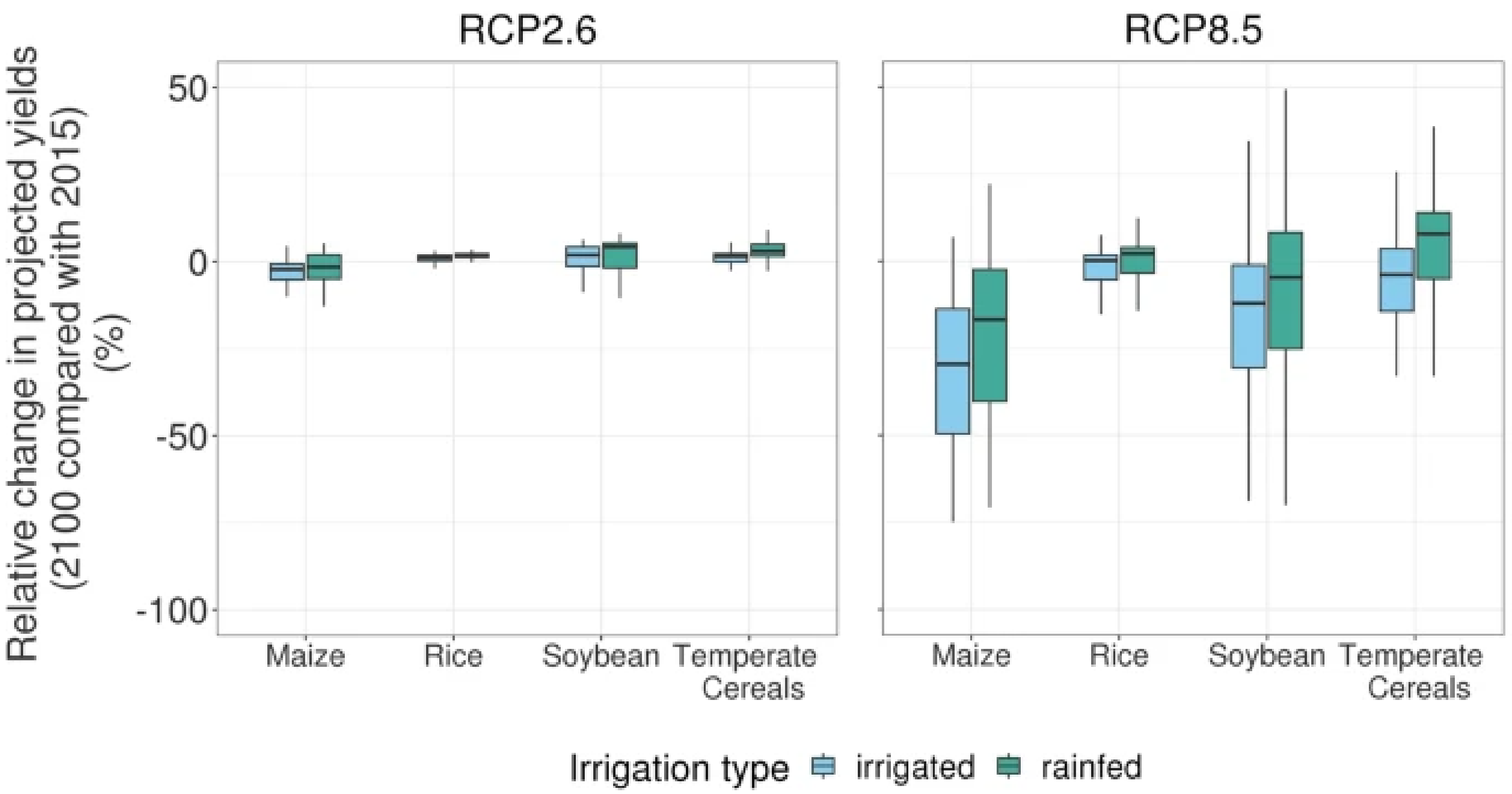
Projected yield change for four major crops



Source: Molina Bacca, E.J., at.al., 2023

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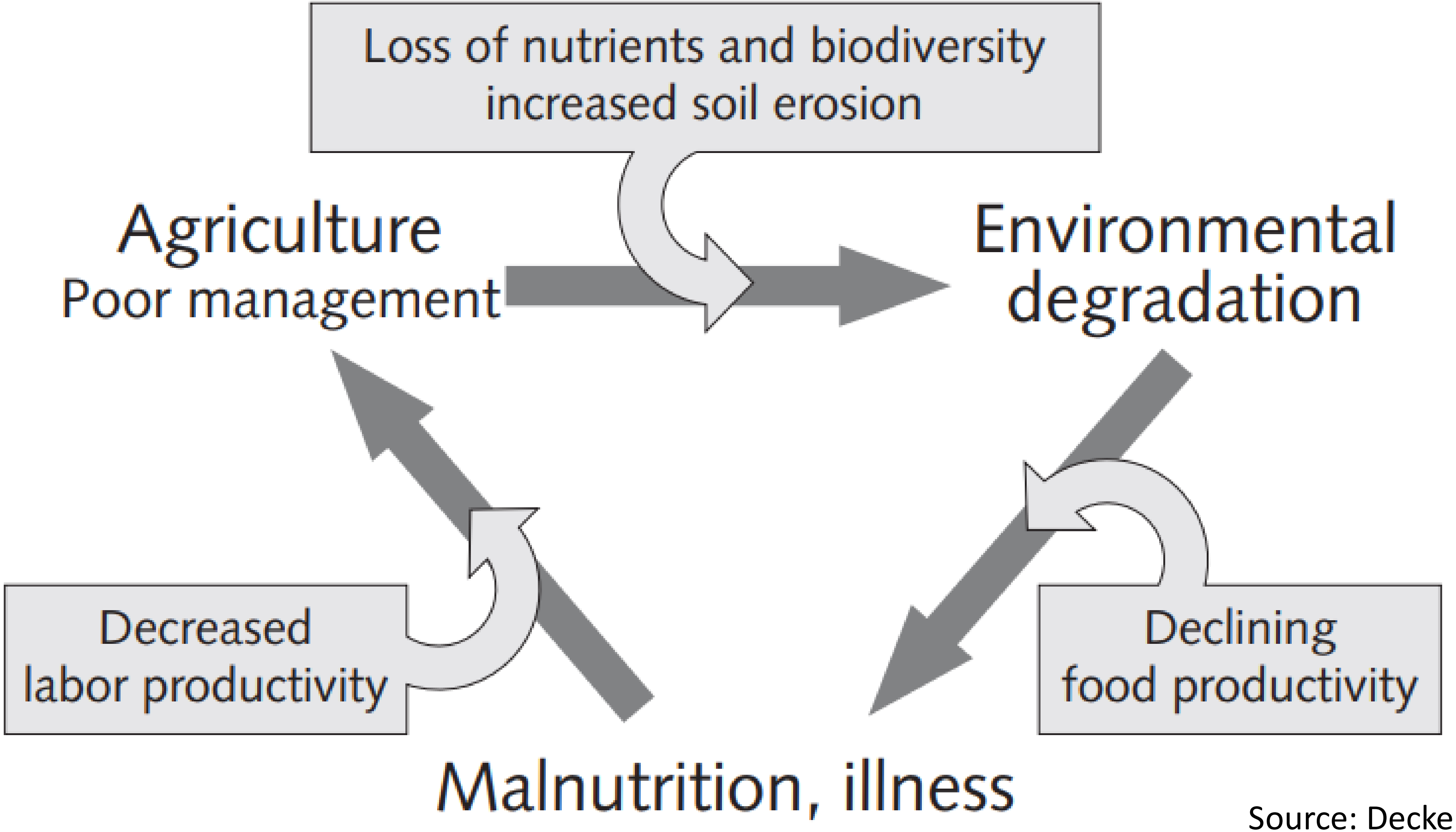
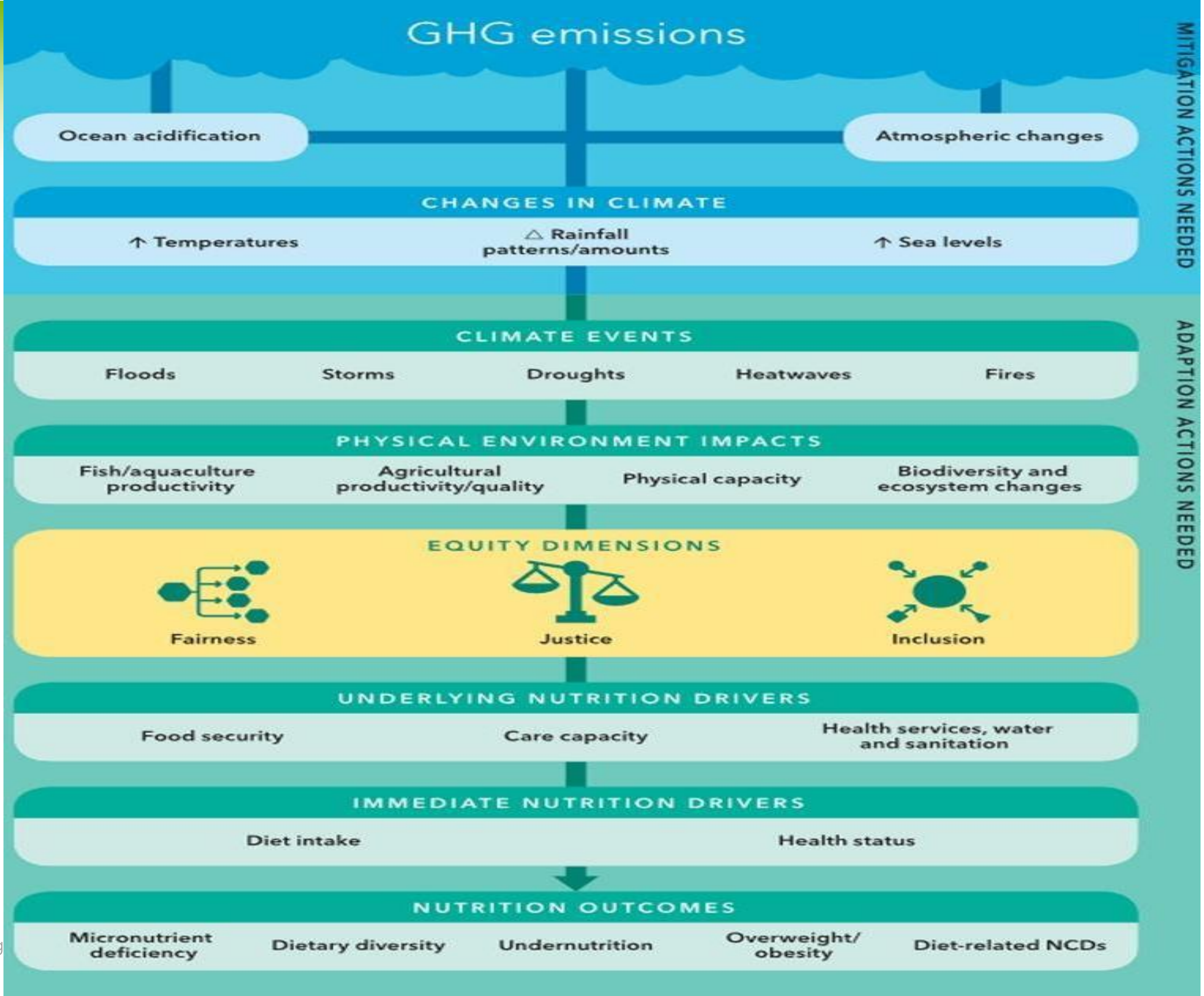
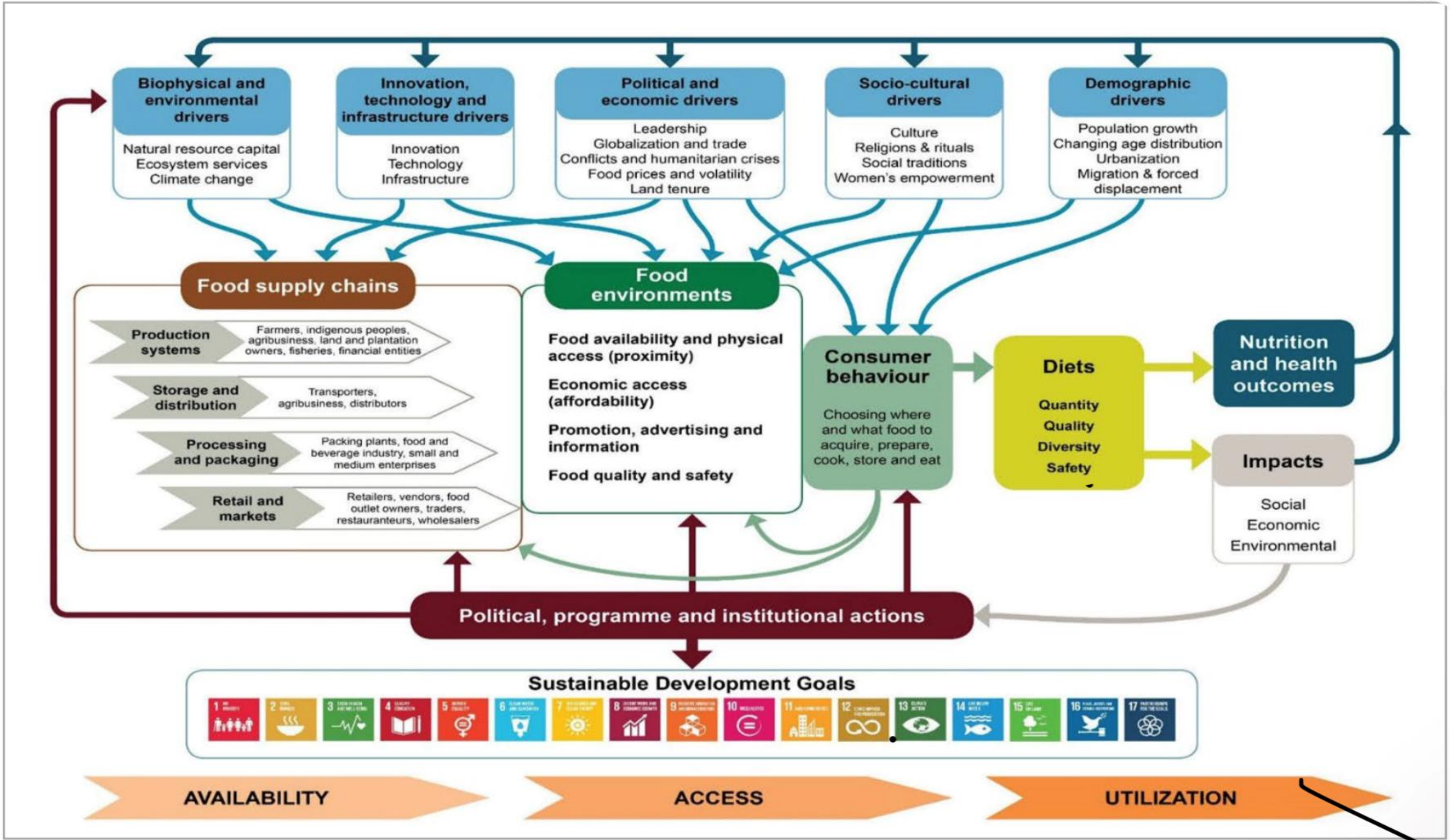
FRAMEWORKS OR PATHWAYS

Not just nutrition, but econutrition



Source: Deckelbaum et.al., 2006


GHG emissions
Ocean acidification
Atmospheric changes
CHANGES IN CLIMATE
↑ Temperatures
△ Rainfall patterns/amounts
↑ Sea levels
CLIMATE EVENTS
Floods
Storms
Droughts
Heatwaves
Fires
PHYSICAL ENVIRONMENT IMPACTS
Fish/aquaculture productivity
Agricultural productivity/quality
Physical capacity
Biodiversity and ecosystem changes
EQUITY DIMENSIONS
Fairness
Justice
Inclusion
UNDERLYING NUTRITION DRIVERS
Food security
Care capacity
Health services, water and sanitation
IMMEDIATE NUTRITION DRIVERS
Diet intake
Health status
NUTRITION OUTCOMES
Micronutrient deficiency
Dietary diversity
Undernutrition
Overweight/obesity
Diet-related NCDs
MITIGATION ACTIONS NEEDED
ADAPTION ACTIONS NEEDED



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, restauranteurs, wholesalers
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

Planetary Boundaries Framework

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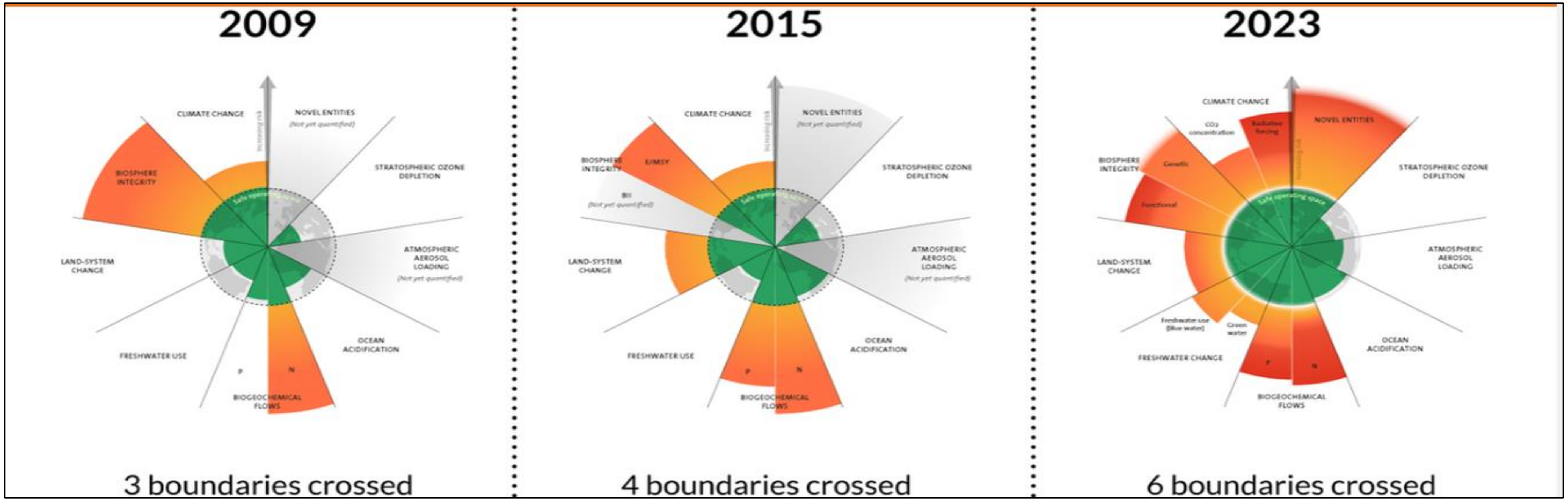
The planetary boundaries concept presents a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come



Credit: "Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023"

Stockholm Resilience Centre

Stockholm University

Need for multi-sectoral approach

Conference of the Parties (COP27) - first where food and agriculture were discussed

SDG goals are siloed – need to create convergence across goals to create a nexus

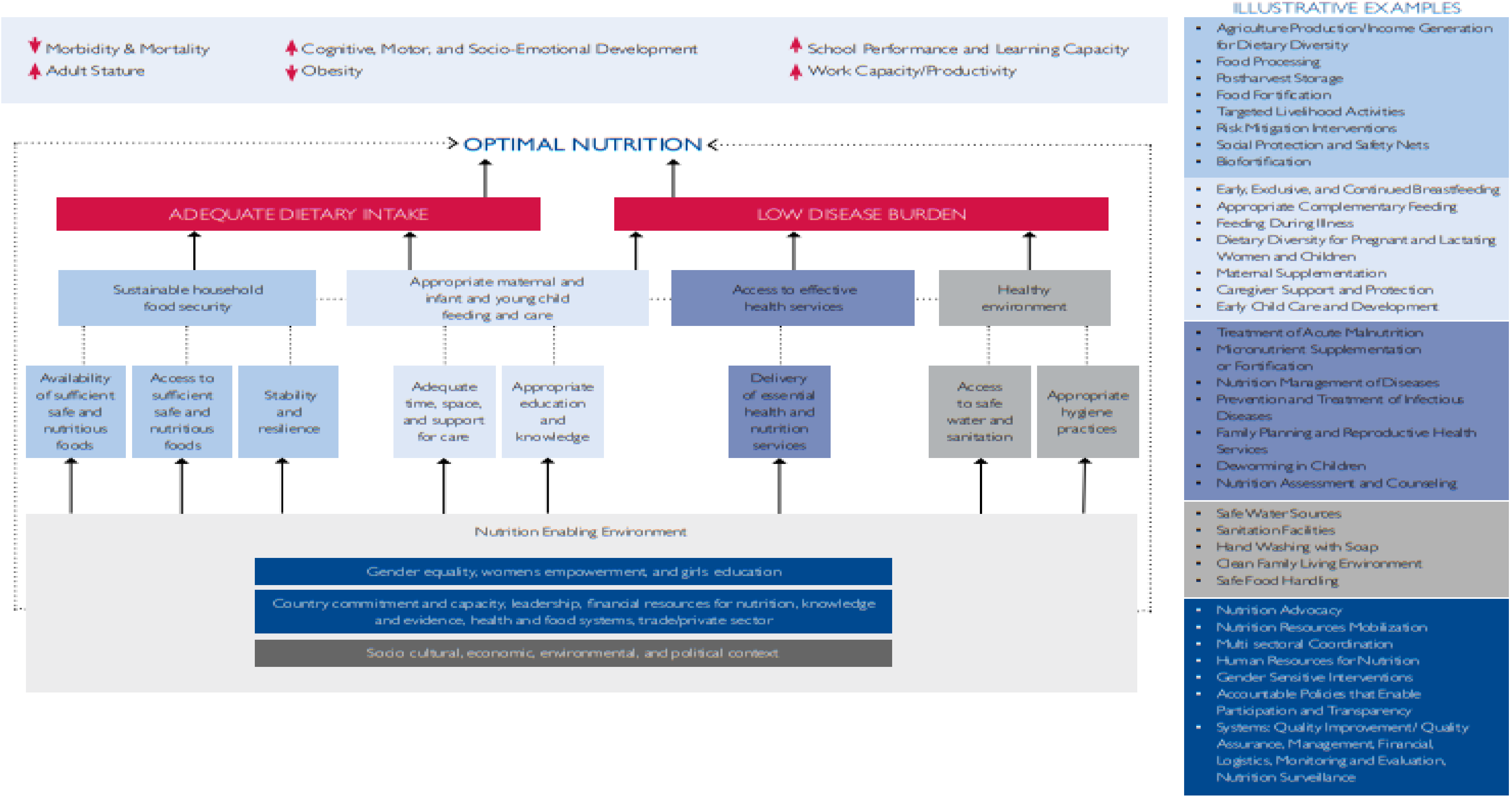
Convergence across policies – nutrition policy disconnected from agriculture, climate change etc. and vice-versa

Not just nutrition-sensitive agriculture.. Nutrition-sensitive environmental approach

Inter-sectoral policy analysis needed

FIGURE 1: USAID MULTI-SECTORAL NUTRITION CONCEPTUAL FRAMEWORK

Adapted from UNICEF, 2013[8] and Black et al., 2013[2]



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What do you see as the major challenges in multi-sectoral approach in your country/region?

ⓘ Start presenting to display the poll results on this slide.

Adaptation and mitigation response options

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Options include, but are not limited to,

- improved and sustainable land and forest management,
- soil organic carbon management,
- ecosystem conservation and land restoration,
- reduced deforestation and degradation,
- And changing diets and reduced food loss and waste

FABLE Consortium

A network for sustainable food systems at national and global scales

The Food, Agriculture, Biodiversity, Land-Use and Energy (FABLE) Consortium

Our approach

Scientific tools that help understand the effect of policies in one sector on another

(integrated assessment)

Converging across SDG's

Synergies and Trade-offs

TOOLS

FABLE Calculator

MAgPIE model

The Food, Agriculture, Biodiversity, Land Use, and Energy (FABLE) Pathways Consortium

A **collaborative initiative** launched in 2017 operating as part of the Food and Land-Use Coalition (FOLU)

Objective: to understand how countries can transition towards sustainable land-use and food systems and collectively meet the Sustainable Development Goals and objectives of the Paris Agreement

Independent research teams from 21 countries and the European Union (more countries joining as we speak)

Published several reports and policy briefs on countries' transition pathways

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

The Food and Land Use Coalition

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FABLE India

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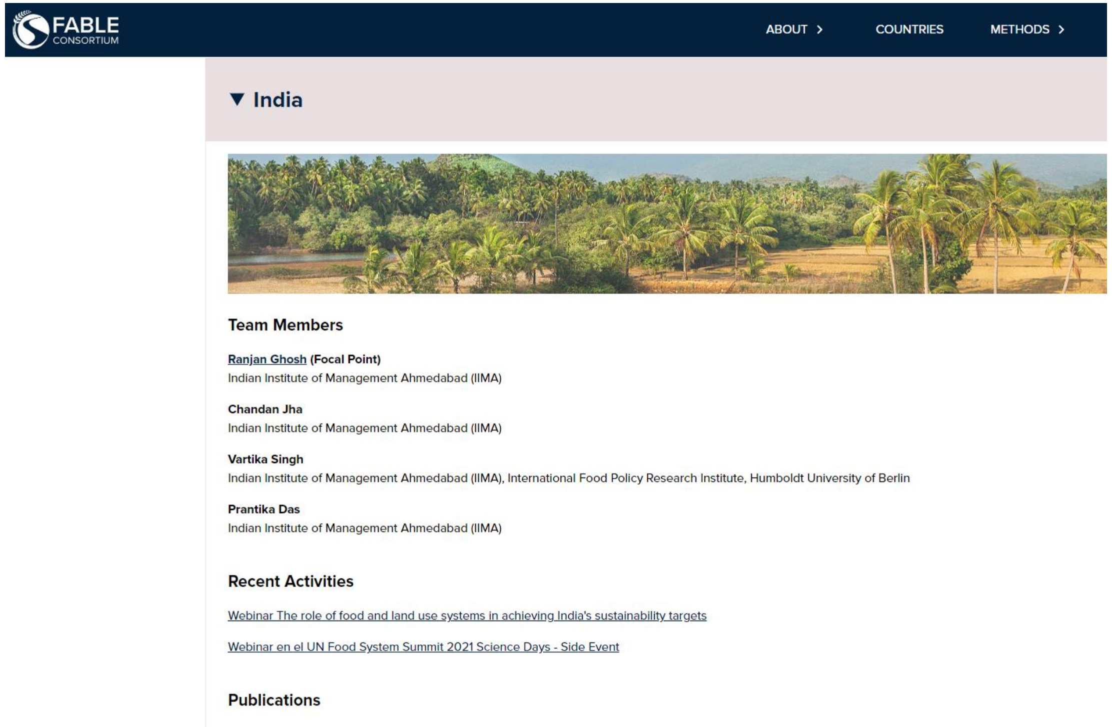
Use of technical tools (land-use models, FABLE Calculator) and soft-linkages between models

Science-based methodology incorporating climate change assessments

Food, land, water, energy nexus

Stakeholder engagement



FABLE CALCULATOR

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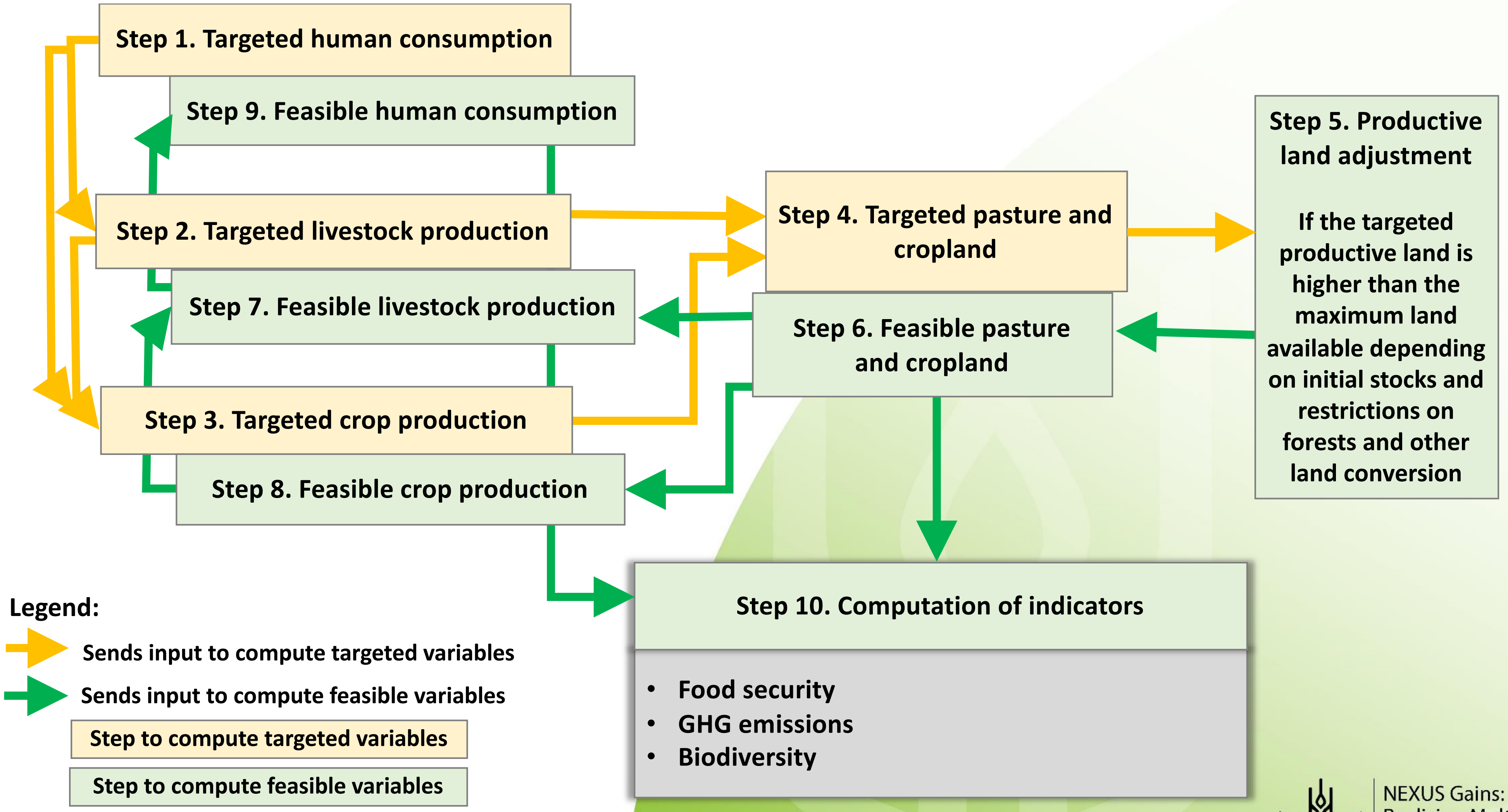
The FABLE Calculator

Overview of the FABLE Calculator



The FABLE Calculator

- It includes **76 products**: crops, livestock products, vegetable oils, and sugar.
- It covers each **five-year time step over 2000-2050**.
- Projections of **future demand drive production and future land use**.
- **Limited land availability** can reduce the consumption level compared to the initial target.

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Selected combination of scenarios:

Scenario on GDP	Scenario on Population	Scenario on food diet	Scenario on land availability	Scenario on the share of food waste	Scenario on livestock productivity	Scenario on Crop productivity	Scenario on Afforrestation /Reforestatio	Scenario on Level of activity of the population
BAU	BAU	ICMR_NIN	NoExpansio	Current	BAUGrowth	BAUGrowth	NoAffor	Middle

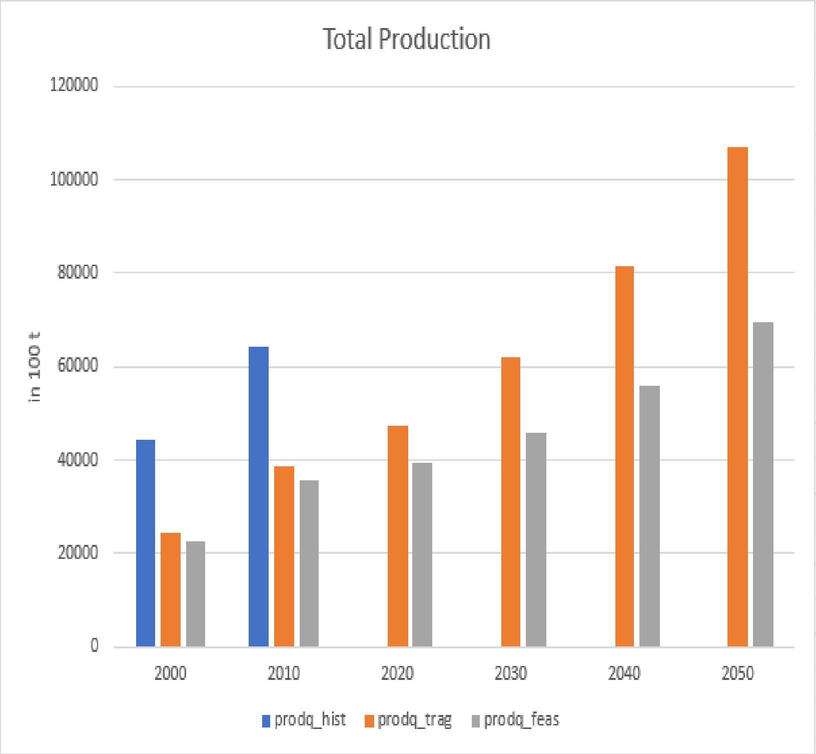


TABLE: TotalResultsProd

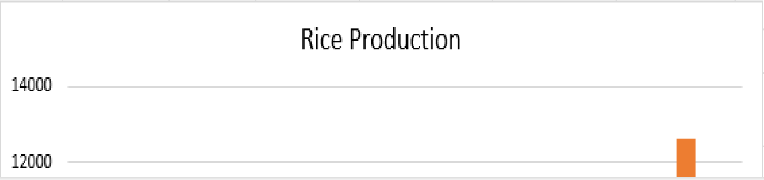
Table - Total production quantity and value

DIRECT	DIRECT	CALC	CALC	CALC	CALC	CALC	CALC	CALC	CALC
		HISTORICAL		TARGET		FEASIBLE		HISTORICAL	TARGET
		local currency	1000 USD	local currency	1000 USD	local currency	1000 USD	100 t or 1000 m3	100 t or 1000 m3
Product	YEAR	prodvloc_hist	prodvusd_hist	prodvloc_targ	prodvusd_targ	prodvloc_feas	prodvusd_feas	prodq_hist	prodq_trag
TOTAL	2000	82460017.081	1895632.577	104985940.846	2413469.905	76184995.682	1751379.211	44436.927	24345.321
TOTAL	2005	109615373.780	2519893.650	126229444.654	2901826.314	84876995.083	1951195.289	51955.303	27339.215
TOTAL	2010	118680631.524	2728290.380	156582360.128	3599594.486	111737874.128	2568686.762	64342.686	38734.702
TOTAL	2015			157454518.657	3619644.107	109799175.674	2524118.981		41111.747
TOTAL	2020			176424372.743	4055732.707	112695837.647	2590708.911		47181.493
TOTAL	2025			197679082.273	4544346.719	117486665.433	2700842.884		54125.933
TOTAL	2030			221493784.487	5091811.138	124331405.108	2858193.221		62068.854
TOTAL	2035			248176740.984	5705212.436	133360017.863	3065747.537		71151.318
TOTAL	2040			278073324.911	6392490.228	144535807.698	3322662.246		81534.043
TOTAL	2045			311570488.019	7162539.954	157487270.526	3620397.024		93400.114
TOTAL	2050			349101765.323	8025327.938	171391893.552	3940043.530		106958.065

TABLE: ResultsProd

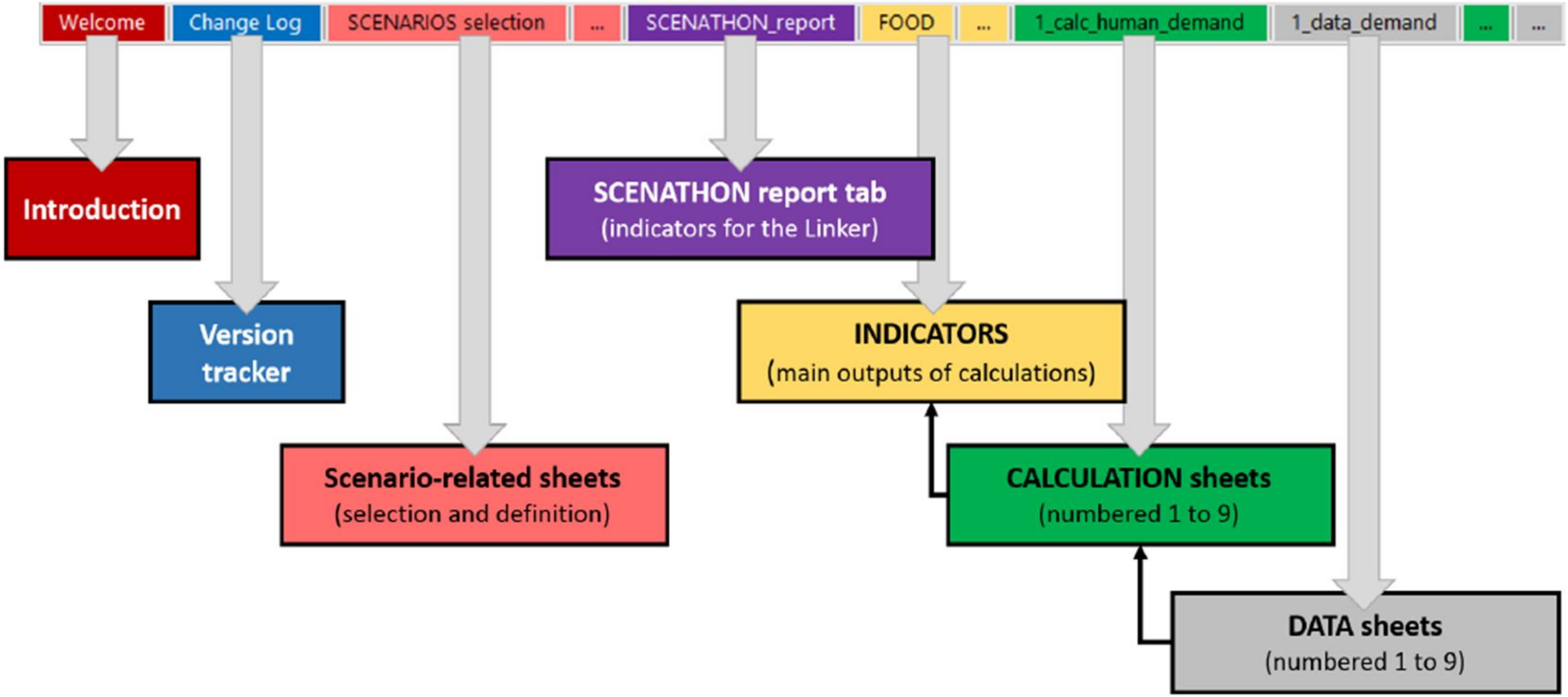
Table - Production value by commodity

DIRECT	OUTPUT-1	DIRECT	DATA-1	DATA-1	DATA-1	CALC	CALC	OUTPUT-1	CALC
					HISTORICAL			TARGET	
			Producer prices		Production quantity	Prod value (local currency)		Production quantity	Prod value (local cu

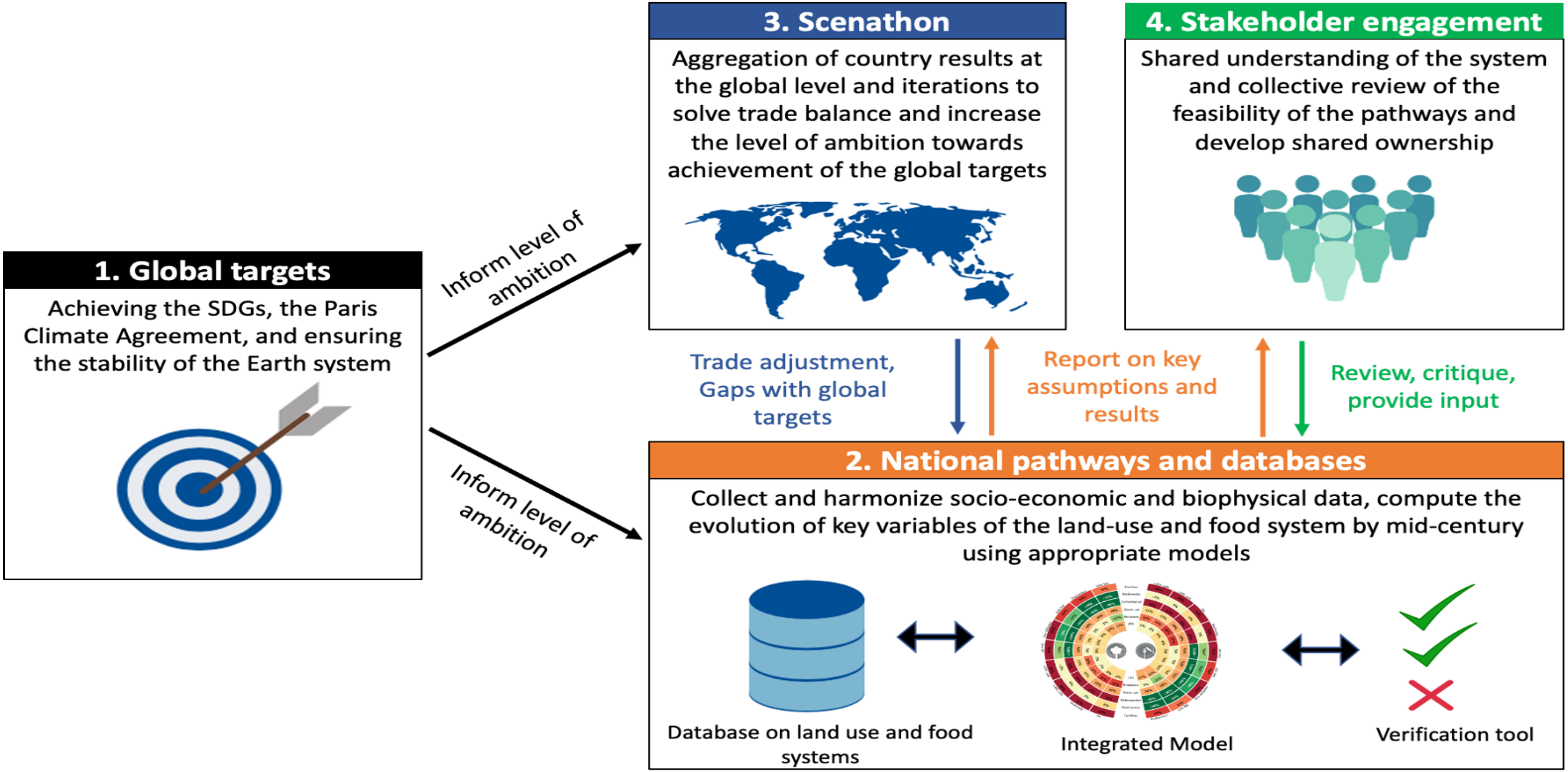


Welcome! | Scenarios Selection | Scenarios Defination | SCENATHON_report | FOOD | PRODUCTION | BIODIVERSITY | LAND | Emission | Water | 1_Calc_data_demand | 1_data_demand | 2_calc_livestock | 2_data_li

Basic Structure



The FABLE Method



MAgPIE (Model of Agricultural Production and its Impact on the Environment)

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Model Basics

Optimization | Recursive dynamic

Cost minimization of consecutive time slices with a length of 5-20 years until 2100.

Resolution | 3 spatial layers

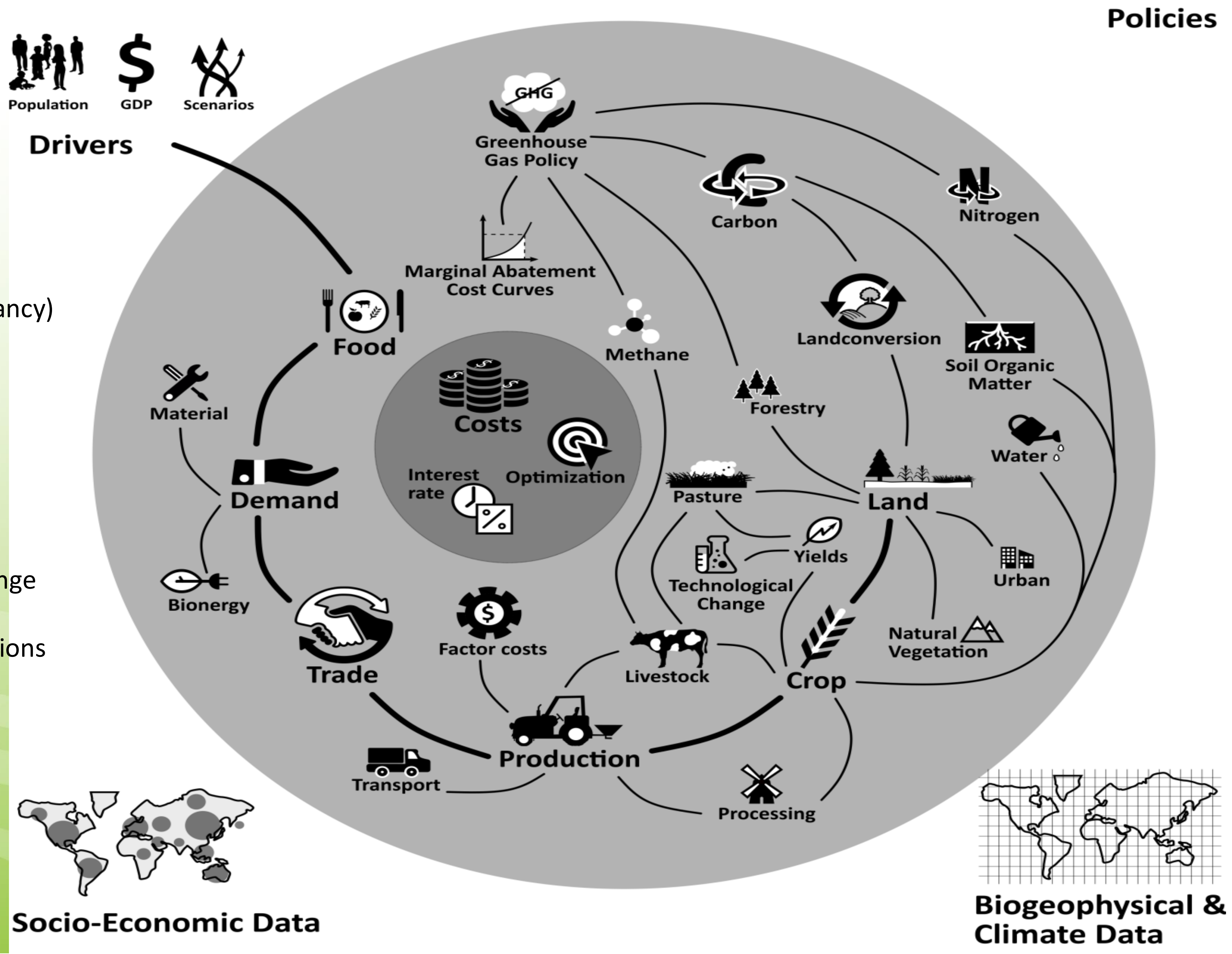
Global | 5-20 world regions | 50-2000 spatial clusters

Balance | Biophysical and economic side

Bringing together biophysical (plant growth, carbon, nutrients, water) and

economic (costs, prices, demand, policies) aspects.

- Global ag. cost minimization
- Optimal land-use patterns
- Food demand (age, sex, demographics including pregnancy)
- Crop, livestock and processed products
- Spatially explicit on 0.5°x0.5°
- Endogenous technological change
- Ag. and land-use change emissions
- Climate change mitigation



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Limitations

Lack of granular data

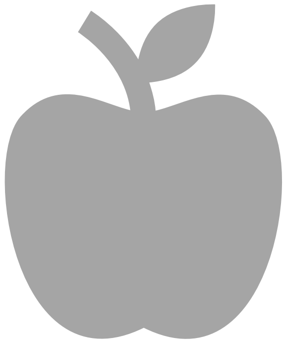
- Consumption (last round from 2011)
- Production (drivers of production decisions)
- Access to food (sources, prices etc.)

Lacking evidence

- Drivers of behavior change (can serve as parameters in our models)
- Whether nature-based farming is sustainable and healthy
- Access and consumption of local foods sufficient to meet nutrient requirements

Case Studies in India

Regulating water use for natural resource conservation in India



Dietary transitions and their environmental impacts

Research question

How can water regulatory policy affect production and food security in India?

NVIRONMENTAL RESEARCH
ETTERS

ETTER • OPEN ACCESS

Assessing policy options for sustainabl
ndia's cereal production system

artika Singh[6,1,2,3,4], Miodrag Stevanović[3], Chandan Kum
anjan Kumar Ghosh[2], Hermann Lotze-Campen[1,3] and A

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nvironmental Research Letters, Volume 18, Number 9
ocus on the Future of Water-Limited Agricultural Landscapes
itation Vartika Singh *et al* 2023 *Environ. Res. Lett.* **18** 094073
OI 10.1088/1748-9326/acf9b6

Background policy context

Food production in the world depends on water to a large extent

- - millions of farmers in the world use irrigation to cultivate major crops, particularly rice and wheat

India is the largest consumer of freshwater globally (91% for food production)

- - 80% of which is used for rice and wheat cultivation

Consequence of Green Revolution where focus was on meeting food self-sufficiency

- - high subsidies, high-yielding varieties

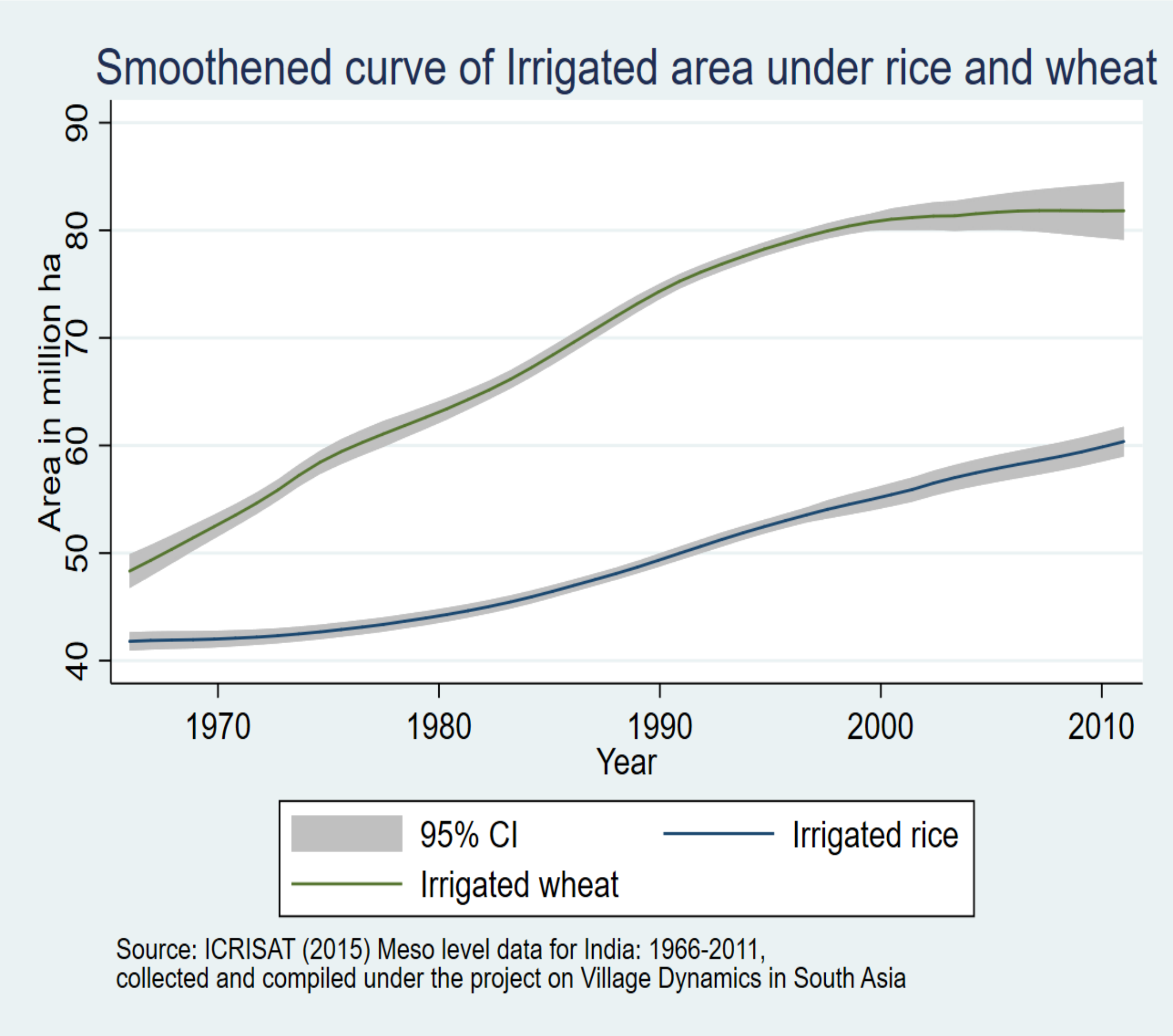
India's agricultural production is resource-intensive and cereal-centric (distortionary subsidies)

- Power subsidies ~ 12 billion USD in 2015-16 while Irrigation subsidies ~2 billion USD in 2013-14

- Some states have ~0 price!

- Irrigation is not demand-driven anymore, but rather dependent on the electricity supply or lower tariffs

- 1/5th groundwater units either in critical or over-exploited state (particularly in the North-west)



Policy measures proposed

Reduce subsidies / increase water prices	Impose physical restrictions/quota
• Differential water tariffs for relevant consumer groups have been found to bring decreases in in irrigation water consumption • Contrary evidence also suggest that demand for water is less elastic at lower price levels • Little political traction • Need a middle path	• Relatively easier to implement • Studies point to quotas helping regulate water use at the margins • Little administrative capacity

Implications

- Implementing constraints on a key resource, water

  –repercussions on the overall production patterns of the country,

  -including commodity prices

- Relative costs of production and well as national and international commodity prices

  - have significant impacts on an economy’s trade patterns and trade balances

- Virtual water assessments have demonstrated that typically wheat and maize are exported from countries that are relatively abundant in water resources

Create 4 hypothetical scenarios and compare it with a Business-as-Usual scenario until 2050

Policy tool	Scenario description	Pumping Cost (USD per meter cube)	Physical Water Availability setting	Scenario name
BAU	No quota implemented, Pumping costs (~INR 4 per kWh)	0.005	No policy	Business as Usual (BAU)
Price-related effect I	Pumping cost prices equivalent to highest price of energy across all states in India from 2007-2013 (~ INR 8 per kWh)	0.01	No policy	Low-price
Price-related effect II	Quadrupling of India prices (~ INR 16 per kWh)	0.02	No policy	High-price
Quantity-related effect I	Reserves 40% of available water for , remaining water is available for human uses (agricultural and non-agricultural)	0.005	Quota policy I	Low-restriction
Quantity-related effect II	Reserves 60% of available water for , remaining water is available for human uses (agricultural and non-agricultural)	0.005	Quota policy II	High-restriction

Finding 1

- Water withdrawals for agricultural cultivation reduce significantly when taxes are levied

- Taxes cause greater shock to water use than physical restrictions (quotas)

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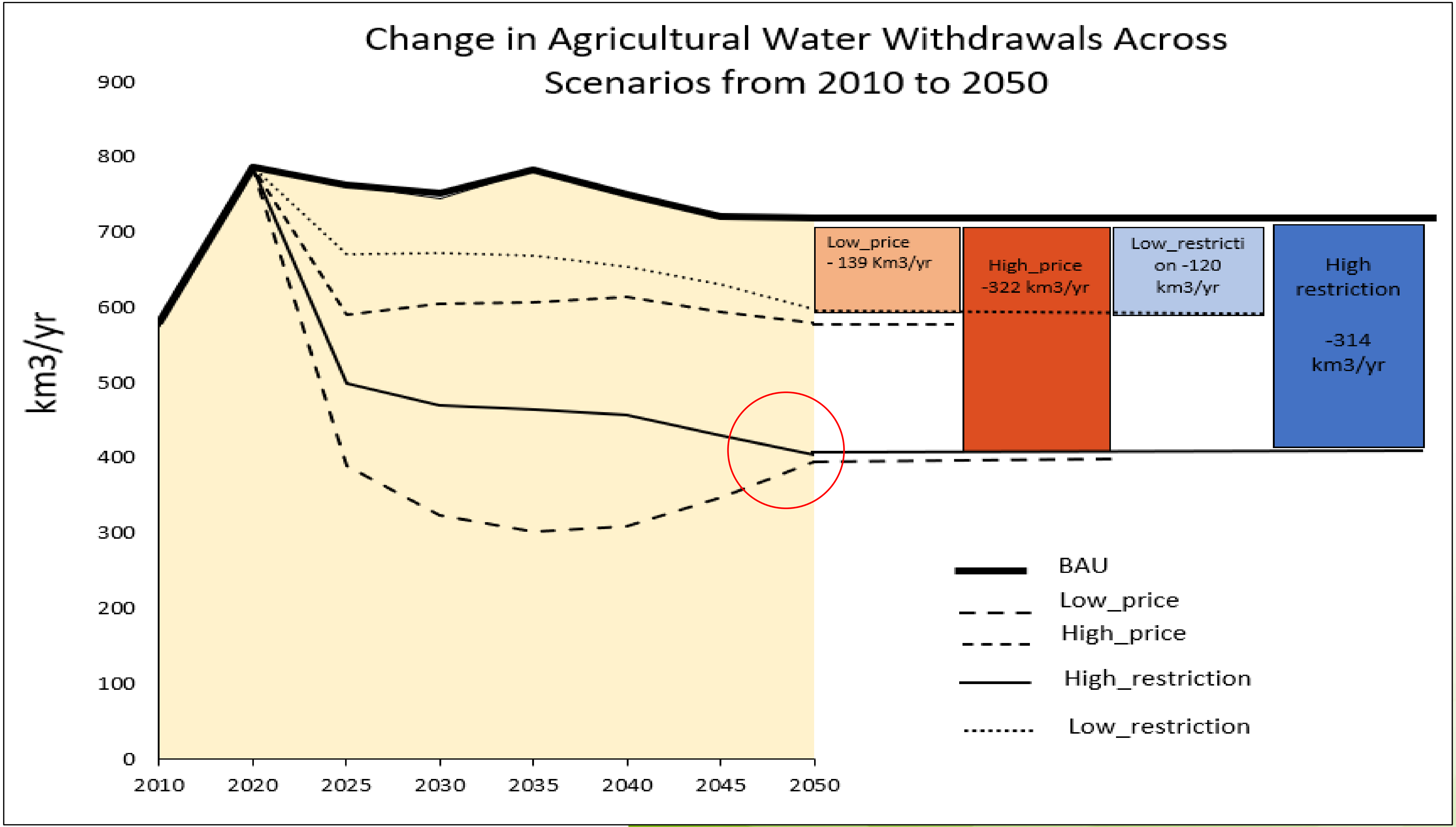
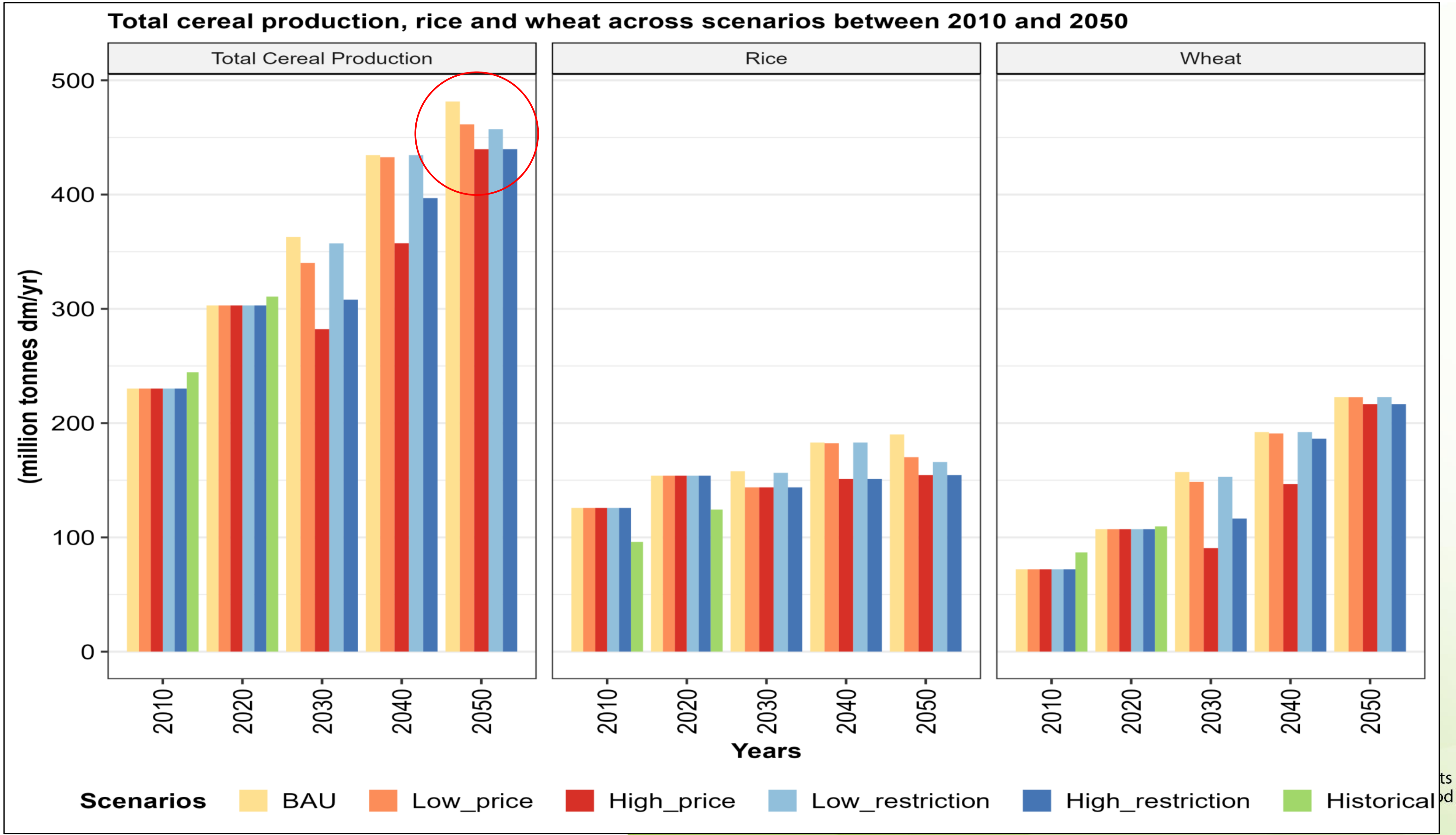


Change in Agricultural Water Withdrawals Across Scenarios from 2010 to 2050
km3/yr
900
800
700
600
500
400
300
200
100
0
2010
2020
2025
2030
2035
2040
2045
2050
Low_price - 139 Km3/yr
High_price -322 km3/yr
Low_restriction -120 km3/yr
High restriction -314 km3/yr
BAU
Low_price
High_price
High_restriction
Low_restriction

Finding 2

- Under both policies, agricultural production takes a hit (but not as much!)

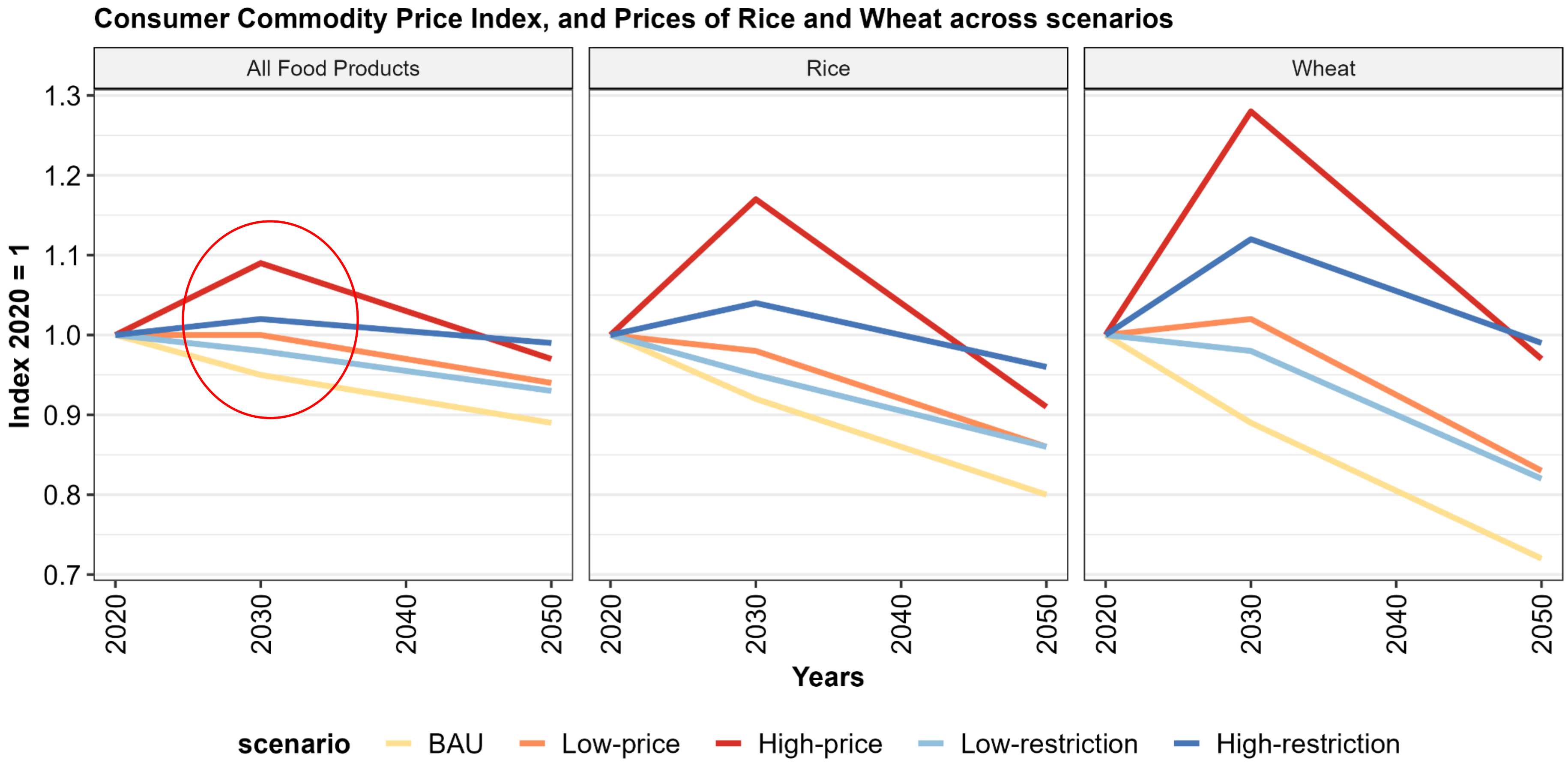

Total cereal production, rice and wheat across scenarios between 2010 and 2050
Total Cereal Production
Rice
Wheat
(million tonnes dm/yr)
0
100
200
300
400
500
2010
2020
2030
2040
2050
Years
Scenarios
BAU
Low_price
High_price
Low_restriction
High_restriction
Historical

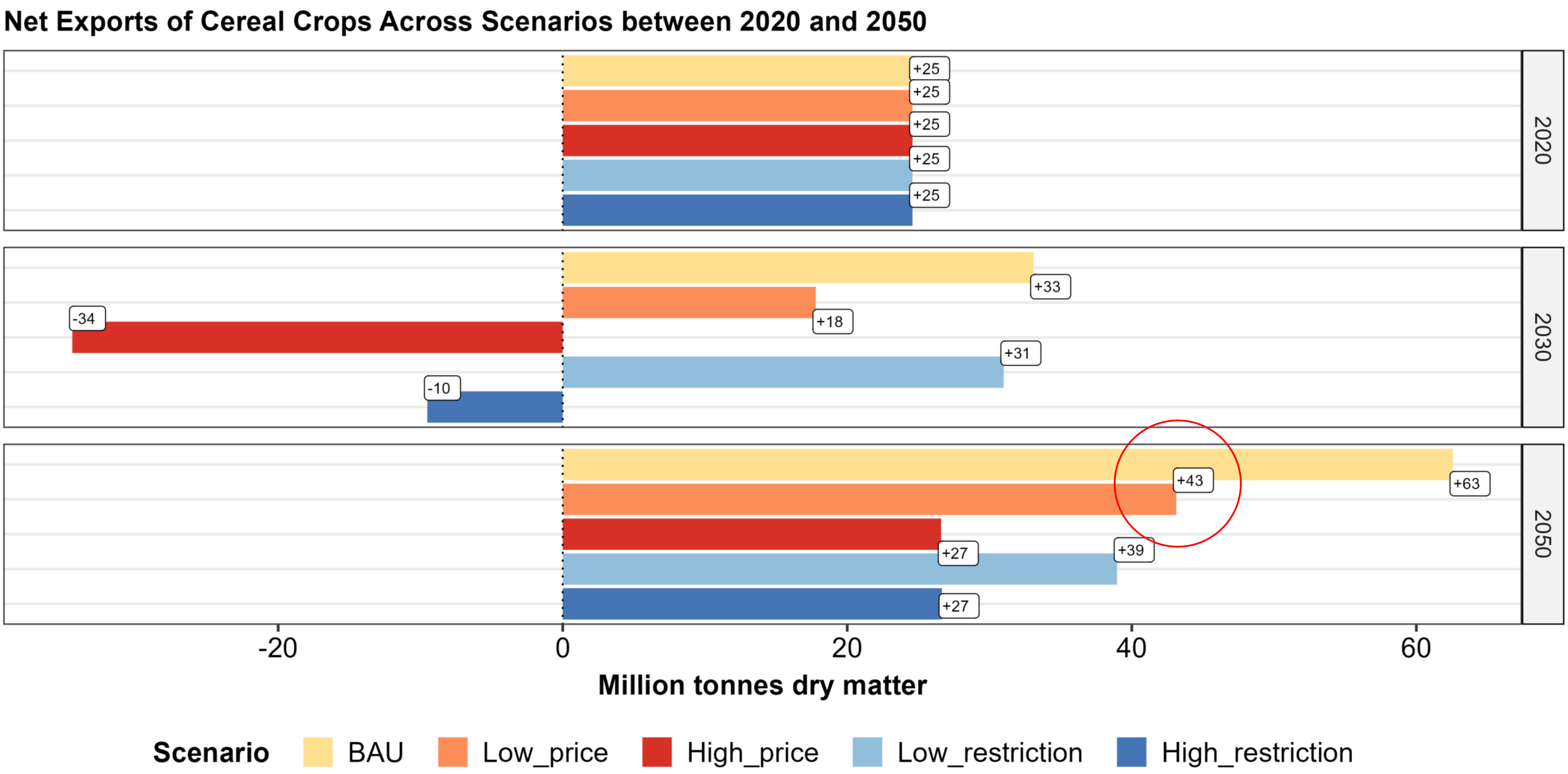
Finding 3

- Large immediate impact on prices, but it stabilizes in the long-run (by 2050)

- Greater price shocks felt for wheat production (highly water intensive)

Net exports decline in short-term, but restore by 2050


Consumer Commodity Price Index, and Prices of Rice and Wheat across scenarios
All Food Products
Rice
Wheat
Index 2020 = 1
1.3
1.2
1.1
1.0
0.9
0.8
0.7
2020
2030
2040
2050
Years
scenario
BAU
Low-price
High-price
Low-restriction
High-restriction


Net Exports of Cereal Crops Across Scenarios between 2020 and 2050
+25
+25
+25
+25
+25
2020
+33
+18
-34
+31
-10
2030
+43
+63
+27
+39
+27
2050
-20
0
20
40
60
Million tonnes dry matter
Scenario
BAU
Low_price
High_price
Low_restriction
High_restriction

Conclusion

- Both policies offer benefits and have shortfalls

  - In the short term, pricing policy prohibitive, offers benefits in the long run
  - Needs political will (!)

- Energy prices can be increased to some extent without much adverse effects

- Spatial targeting of physical restrictions may offer benefits

- Deeper analysis at sub-national level (particularly basin level) is needed

Research Question

Are healthy diets environmentally sustainable? What gains can be had from switching to healthy diet baskets?

Globally,

- Emphasis on Planetary Healthy Diets

[EAT Lancet Commission Recommendations 2019]

- Diets that save energy, lessen food waste, and include environmental sustainability

- Transitioning to balanced intake of most food groups considered both human and environment friendly

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Key parameters of human and planetary healthy diets

Predominantly plant-based diets, with significant room for consumption o animal, oceanic and alternative proteins

More protective foods like fruits, vegetables, whole grain, legumes and nuts

Limit salts, sugars and saturated fats

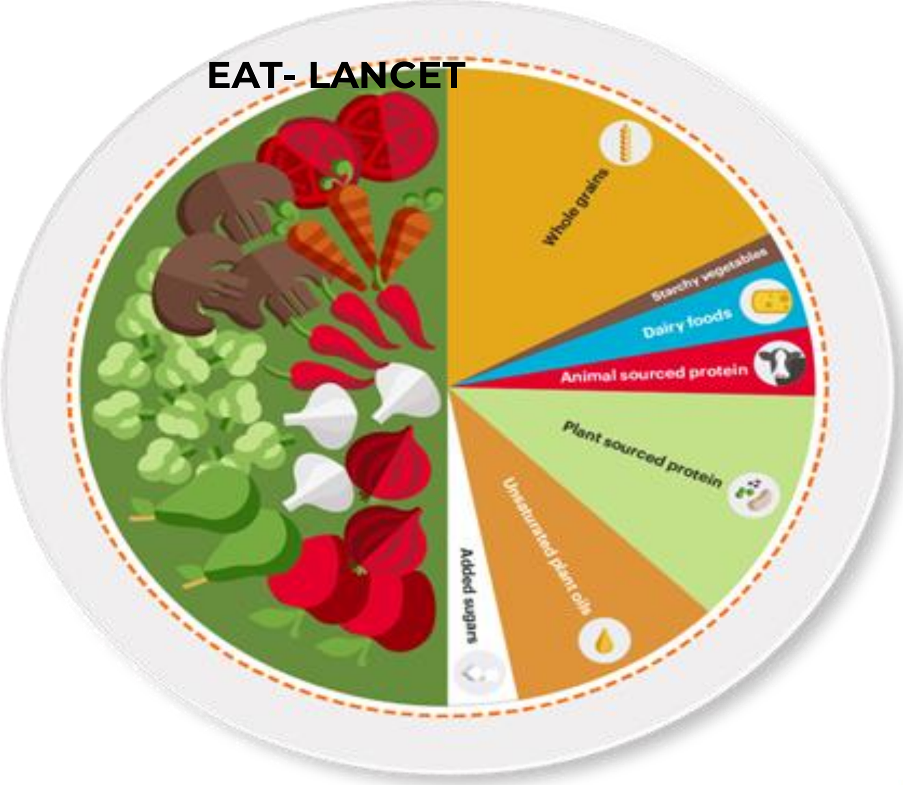
Increased consumption of whole, rather than refined grains

Preferably no/limited ulta-processed foods

Other important factors:

i. Reduced food loss and waste
ii. Improvement in soil health
iii. Non-use of degenerated land
iv. Equity in distribution
v. Reduction in obesity/underweight populations

Recommended healthy diets (human and planetary)



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and Ecosystems

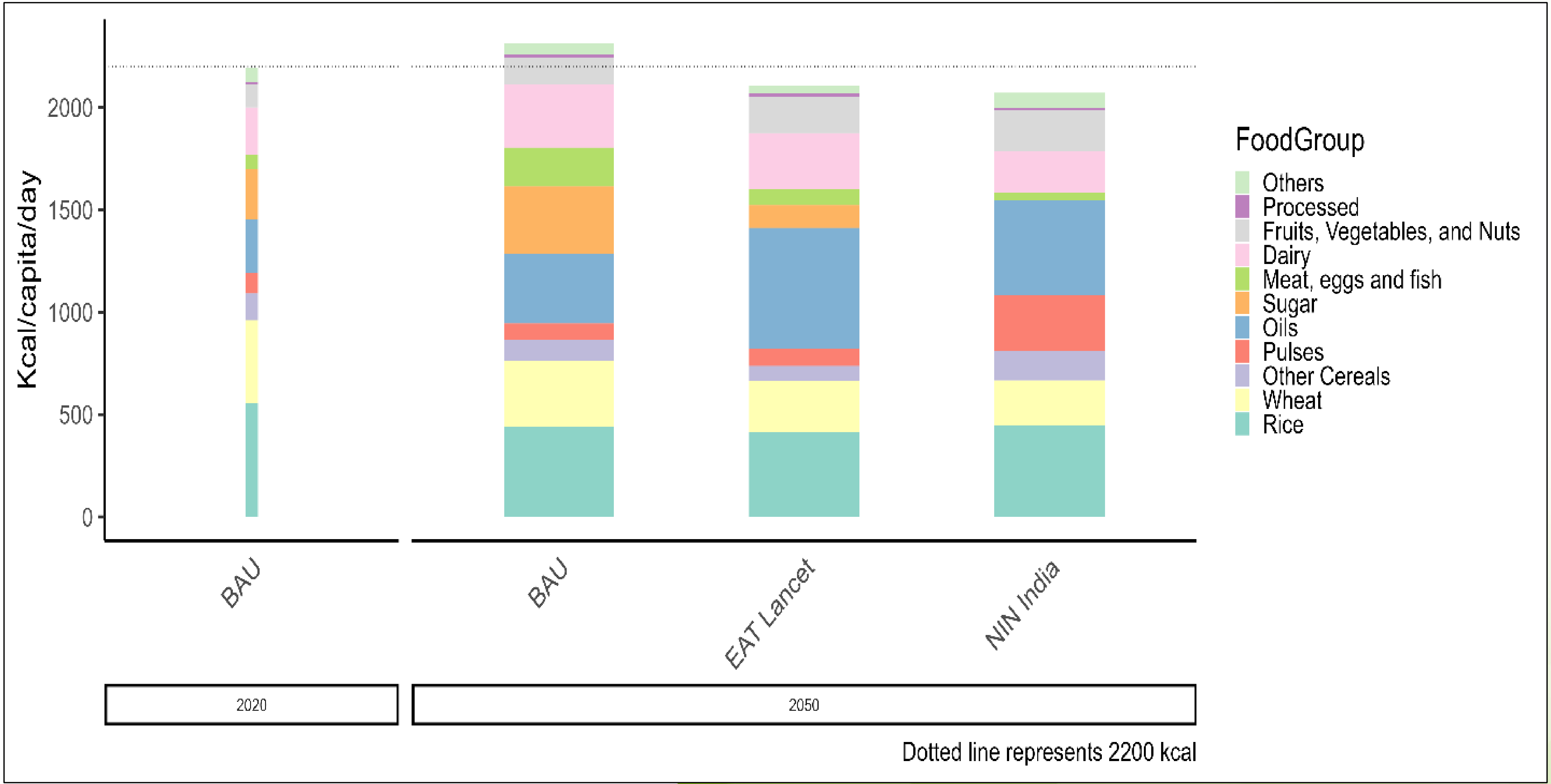
Name	Diet type	Trade assumption
BAU / SSP2	SSP2 diets following endogenous demand	Focus on self-sufficient production with deficit met through imports or surplus being exported. Trade tariffs and margins are included
BAU_liberalized_trade	SSP2 diets following endogenous demand	Reduced trade tariff barrier with upto 30% tariff reduction by 2050
EAT_all	All regions including India transition to EAT Lancet dietary recommendations by 2030	Focus on self-sufficient production with deficit met through imports or surplus being exported. Trade tariffs and margins are included
NIN_India_EAT_others	India transitions to dietary recommendations by the National Institute of Nutrition (NIN) whereas all remaining regions transition to EAT Lancet	Focus on self-sufficient production with deficit met through imports or surplus being exported. Trade tariffs and margins are included
NIN_India_SSP2_others	Only India transitions to NIN recommended diets, whereas all other regions follow the SSP2 diets	Focus on self-sufficient production with deficit met through imports or surplus being exported. Trade tariffs and margins are included
NIN_India_SSP2_others_liberalized_trade	Only India transitions to NIN recommended diets, whereas all other regions follow the SSP2 diets	Reduced trade tariff barrier with upto 30% tariff reduction by 2050

Finding 1

- Greater diversity in food consumption is possible by integrating locally recommended diet baskets.

- Feasible to meet Minimum Dietary Energy Requirements (MDER)

Calorie Intake



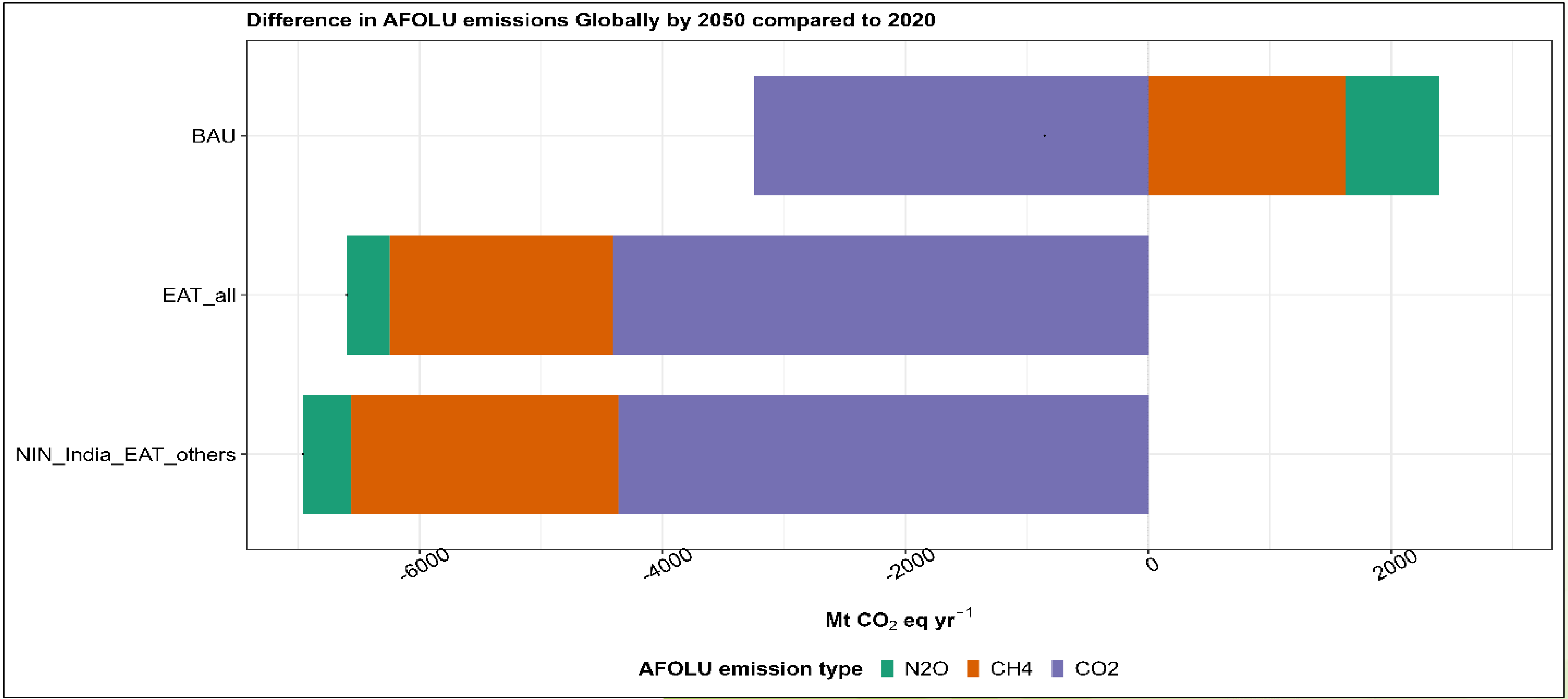
Finding 2

- Locally recommended diets have positive environmental impacts than BAU

- Lesser expansion of pasture lands, reduced reduction of other natural lands

- Reduced GHG emissions

Change in GHG Emissions



Takeaways

Using the case of dietary transitions in India, we demonstrate the role of modelling tools in answering pertinent policy questions.

Need for further validation and downscaling of tools at the micro-level to determine the impact of policy measures on important human and environmental health outcomes.

The **nexus approach of assess food-land-water-energy** allows an assessment for meeting **SDGs** alongwith synergies and trade-offs between sectors.

How can we evaluate national policies to integrate multi-sectoral approach? PDS?

Conclusion

- Tools that enable analysis of both short-term scenarios for sustainable transformation are needed

- Analysis of Nexus issues – food, land, energy, water enables to understand synergies and trade-offs between indicators

- Deep dive into issues at the sub-national level is the need of the hour

Thank you

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