USDA
United States Department of Agriculture

Nutrition Indicators for CGE Models

Ron Sands
USDA Economic Research Service

Robert Beach
RTI International

2022 GTAP Virtual Conference
June 8-10, 2022

The findings and conclusions in this presentation are those of the author and should not be construed to represent any official USDA or U.S. Government determination or policy. This presentation was supported by the U.S. Department of Agriculture, Economic Research Service.

Motivation

- In a computable general equilibrium (CGE) model, we are able to track quantities of food produced and available for consumption, by country or world region, over time
- Food balance sheets from FAO are the data source for calibrating model base year
  - calories available for consumption by world region
  - protein and fat per person per day
- If the CGE model consumer demand system can simulate calorie consumption over time by food group, other nutritional indicators can be constructed
  - protein, fat (grams per person per day) based on FAO food balance sheets
  - micronutrients based on food conversion tables such as Harvard GENuS
- World food consumption varies across drivers of global change, especially across income scenarios
- This study provides a range of nutritional indicators across diet and income scenarios

Outline

- Economic Framework
  - Global computable general equilibrium
  - Simulation of world agriculture through 2050
  - 13 world regions
- Methodology
  - Future Agricultural Resources Model (FARM)
  - Merging social accounting matrix and food balances
  - Calories as unit for agricultural commodities
- Application to global diet scenarios
  - Static diet (reference scenario)
  - 50 percent EAT-Lancet healthy diet
  - Income-driven diet
- Conversion to other measures
  - grams of protein by food group
  - grams of fat by food group

Future Agricultural Resources Model (FARM)

- Recursive dynamic CGE model: essentially a sequence of static equilibria with capital stocks updated between time steps, but lacking foresight of future economic variables
- Land use can shift among crops, pasture, and managed forests in response to population growth and changes in income, with behavioral responses determined by price and income elasticities
- FARM can substitute other inputs for land if land becomes expensive
- Crop yield is endogenous, even with underlying productivity trends that are exogenous to the model

Key data sets

- Global social accounting matrix (SAM) from Global Trade Analysis Project (GTAP)
- Food balance sheets from the Food and Agriculture Organization (FAO) of the United Nations
- Tables for converting food consumption by weight to calories

Agricultural production sectors in GTAP social accounting matrix

Group	Subgroup	Symbol	Description
Primary agriculture	Crops	WHT	Wheat
		PDR	Paddy rice
		GRO	Other grains
		OSD	Oilseeds
		C_B	Sugar (cane and beet)
		V_F	Vegetables, fruits, nuts, roots and tubers
		PFB	Plant-based fibers
		OCR	Other crops
	Fisheries	FSH	Fish
	Forestry	FRS	Forestry
Animal products		CTL	Cattle and other ruminants
		RMK	Raw milk
		WOL	Wool
		OAP	Other animal products
Food processing		VOL	Vegetable oils
		PCR	Processed rice
		SGR	Sugar
		B_T	Beverages and tobacco products
		OFD	Other food
		CMT	Meat from cattle and other ruminants
		MIL	Dairy products
		OMT	Other meat products

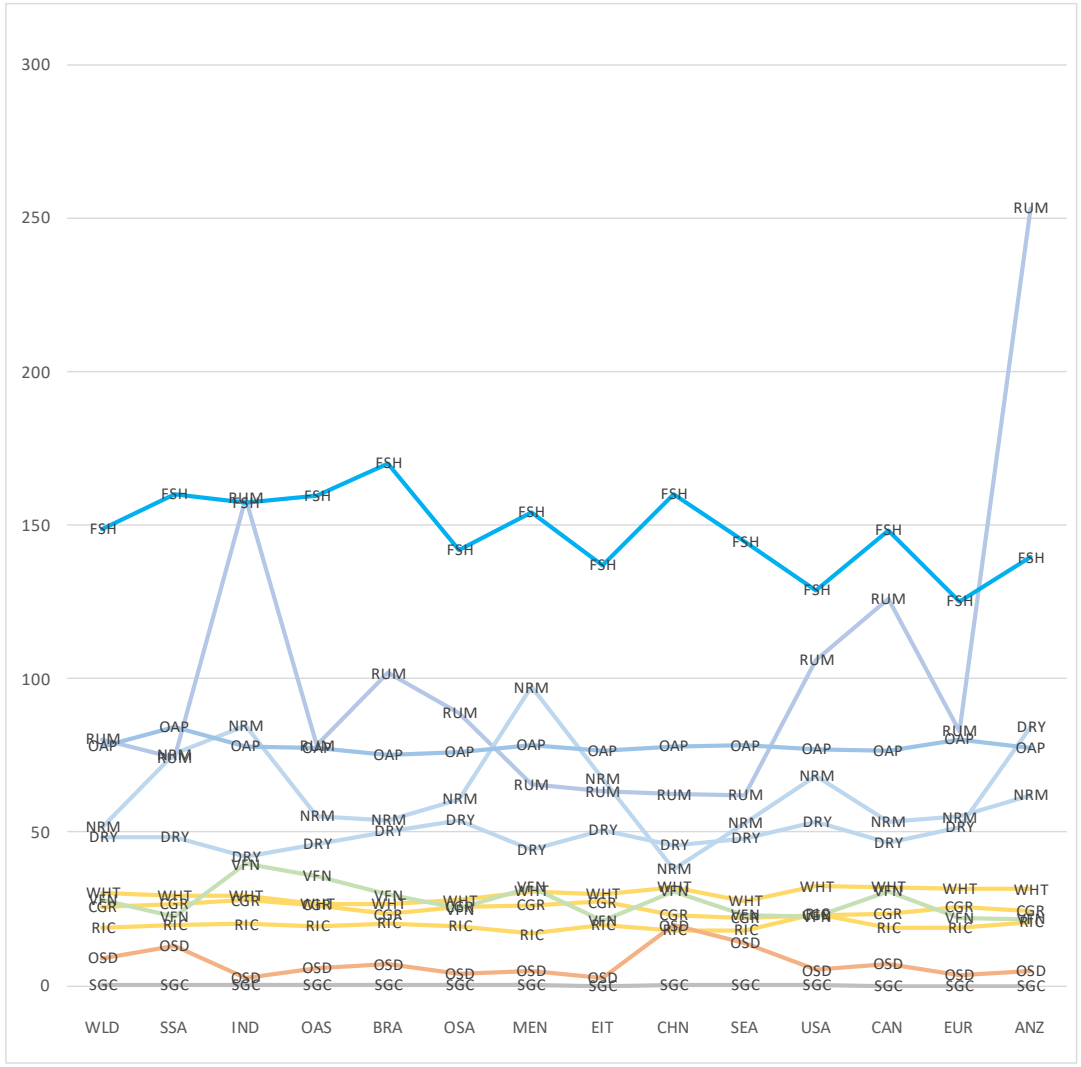
Food Balance Sheet activities (columns)

Activity type	Activity	Notes
Supply	Production	
	Imports	
	Change in stocks	
	Exports	
	Available supply	Production + Imports + Change in stocks – Exports
Domestic utilization	Feed	
	Seed	
	Food manufacture	
	Other uses	
	Waste	Losses during storage and transportation
	Food	
Food supply per person	kg/person/year	
	grams/person/day	
	kcal/person/day	
	protein/person/day	grams
	fat/person/day	grams

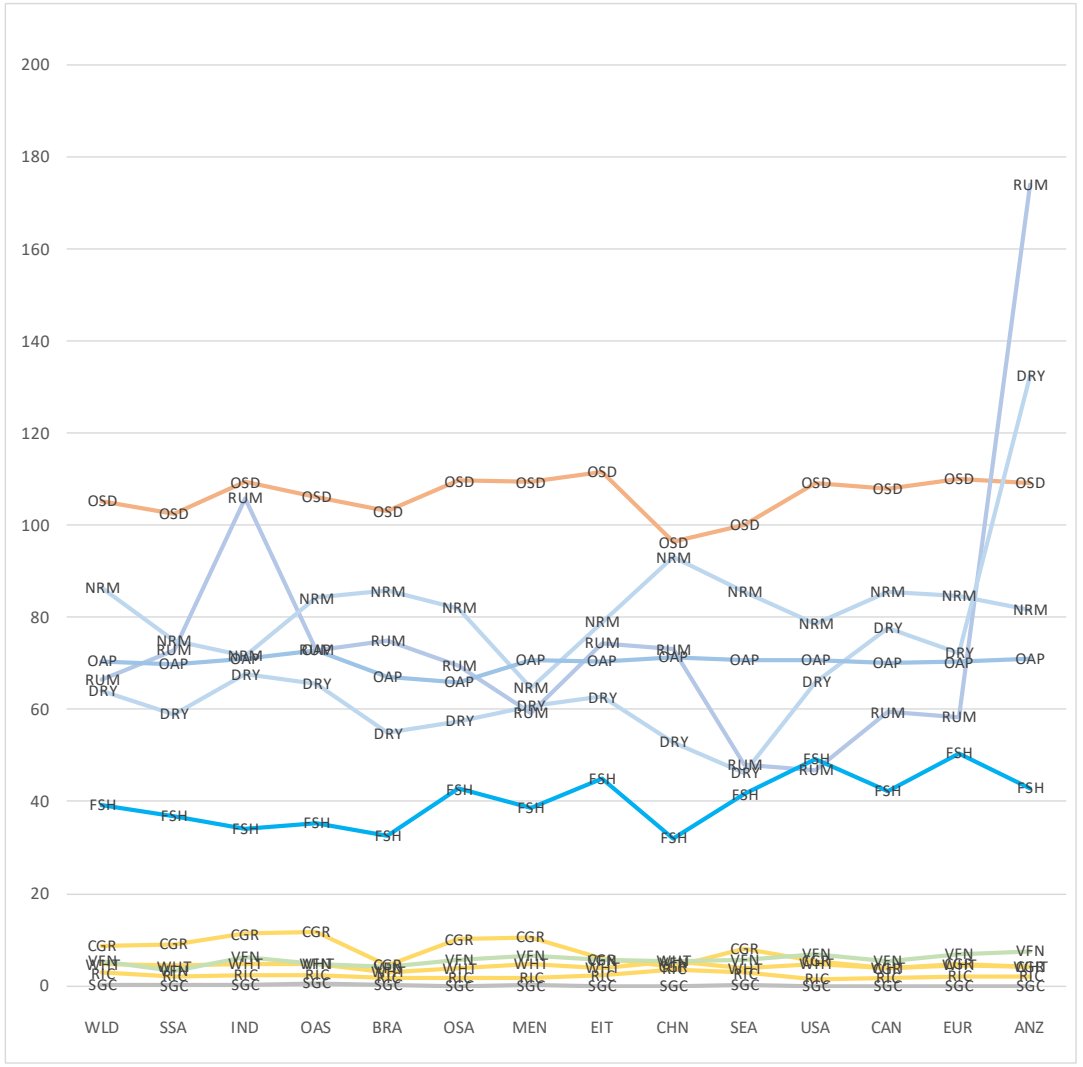
World regions in Future Agricultural Resources Model (FARM)

Symbol	Region name	Notes
SSA	Sub-Saharan Africa	
IND	India	
OAS	Other Asia (south)	
BRA	Brazil	
OSA	Other South America	Including Central America, Caribbean, and Mexico
MEN	Middle East and North Africa	Including Turkey
EIT	Economies in Transition	Russia, Belarus, Ukraine, Kazakhstan, Kyrgyzstan, Armenia, Azerbaijan, Georgia, Tajikistan, Turkmenistan, Uzbekistan
CHN	China	
SEA	Southeast and East Asia	Including Japan
USA	United States	
CAN	Canada	
EUR	Europe	Including Estonia, Latvia, Lithuania
ANZ	Australia and New Zealand	Including Oceania

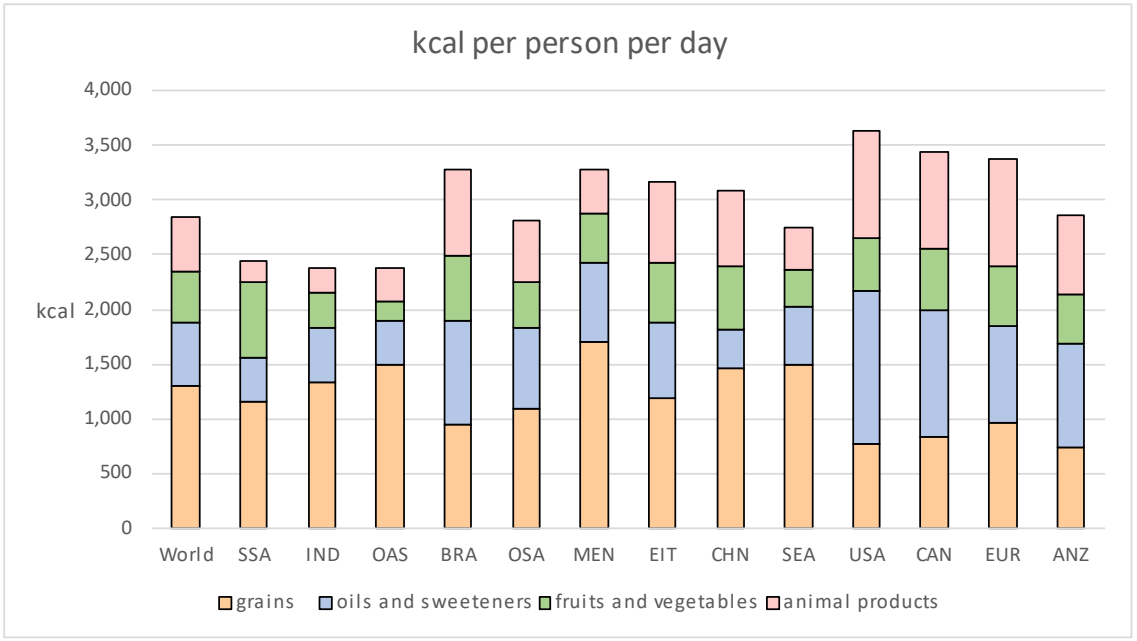
grams of protein per 1000 kcal

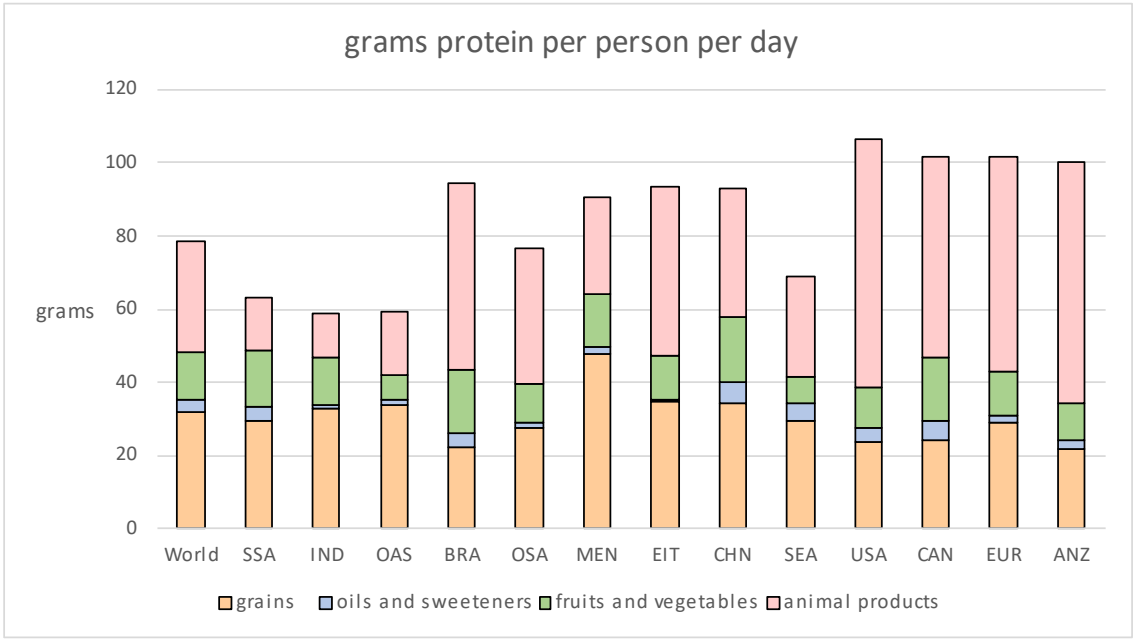


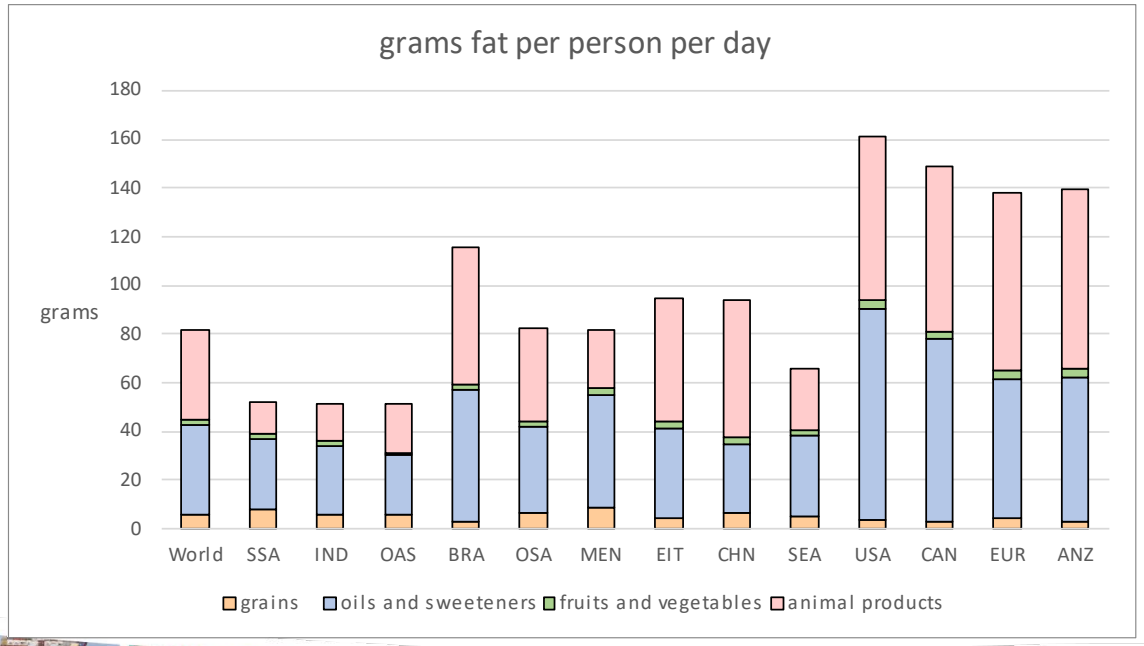
grams of fat per 1000 kcal



Nutrition indicators in model base year (2011)





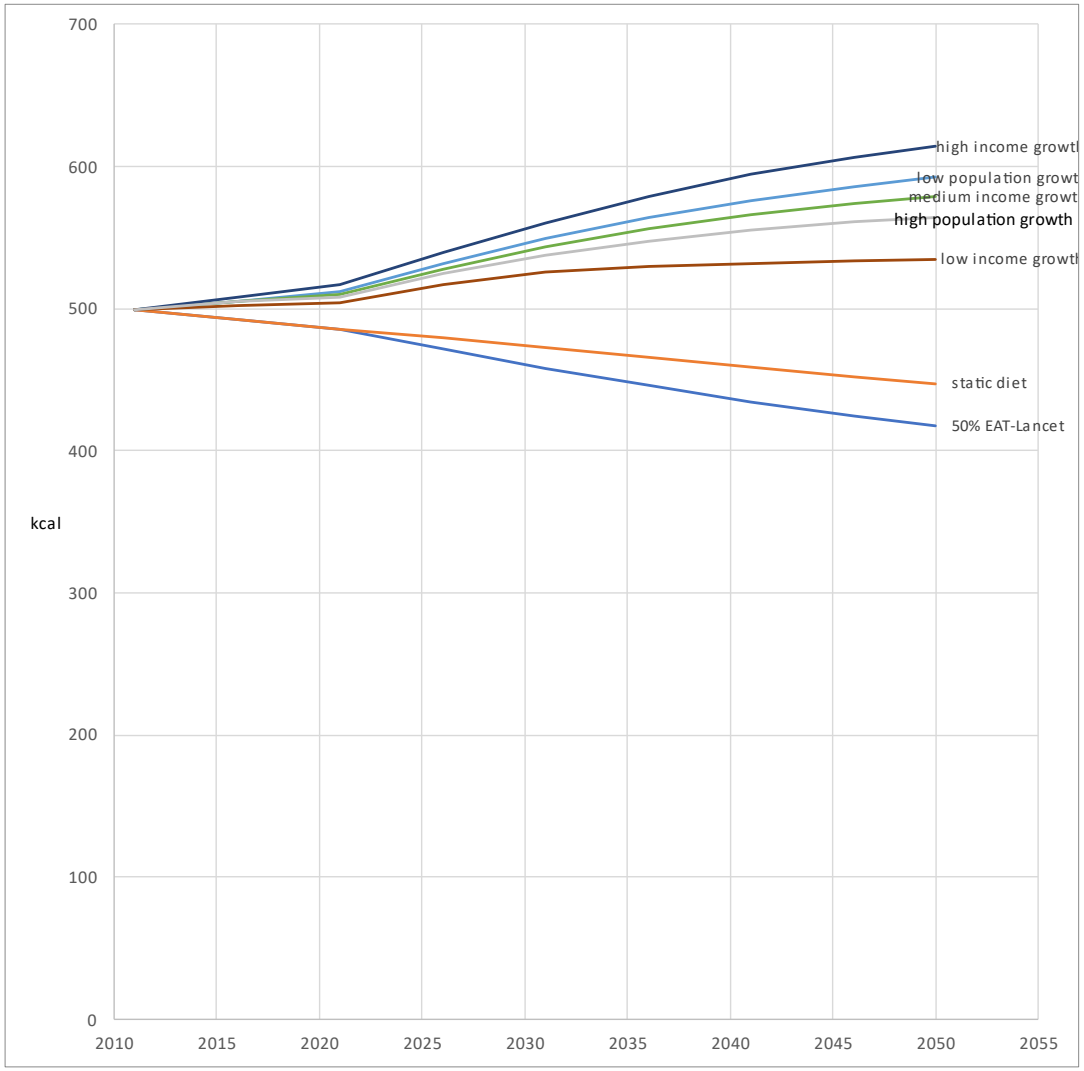


Scenarios

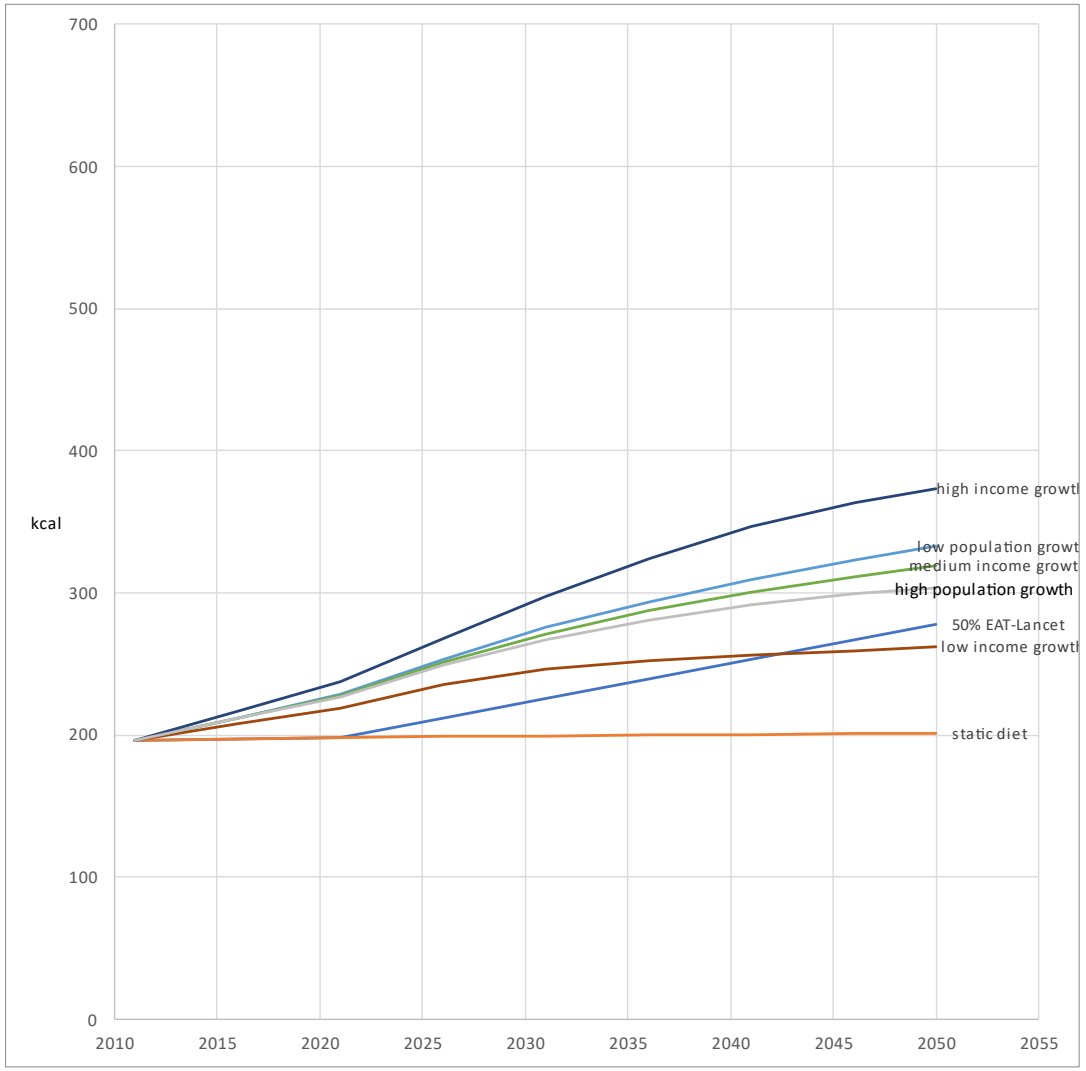
- (1) Static diet (reference scenario): All world regions maintain their 2011 historical diet. There is no income or price response in this scenario.
- (2) 50 percent EAT-Lancet Healthy Reference Diet: 50 percent convergence from 2011 historical diet toward the Healthy Reference Diet in Willet et al. (2019). With full convergence, average consumption of food calories becomes 2500 kcal/person/day within each world region, which is an increase for developing countries and a decrease for wealthy countries. Consumption of animal products increases in developing countries but declines in wealthy countries.
- Income-driven diets: based on historical food consumption patterns in response to increasing per capita income. The general pattern is for total per capita calories to increase, along with a greater share of animal products in the diet.
  - (3) Low income growth
  - (4) Medium income growth
  - (5) High income growth

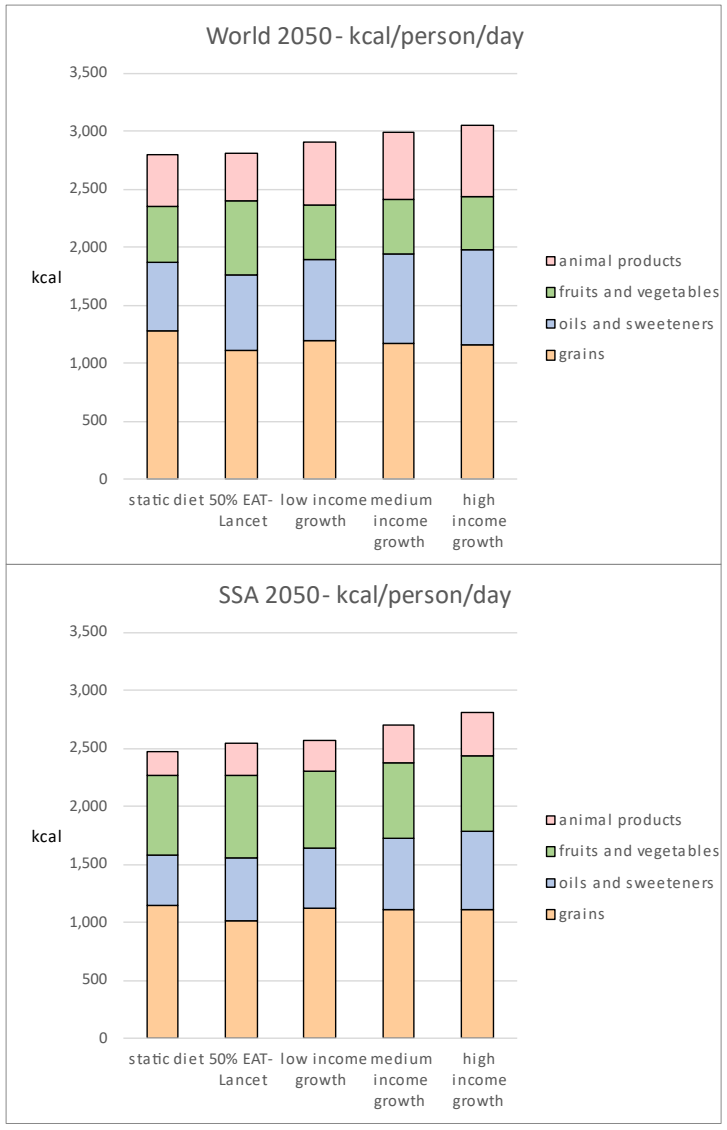
W. Willett et al. (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems, The Lancet 393: 447-492.

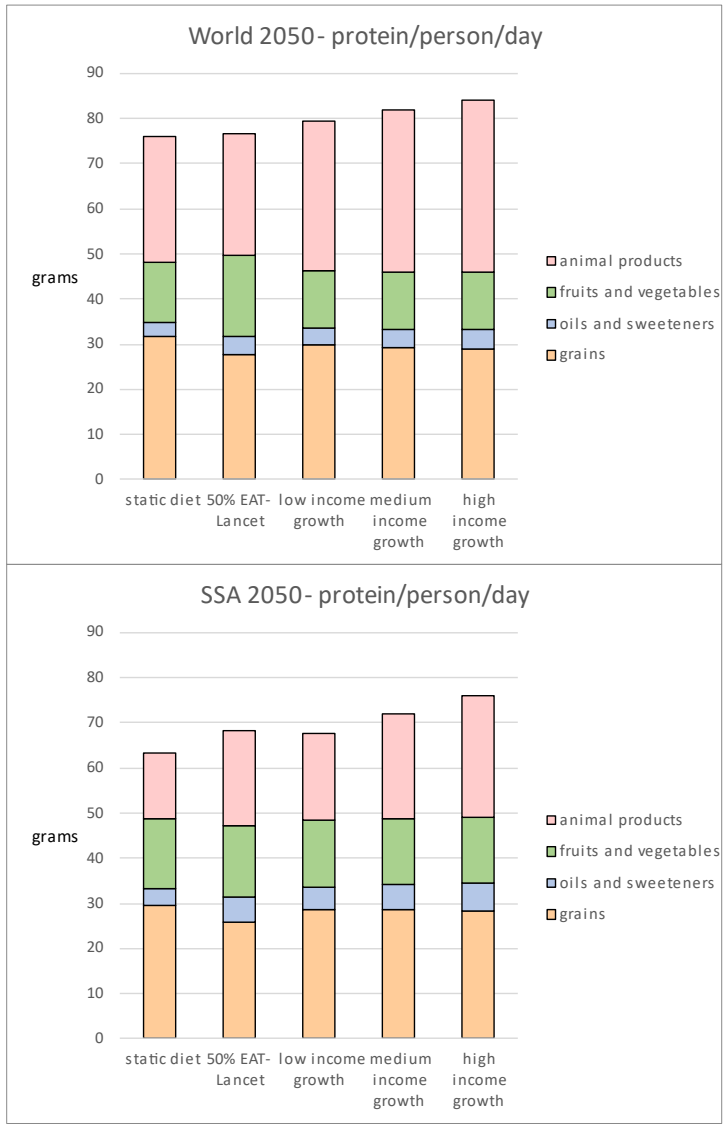
Per capita consumption of animal products (World)

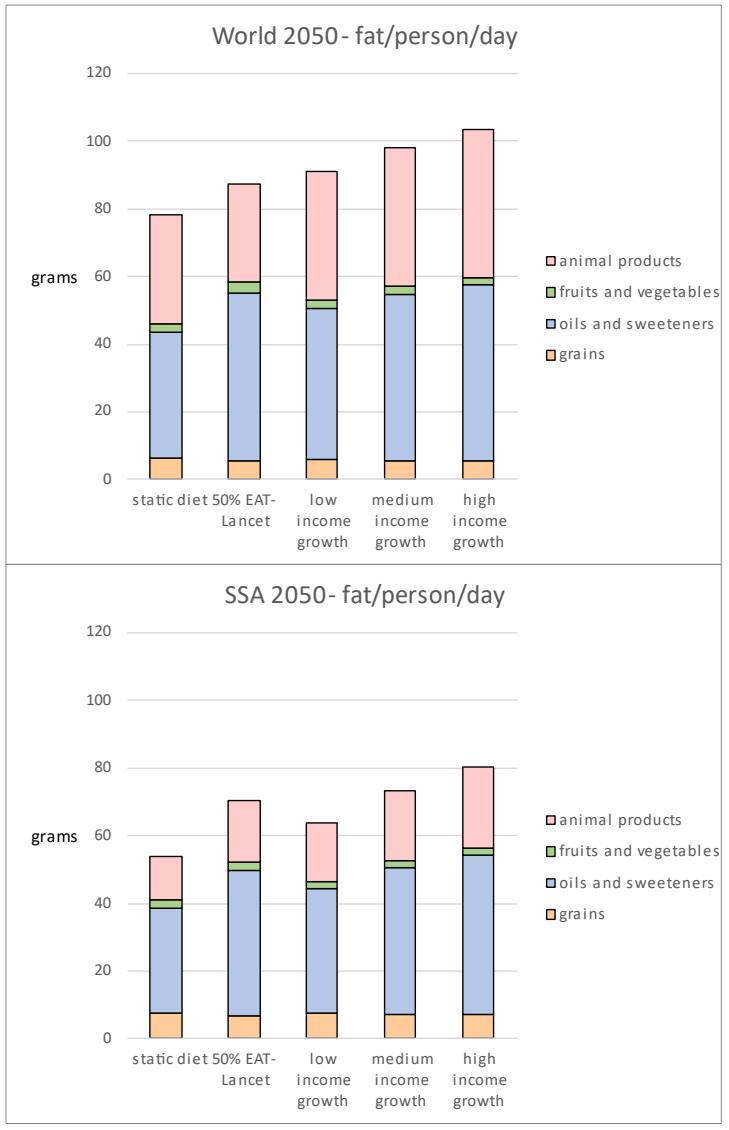


Per capita consumption of animal products (SSA)




World 2050- kcal/person/day
kcal
3,500
3,000
2,500
2,000
1,500
1,000
500
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains


World 2050- protein/person/day
grams
90
80
70
60
50
40
30
20
10
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains


World 2050- fat/person/day
grams
120
100
80
60
40
20
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains

SSA 2050- kcal/person/day
kcal
3,500
3,000
2,500
2,000
1,500
1,000
500
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains

SSA 2050- protein/person/day
grams
90
80
70
60
50
40
30
20
10
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains

SSA 2050- fat/person/day
grams
120
100
80
60
40
20
0
static diet
50% EAT-Lancet
low income growth
medium income growth
high income growth
animal products
fruits and vegetables
oils and sweeteners
grains

Future Directions

- Partition grams of fat using food conversion tables
  - Saturated
  - Monounsaturated
  - Polyunsaturated
- Micronutrients by food group can also be tracked
- Number of food groups can be expanded
  - GTAP data cover five types of animal products (including fish)
  - Fruit and vegetable group could be partitioned

Food Conversion Table

	Nutrient	Unit (per 100 g food)
Macro-nutrients	Calories	kcal
	Protein	g
	Carbohydrates	g
	Fat	g
	Saturated fat	g
	Monounsaturated fat	g
	Polyunsaturated fat	g
	Dietary fiber	g
Micro-nutrients	Vitamin C	mg
	Vitamin A	micrograms RAE
	Folate	micrograms
	Calcium	mg
	Iron	mg
	Zinc	mg
	Potassium	mg
	Copper	mg
	Sodium	mg
	Phosphorus	mg
	Thiamin (B1)	mg
	Riboflavin (B2)	mg
	Niacin (B3)	mg
	B6	mg
	Magnesium	mg

Summary

- Strategy is to model food consumption in two stages
  - Food groups
  - Foods within each group
- This provides guidance for setting up the consumer demand system in a CGE model and for presentation of nutrition indicators
  - energy (calories per person per day)
  - protein (grams per person per day)
  - fat (grams per person per day)
- The first challenge is to replicate FAO calculations of food available for consumption in the model base year (in this case 2011)
- The second challenge is to simulate food consumption over time in response to drivers of global change
  - Maintain food balance (in quantities) during all time steps through 2050
  - Per capita food consumption should remain in a plausible range
- Once defensible results are obtained for calorie consumption over time and across world regions, results can be extended to other nutritional indicators
- This study follows naturally from the GTAP 2021 presentation and conference paper “Tracking calories in CGE models: from fork to farm”
- Some humility is needed for global economic modelers venturing into nutrition indicators
  - Nutrition is a complex subject
  - We can construct basic indicators and how they change over time in response to drivers of global change