




Comparing food system sectoral changes in 2050 with historical transformations

A multi-model analysis

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FOOD SYSTEMS & GLOBAL CHANGE

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Part of Cornell's work leading on the modelling assessment for EAT-Lancet Commission 2.0

Introduction

- Food systems contribute around **one third of all anthropogenic greenhouse gas (GHG) emissions** globally (Crippa et al., 2021) and are a leading factor in the **destabilization of several planetary boundaries** (Campbell et al., 2017).
- Additionally, **current food systems outcomes leave 3 billion globally unable to afford healthy diets** (FAO, 2023), **poor quality diets among the leading mortality risks globally** (GBD 2019 Risk Factors Collaborators, 2020).
- In **response to these multiple intersecting crises**, there is an **urgent need to transform food systems** (Fanzo et al., 2021; Singh et al., 2021; Webb et al., 2020; Willett et al., 2019)

Introduction

- Scenario modelling and analysis have been routinely used to grapple with food systems transformation: Including the EAT-Lancet Commission (Willett et al 2019) - static input-output modelling & the Food Systems Economics Commission (FSEC, 2024) - integrated assessment framework to explore future food systems pathways.
- Rather than single model analyses, we employ a multi-model ensemble of 9 dynamic global economic models running two food systems scenarios:
  - (1) continuation of current trends ‘business-as-usual’ (BAU) to 2050
  - (2) food systems transformation scenario (“EL2”) that combines EAT-Lancet diet recommendations, supply-side productivity increases, and reductions to food loss and waste (FLW)

Methods: Multi-model ensemble

- Multi-model ensemble building on AgMIP (Agricultural Model Intercomparison and Improvement Project) food system modelling efforts (e.g. Nelson et al., 2014; Rosenzweig et al., 2018; Stehfest et al., 2019).
- Ensemble includes 9 global economic models, which have featured in a wide range of high-level science-policy reports

Model	Full name	Model type	Institution	Country
AIM	Asia-Pacific Integrated Model	CGE	National Institute for Environmental Studies & Kyoto University	Japan
ENVISAGE	Environmental Impact and Sustainability Applied General Equilibrium	CGE	Purdue University	USA
FARM	Future Agricultural Resources Model	CGE	U.S. Department of Agriculture	USA
IMAGE	Integrated Model to Assess the Global Environment	CGE	Netherlands Environmental Assessment Agency (PBL)	Netherlands
MAGNET	Modular Applied GeNeral Equilibrium Tool	CGE	Wageningen University	Netherlands
GLOBIOM	Global Biosphere Management Model	PE	International Institute for Applied Systems Analysis (IIASA)	Austria
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade	PE	International Food Policy Research Institute (IFPRI)	USA
MAgPIE	Model of Agricultural Production and its Impact on the Environment	PE	Potsdam Institute for Climate Impact Research (PIK)	Germany
CAPRI	Common Agricultural Policy Regional Impact	PE	European Commission Joint Research Centre	EU

Methods: Scenarios

- Two scenarios: 1) a 'business-as-usual' (BAU) scenario based on current trends that model BAU assumptions on diets, crop and livestock productivity, food loss and waste (FLW). 2) second scenario - core EAT-Lancet reference diet whereby the diet is achieved globally by 2050, along with higher productivity growth rates similar to trends associated with SSP1, and a reduction of FLW.
- Diet change assumed to be driven by consumer preferences shifts.
- Both scenarios include climate-related impacts to crops (using IPSL GCM average of the GGCMI crop model ensemble for soybean, maize, wheat, and rice), livestock, and agricultural labour
- Current results use SSP v2 data on GDP and population. Updated results will include v3 release.

Scenario		Key Dimensions			Mitigation and Land-use Policies
		Diet	Productivity Assumptions	Food Loss and Waste (FLW)	
BAU	Business as usual scenario based on **SSP2** with a higher climate impact reflected by **RCP 7.0**	Model BAU assumptions on diets to 2050	Model BAU assumptions on crop and livestock productivity. (Exogenous yield trends from IMPACT have been shared)	Model BAU assumptions on FLW	Model BAU assumptions on climate mitigation and LUC policies
EL2	**Full EAT-Lancet scenario** (diet, productivity, FLW) **without mitigation** and higher climate impacts based on **RCP 7.0**	Globally achieves EAT-Lancet diet by 2050	High productivity growth rate similar to productivity trends associated with SSP1	Reduction of FLW	Model BAU assumptions on climate mitigation and LUC policies

Methods: historical analysis

- Long-run historic agricultural land and population from the History database of the Global Environment (HYDE) (version 3.3). HYDE provides land data at global and country level from -10,000CE to present.

PBL Netherlands Environmental Assessment Agency

Utrecht University

- FAO Food Balance Sheet (FBS) data are used to compare global production from 1960 to 2020 with projected production under BAU and EL2 scenarios out to 2050.

Preliminary Results: Food system changes, BAU 2050 vs 2020

- Across global agriculture, increases on average to per capita calorie availability (+6%), production (+35%), area (+8%), emissions (+36%). Decrease on average to producer prices (-5%).
- Some heterogeneity across different food sectors.

Sector	Calorie availability			Price			Production			Area			Emissions		
% change	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min
All agriculture	6	9	-1	-5	16	-11	35	44	22	8	13	5	36	107	19
All crops	6	10	-3	-10	21	-31	34	44	21	9	15	4	16	42	0
Rice	-5	1	-15	2	22	-31	20	33	10	-3	7	-19	18	27	-1
Wheat	0	10	-10	-3	16	-34	30	42	8	1	13	-7	14	58	3
Coarse grains	20	25	-2	0	43	-25	35	48	27	20	29	1	35	58	6
Veg., fruit, nuts	18	48	-15	-13	27	-33	36	61	-1	15	29	-7	-3	32	-34
Oilseeds	12	22	-8	-7	17	-30	39	47	18	9	16	-8	28	55	-28
Sugar crops	6	28	-6	-10	30	-23	30	53	12	6	39	-4	24	51	-22
All livestock products	7	25	2	3	13	-9	33	54	25	4	15	3	71	138	25
Ruminant meat	18	30	4	9	73	-7	43	63	23	9	16	3	53	146	17
Non-ruminants (meat and eggs)	4	27	-2	-12	16	-23	35	62	21	19	34	4	35	86	21
Dairy	10	32	1	2	14	-10	33	59	19	4	13	-4	25	129	23

Preliminary Results: Food system changes, EL2 vs BAU scenario 2050

- Decreases on average on key food systems dimensions, with livestock products seeing larger relative declines than crops.
- E.g. 57% reduction in livestock product calorie availability vs 13% for crops. Largely driven by diet changes in scenario

Sector	Calorie availability			Price			Production			Area			Emissions		
% change	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min	Med.	Max	Min
All agriculture	-16	-9	-54	-12	29	-32	-27	-5	-45	-9	-3	-46	-40	-15	-49
All crops	-13	-1	-57	-5	55	-27	-20	-3	-45	-5	2	-38	-27	-12	-49
Rice	-36	-22	-59	-36	-6	-54	-34	-16	-54	-29	-15	-53	-40	-16	-58
Wheat	-27	-12	-66	-33	-8	-41	-34	-15	-59	-26	-5	-50	-48	-22	-57
Coarse grains	-35	-7	-60	-29	-8	-38	-39	-6	-49	-30	-11	-46	-46	-13	-55
Veg., fruit, nuts	44	54	-27	6	136	-12	29	50	-22	29	73	-33	40	42	37
Oilseeds	16	76	-14	-4	34	-15	0	32	-17	3	61	-45	3	15	-8
Sugar crops	-46	-42	-71	-26	-7	-35	-40	-20	-59	-36	-21	-46	-58	-50	-66
All livestock products	-57	-22	-62	-25	-8	-75	-42	-17	-58	-22	3	-61	-35	-16	-55
Ruminant meat	-72	-15	-87	-38	-13	-89	-55	-14	-80	-33	-5	-83	-36	-15	-57
Non-ruminants (meat and eggs)	-57	-29	-74	-18	13	-90	-44	-28	-61	38	125	-49	-41	-27	-49
Dairy	-31	-15	-51	-21	-8	-62	-38	-6	-53	-5	14	-32	-38	-15	-39

Preliminary Results: Value of production

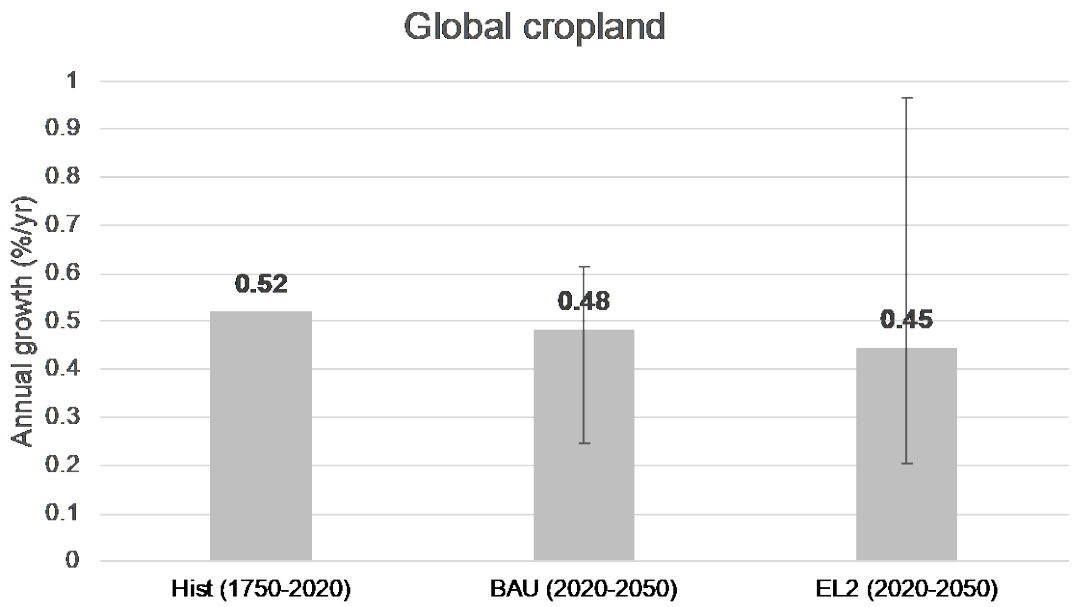
- Value of global agricultural production in EL2 scenario is larger than 2020 (+66%) but smaller than BAU 2050 (-17%).
- Value of veg., fruits, and nuts production in EL2 scenario is larger than both 2020 (28%) and BAU 2050 (36%).
- Value of ruminant meat in EL2 scenario is smaller than both 2020 (-71%) and BAU 2050 (-83%).

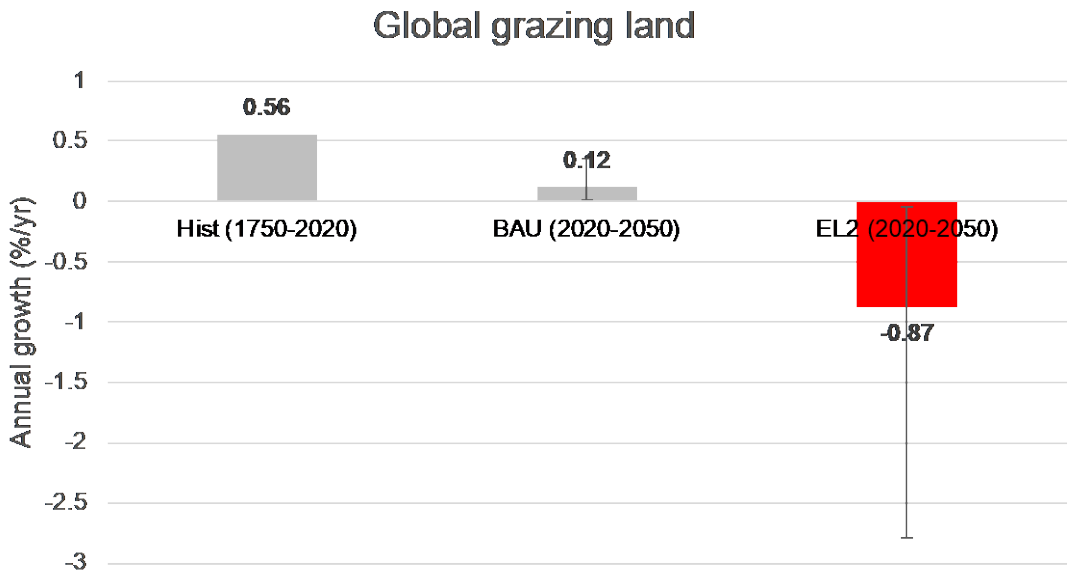
Value of production (billion USD)

Sectors	BAU 2020	BAU 2050	EL2 2050	BAU 2050 - BAU 2020	EL2 2050 - BAU 2020	EL2 2050 - BAU 2050
All agriculture	4225	8437	7034	4212	2809	-1403
All crops	2848	5171	4752	2323	1905	-419
Rice	209	569	214	360	5	-355
Wheat	172	256	139	85	-33	-118
Coarse grains	246	406	246	160	-1	-160
Veg., fruit, nuts	**1924**	**1808**	**2466**	**-117**	**542**	**659**
Oilseeds	323	530	716	207	392	186
Sugar crops	111	246	104	135	-7	-142
All livestock products	1377	2087	1071	709	-306	-1016
Ruminant meat	**296**	**494**	**86**	**199**	**-209**	**-408**
Non-ruminants (meat and eggs)	480	1089	637	609	157	-452
Dairy	331	756	562	425	231	-194

Preliminary Results: Land changes

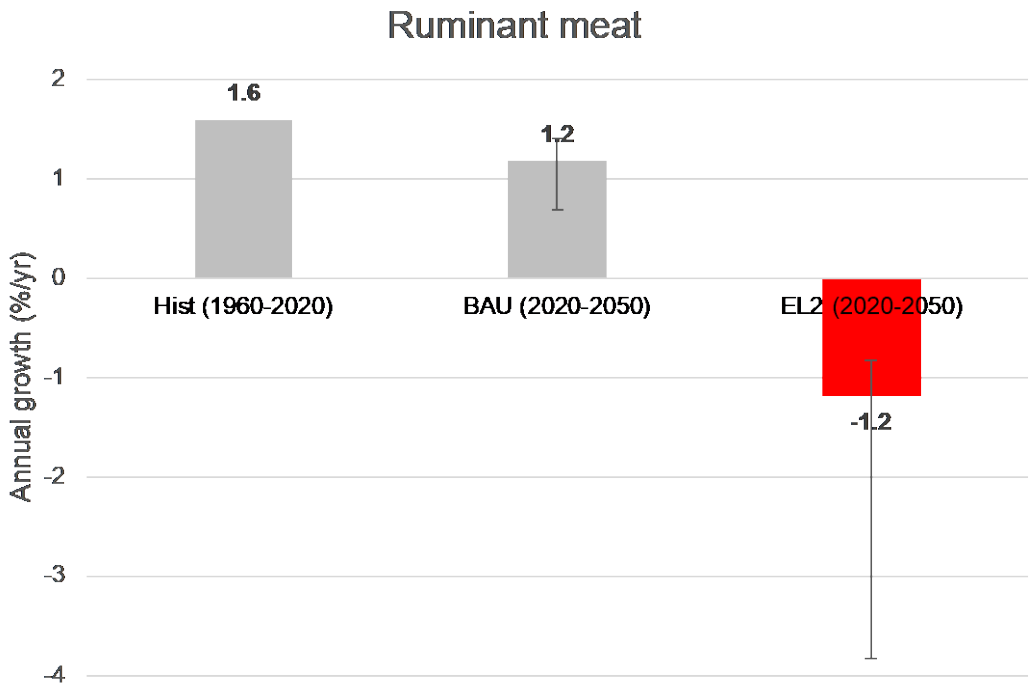
- Positive growth rate of global cropland in EL2 scenario but smaller than historic average and BAU projections
- Negative growth rate of global grazing land in EL2 scenario, substantial break with historic average and BAU projections

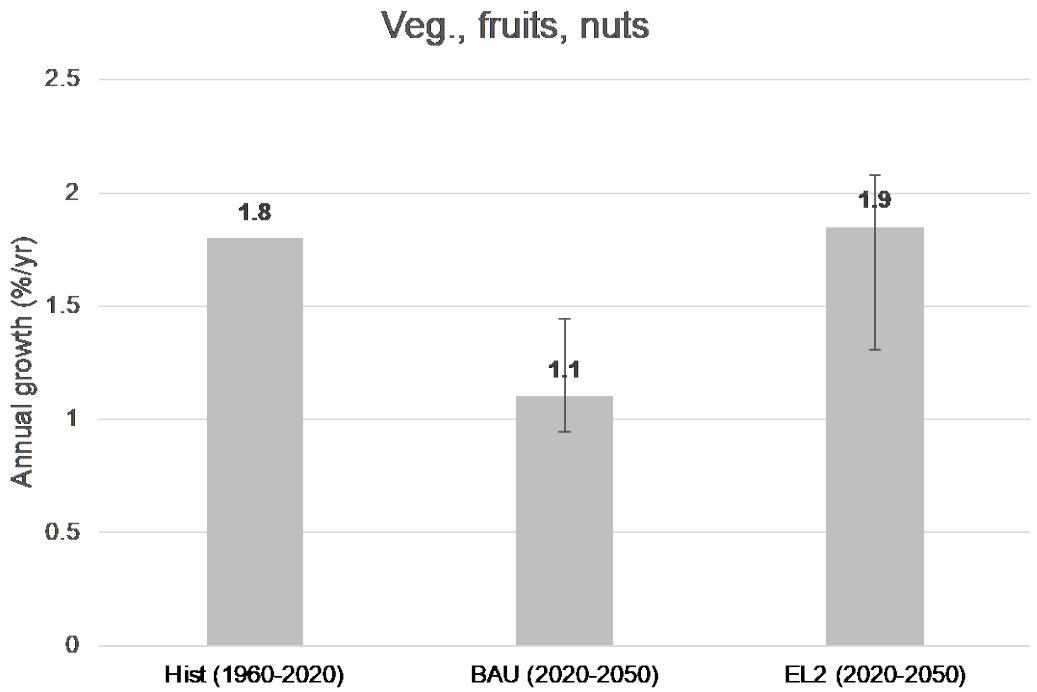




Preliminary Results: Production changes

- Growth rates of global production of ruminant meat in EL2 scenario is a substantial break with recent history and BAU projections
- Global production of veg., fruits, and nuts in EL2 scenario is comparable to growth rates from recent history but almost double BAU scenario





Discussion

- Model ensemble results highlight agreement and uncertainty in food systems transformation.
- Several reasons for differences across model ensemble results e.g. model composition effects, differing interpretation and implementation of scenarios, and differing model design, parameterization, and representation.
- EL2 transformation scenario shows a possible future with fundamental revaluing of, and within, food systems.
- Historical analysis, particularly for ruminant meat, shows changes to land and production would represent a substantial departure from previous trends.

Thank You

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