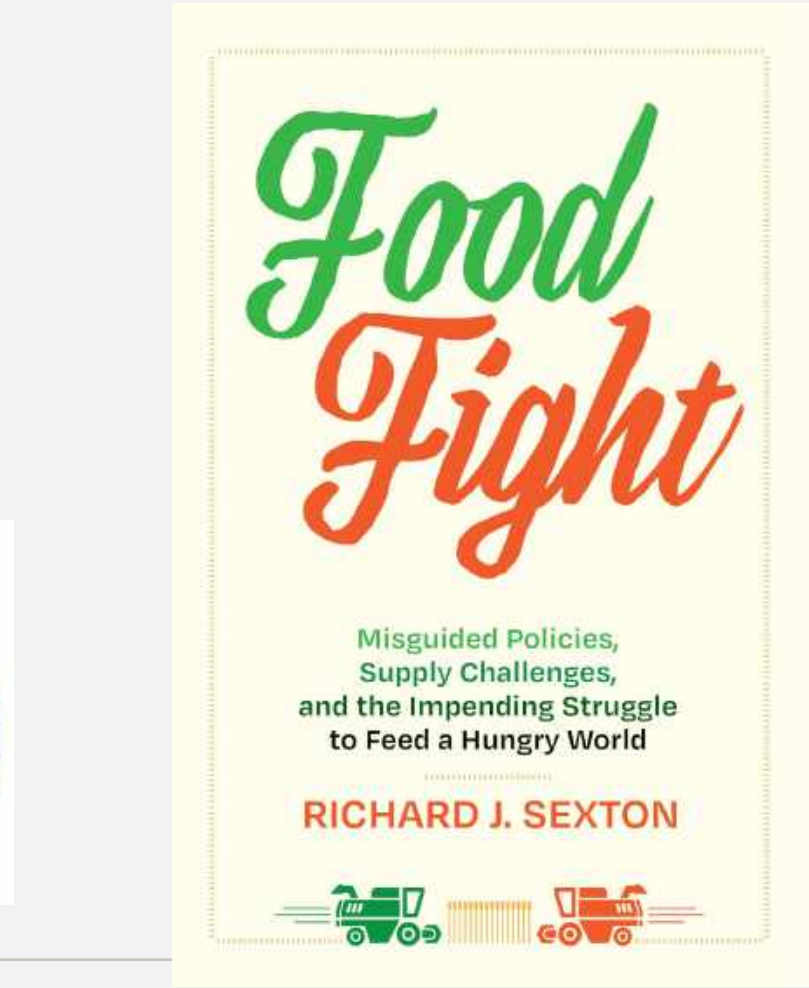
Food Fight: The Impending Struggle to Feed a Hungry World.

Richard J. Sexton

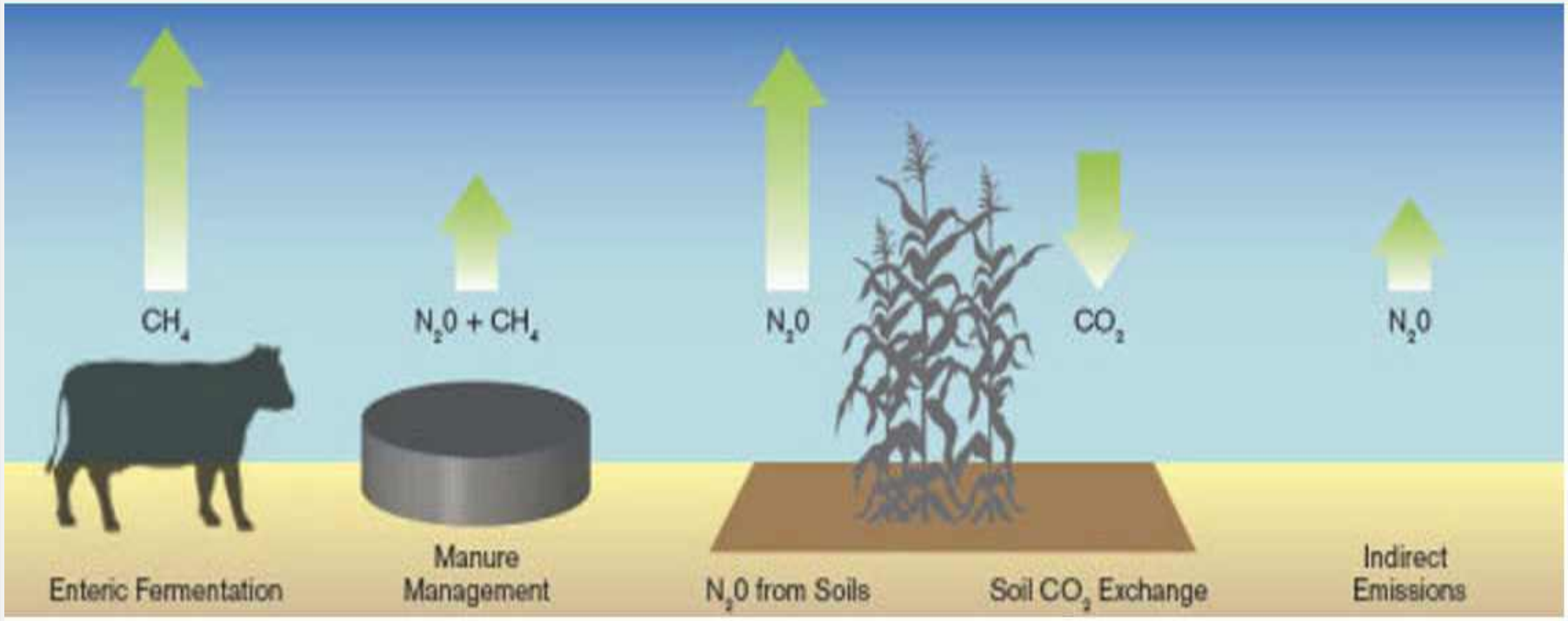
Agricultural & Resource Economics, UC Davis

World Processing Tomato Congress, June 8, 2026

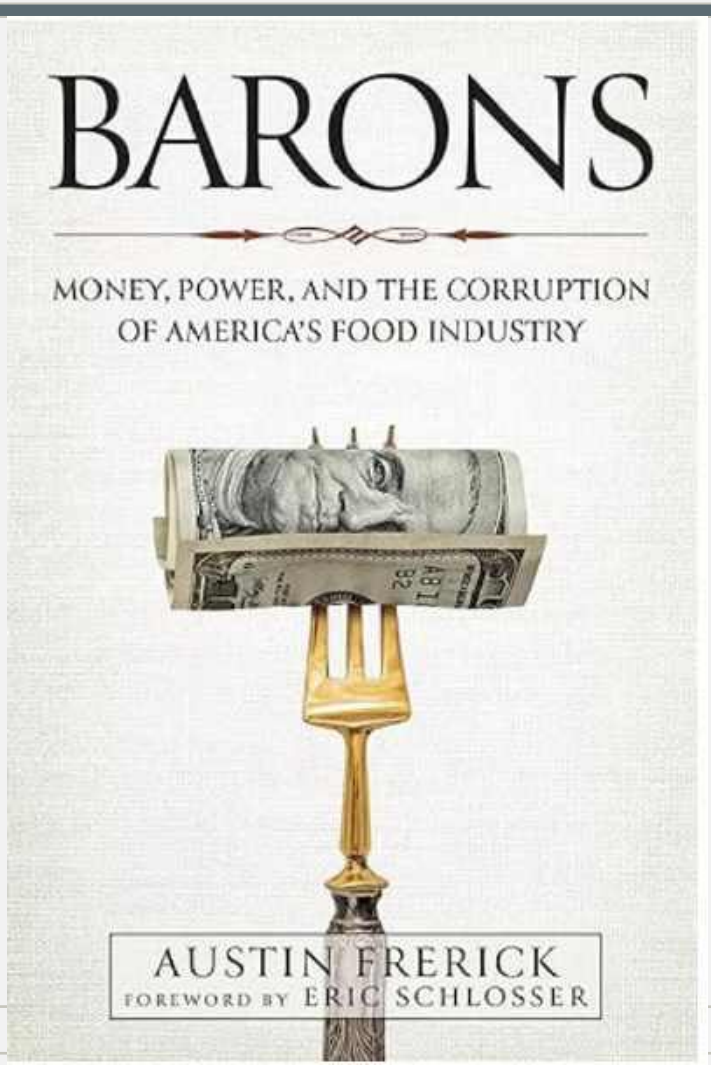


What worries people about agriculture today?

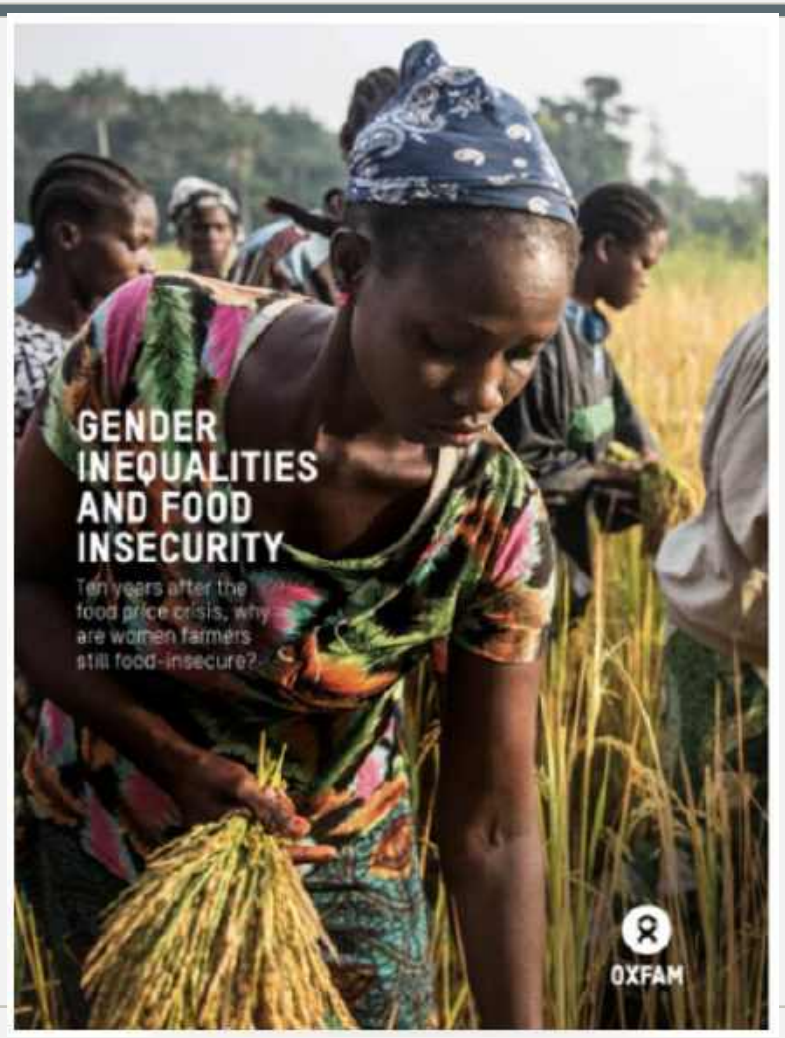
Its greenhouse gas emissions



Its domination by evil corporations



Its inequities



It giving us the “wrong” foods

What about producing enough food?

Food supply problems exist today . . .

Per the UN, in 2024

- 673 million people faced hunger
- 2.3 billion were moderately or severely food insecure
- 2.6 billion (32% of global pop) could not afford a healthy diet
- The real cost of a healthy diet increased by 35% from 2019 – 2024

. . . and may well get worse

- Substantial growth in demand for ag products into the future
  - Population growth
  - Income growth
  - Substantial changes in dietary compositions, with more calories from meats
  - Policy-driven expansion of biofuels
- Significant challenges to expanding food production at rates we have achieved in the past
- Western governments (US, EU) are enacting policies guaranteed to reduce food production

Today's talk

- Demand growth for ag products in this century
  - Why is forecasting demand so hard and fraught with peril?
  - Why are we likely to be underestimating it?
- Challenges to expanding supplies—they are many and they're serious
- Examine supply-reducing policies in US, EU, and elsewhere
- Consider "conventional wisdom" policies to address food availability
- Discuss alternative policies that can ensure sufficient food supply and address environmental and equity

Why haven't you heard more about this issue--1?

- ## Errors of the doomsayers

- "The power of population is indefinitely greater than the power in the earth to produce subsistence for man." Thomas Malthus ~1798

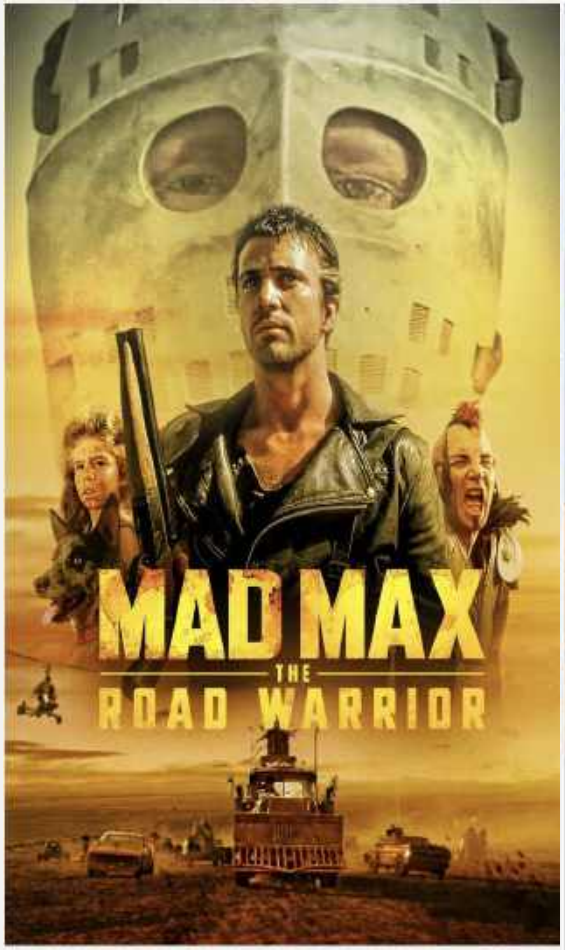
- "By 1985 enough millions will have died to reduce the earth's population to some acceptable level, like 1.5 billion people." *The Population Bomb* Paul Ehrlich~1968

Why haven't you heard more about this issue--2?

Blind-faith believers in technology

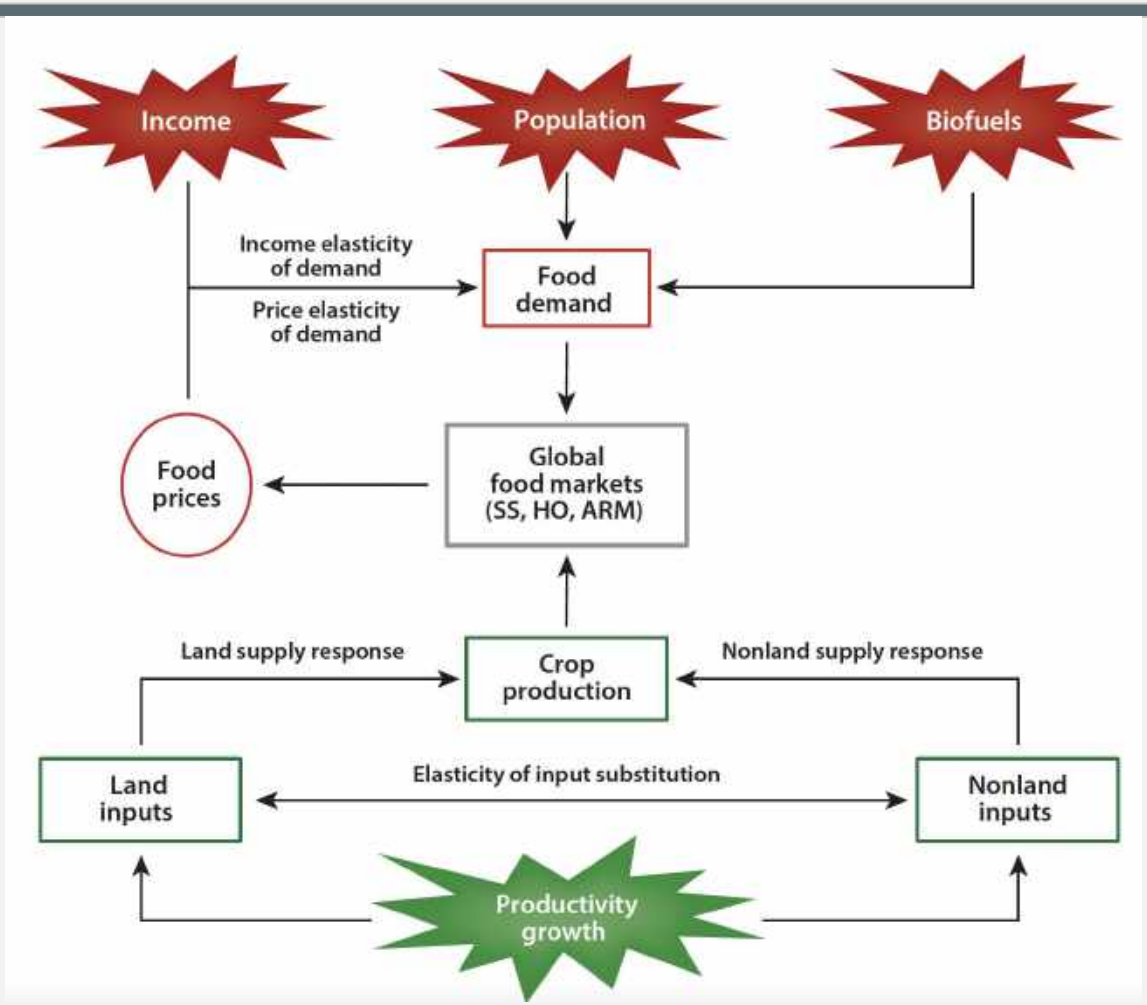
- "Developing country productivity growth will make up for any decline in productivity growth in the West."
- "Robots can now weed fields"
- "They are now growing produce using *vertical farming*"

Why haven't you heard more about this issue--3?



Demand for ag production in the 21st Century

Forecasting Global Food S&D



Where are we today?

- World average is 2,963 calories a day
- 3,537 in N. America and Europe
- 3,035 in Latin America and Caribbean
- 2,922 in Asia
- 2,589 in Africa
- Room for growth for 86% of world's population
- Calories are a poor measure of food demand

Pieces to the demand puzzle

1. How much is population expected to grow?

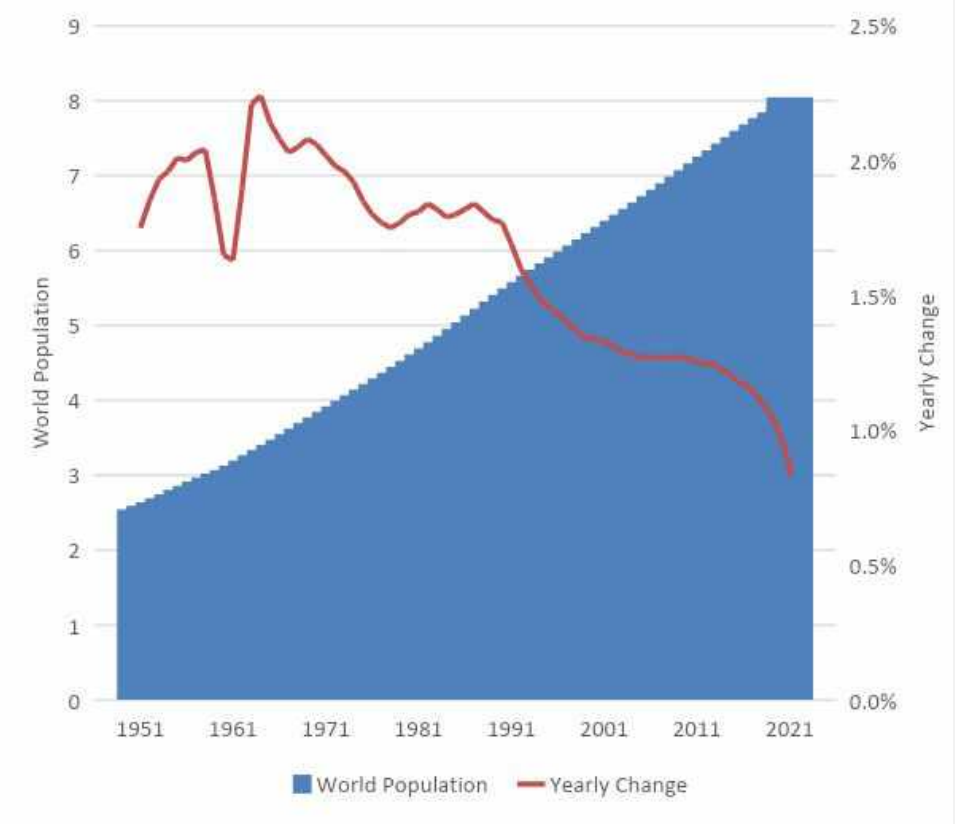
2. How much will incomes grow and where in the world will they grow fastest?

3. How will dietary composition change? Will we eat more or less animal products?

4. How much ag production will be used to produce biofuel?

1. Population growth

- 8.2 billion people today
- UN estimates
  - 10.3 billion people in 2080, then leveling
  - Most growth in Sub-Saharan Africa and Central and Southern Asia
  - 95% CI: [9.0B, 11.4B]



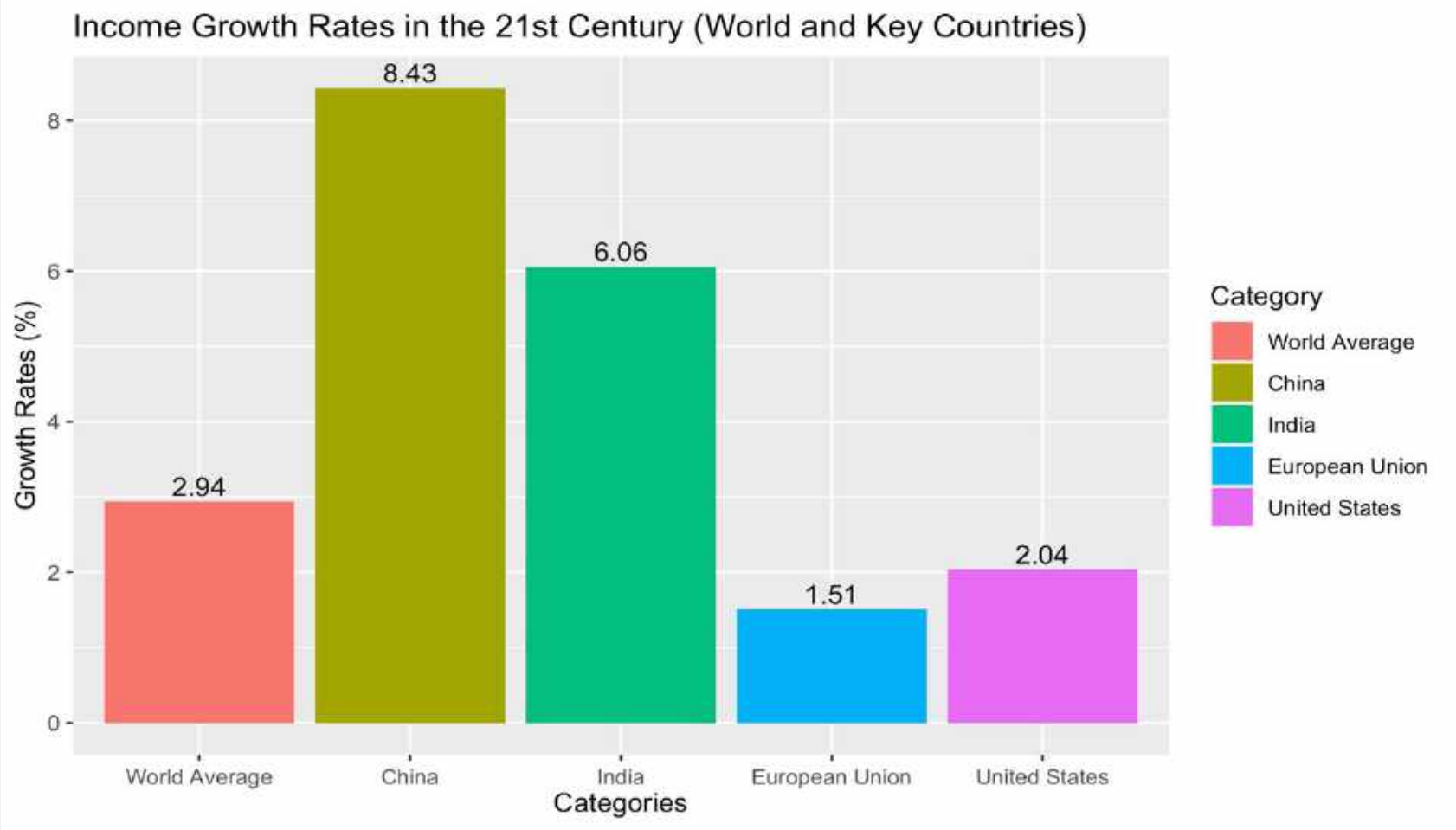
2. Income growth

- Why is this important?
  - Engel's Law—income elasticity is positive but less than 1.0: food consumption rises at a decreasing rate as incomes rise
  - Bennett's Law—composition of what we eat changes as income grows
- Average income elasticities
  - Meat and fish = 0.73
  - Dairy = 0.72
  - Staples are much lower
- Food income elasticities are higher in the developing world
  - Where most population and income growth is likely to

Trends in income growth

- Is the past a portal into seeing the future?
  - 1961 – 2022 world GDP ≈ income annual growth = 3.47%
  - Annual growth this century = 2.97%
  - How fast will incomes grow over the rest of this century?
- Income convergence—emerging countries are growing fastest in general
  - India and China, 35% of world population, have been growing much faster than the world average

Income convergence



3. What will we eat moving forward?

- Meat, eggs, and dairy convert feed inputs into food outputs inefficiently
- Measuring food consumption in "cereal equivalents" captures this distinction
  - CE measures feedstuff used to produce one unit of animal products in terms of the dietary energy equivalent of a unit of corn
- Some CE estimates: Beef = 19.8, pork = 8.5, poultry = 4.7.

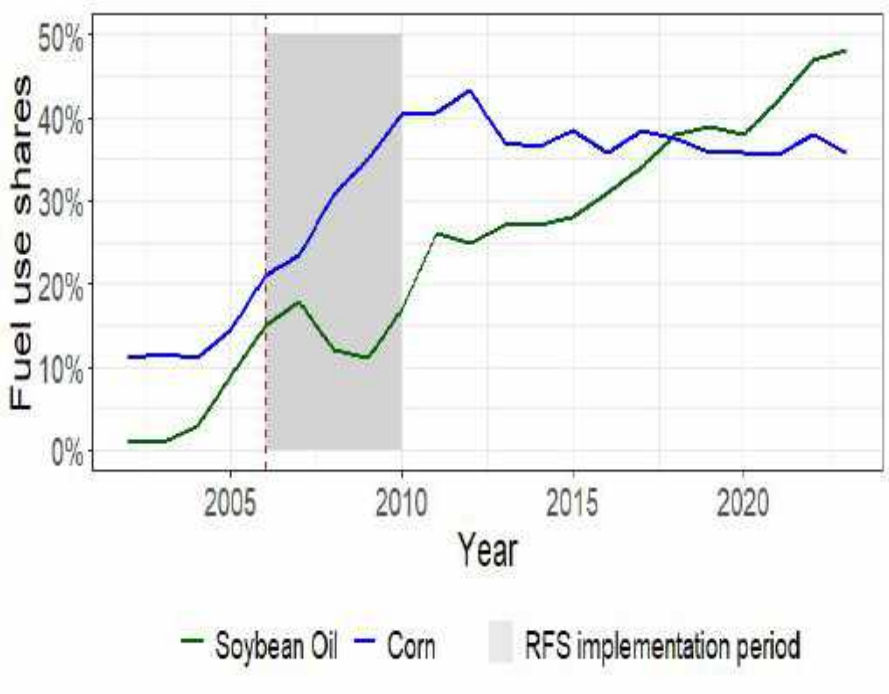
Expanding demand for animal products

- Some meat consumption stats
  - U.S. is #1 (among major countries) at 122.8 kg per capita
  - Argentina is 113.26
  - Germany is 71.32 kg.
  - China is 70.57 kg
  - India is 6.63 kg
- Expanding world demand for animal products is an "inconvenient truth" for world policymakers

4. Biofuels

The U.S. Example

- About 1/3 of U.S. corn crop goes to produce ethanol
- Nearly half of U.S. soybean oil is used for biofuel
  - 75% of diesel in CA is biodiesel vs. 10% nationally
- Biofuels may be occupying up to 25% of U.S. farmland based upon productivity potential



Biofuel demand is driven by policy, not market forces

- U.S. demand
  - National Renewable Fuels Standard (RFS) ~ 2005
  - California's Low Carbon Fuel Standard
  - Standards for Sustainable Aviation Fuel (SAF) are on the horizon
- Other countries have their own standards for biofuels
  - Brazil mandates are rising to E30 and biodiesel to B15
  - EU countries either mandate E5 or E10 but the plan is for E20 by 2030
- Absent policy interventions biofuels are not cost competitive with fossil fuels

The false promise of biofuels

- Biofuels are not a positive for the environment or for carbon emissions due to indirect land use change (ILUC)
- But mandates for their increased use are in place
  - Europe—E5, E10 now but E20 by 2030?
  - U.S.--E15 will soon be available year around and be cheaper than E10 due to the credits it generates.
- Will corn ethanol qualify as a sustainable aviation fuel?
- Biofuels in U.S. are now promoted mainly as a tool to support farm incomes but even this claim is largely false

Uncertainty across all four factors

Population: Where within (or outside) the 2.4 billion range in the UN's 2100 population projections confidence interval will we be?

Income: How much will incomes grow in this century?

Dietary composition: How much will meat and dairy demand expand as incomes grow?

- Calories are NOT a good measure of food demand

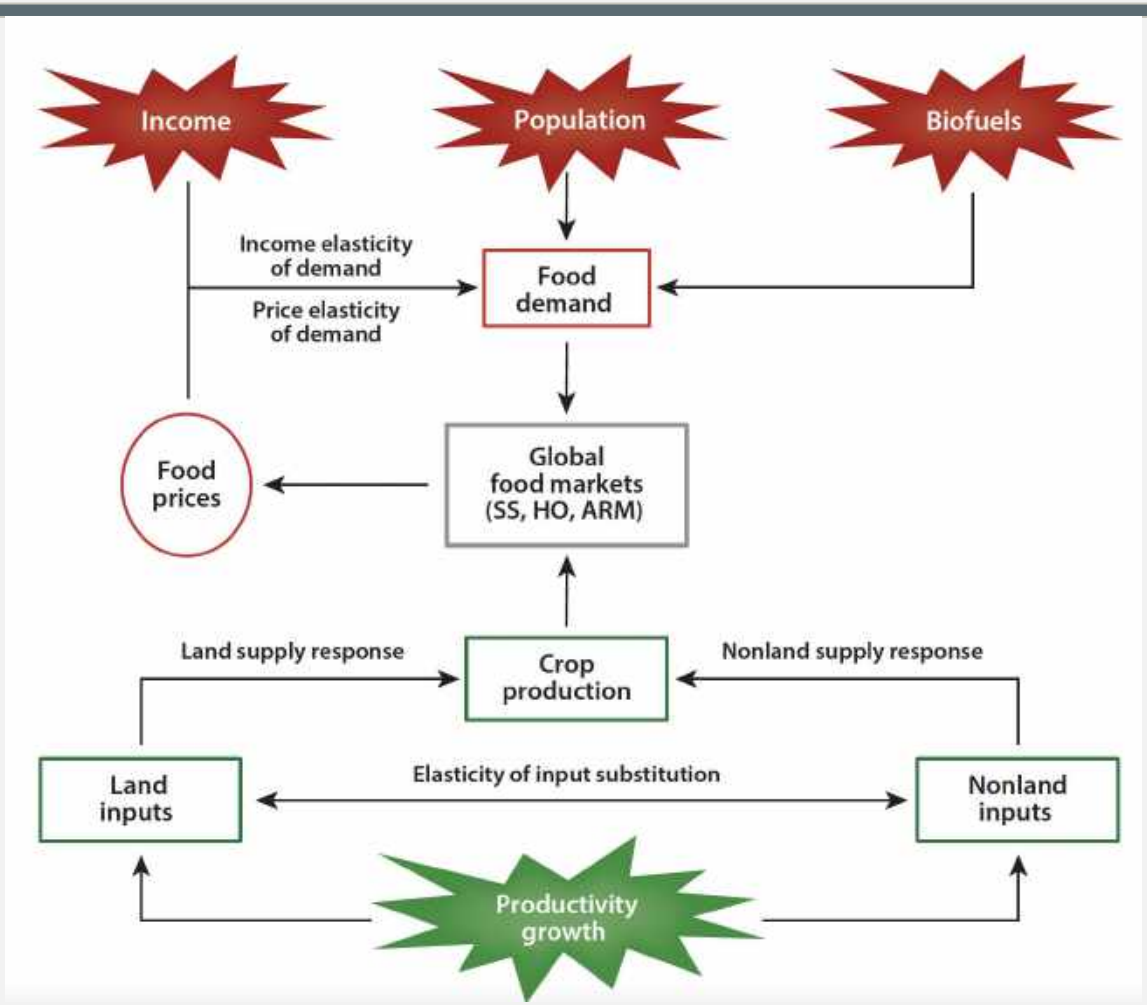
Biofuels: How will they fare in upcoming policy debates?

The supply side






Macro models of Global Food S&D



Two ways to expand supplies

- Extensification is expanding the land base in agriculture
  - This is the worst outcome in terms of GHG emissions and other environmental harms
  - Many policies in place today encourage extensification—indirect land-use change or ILUC
- Intensification is getting more production from a given agricultural land base
  - Ag productivity growth is the key
  - 2010 study by Stanford climate scientists showed yield improvements from from 1961 – 2005 saved 161 gigatons of carbon emissions = 43,286 lbs. = 19,675 kg. for every person alive today

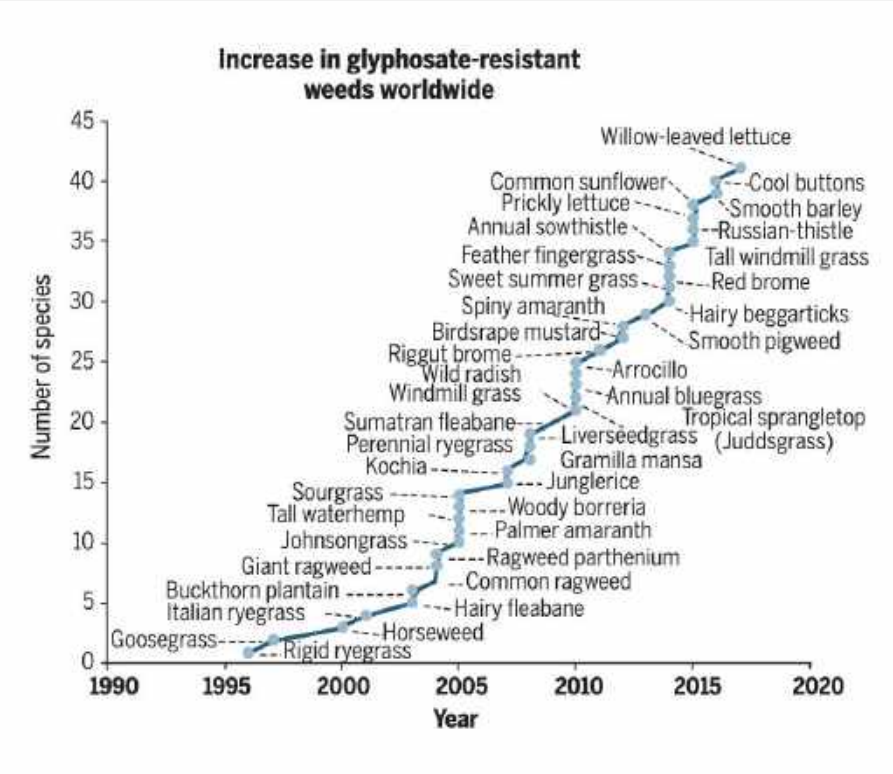
Productivity growth has slowed

- Julian Alston and Phil Pardey: U.S. total productivity growth rates
  - 1910 – 1950: 0.83%
  - 1950 – 1990: 2.12%
  - Post 1990: 1.16%
- 1950 – 1990 surge was a one-time phenomenon, not to be replicated
- USDA researchers Fuglie et al.: worldwide TFP growth rate from 2008 – 21 was 1.27%

Other headwinds to expanding food production

1. Pest resistance

- Modern chemicals are most vulnerable to resistance: specificity → resistence
- Gould et al. *Science* 2018: "Current evidence suggests that insect and weed evolution may outstrip our ability to replace outmoded chemicals and other control mechanisms."
- Climate change will exacerbate pest problems

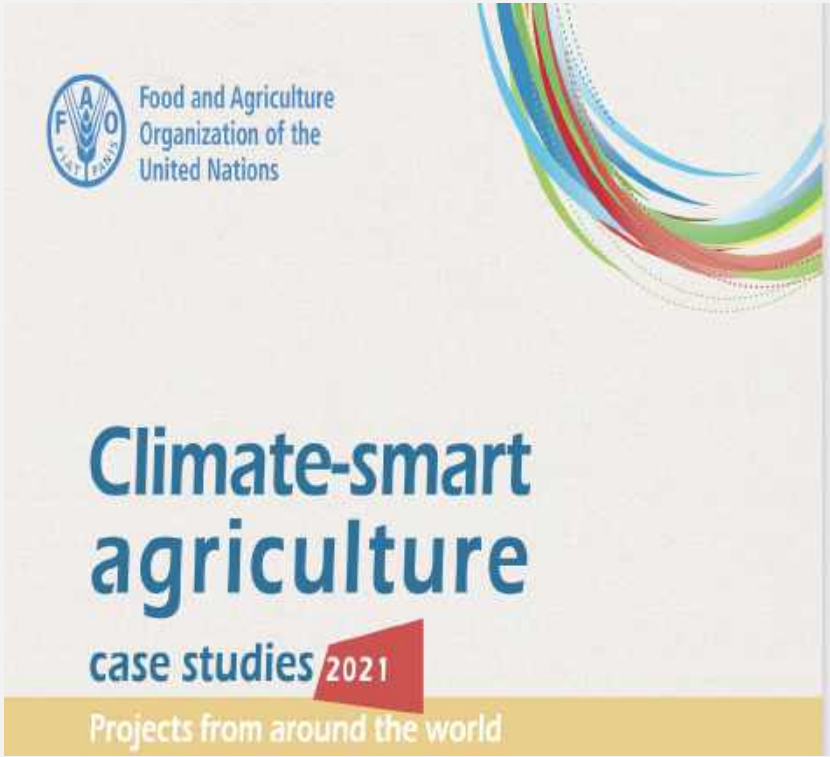


2. Climate change

- David Lobell et al. *Nature Climate Change* 2014 meta study
  - Significant yield decreases occur by 2040
  - Average yield reduction of 13.7% by 2100.
  - Adapted crops yield on average 7.16% greater than non-adapted.

3. “Climate-smart agriculture”

- FAO says agriculture and related land-use emissions account for 17% of global GHG
- EU and US want to take ag land out of production
- Most “climate smart” practices reduce yields
- No-till, cover cropping don’t have much effect on emissions



Yield-reducing "credence attributes"

- Credence attributes—product characteristics that cannot be discerned directly by consumers and must be certified credibly
- Examples: Organic, non-GMO, local, animal welfare
- Product differentiation is introduced at the farm, and preserved by downstream intermediaries
- Production of credence-attribute products is supported by policies across the world

Policies in support of credence attributes

- National laws and standards
  - EU, Mexico, Africa, Russia bans on GMOs
  - EU, US subsidies for organic ag, small farms, local foods . . .
  - EU animal welfare laws
- Subnational authority—California's animal-welfare laws
- Market intermediaries--animal welfare, non-GMO
- Third-party certifiers—animal welfare, fairness in marketing, non-GMO

Some Productivity Facts for Credence Attributes

Organic

- Meta studies on test plots peg the yield gap between conventional and organic production at 20-25% averaged across crops and countries
- Commercial yield gap is higher—on the order of 35 - 45%
- ILUC applies here as well
- EU employs a variety of subsidies with the goal of at least a 25% organic land share by 2030
- U.S. subsidizes farmers to convert conventional land to organic

Non-GMO

- Klümper and Qaim (2014) GMO meta analysis
  - 22% yield increase to GM variety
  - 37% reduced chemical use
- Yield impacts greatest in developing countries
- No health harms to consuming GM products have ever been detected

Implications of food credence attributes

- Reduced yields and productivity in nearly all cases
- Lower yields pose a direct challenge to claims that credence attributes benefit the environment
- The same indirect land use effects that apply to biofuel production apply to yield-reducing credence goods
- Intensive vs. extensive expansion of production

Winners and Losers from policies promoting credence attributes

- Winners: Those who want to eat the foods that embody the credence attributes, i.e., rich people in rich countries
- Losers: Poor consumers, who generally don't buy expensive credence-attribute goods and who will pay more for conventional foods
  - Mérel, Qin, Sexton ERAE 2023 estimate organic policies of US/EU raise food costs for poor by $64 – 133 billion/year
- Loser: The environment? Nobody can credibly claim that implementing yield-reducing and productivity-diminishing policies benefits the environment on net due to ILUC

Policies certain to reduce food production & raise prices

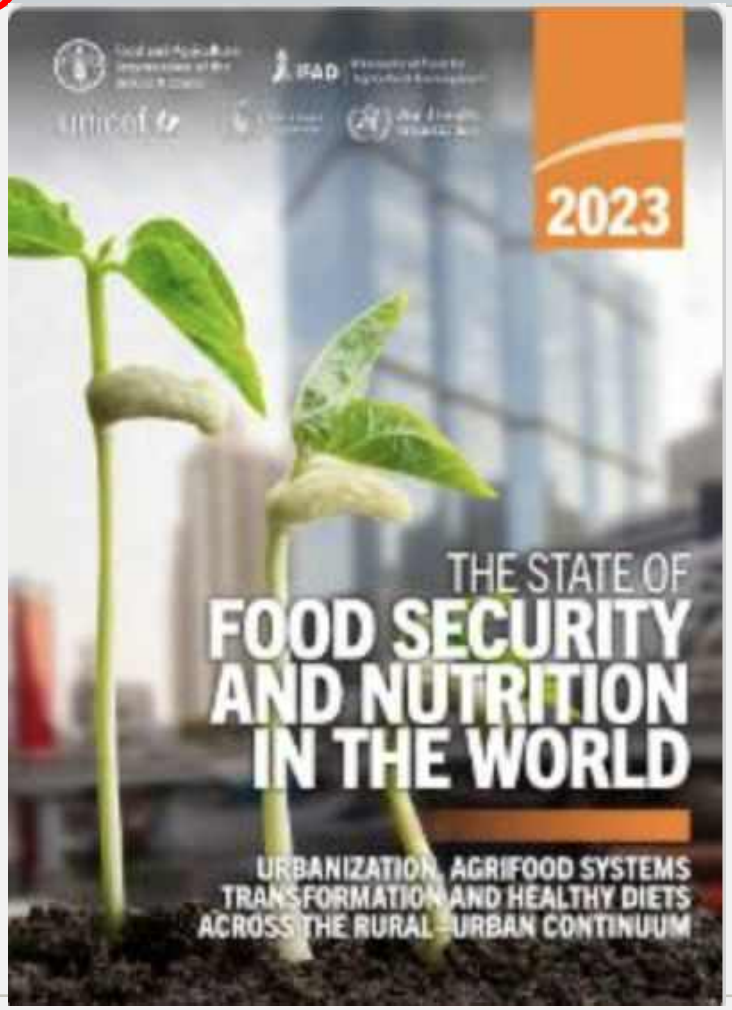
- Bans on use of GMOs
- Subsidies to expand production of credence foods—organic, local, nonGMO, animal friendly, etc.
- Policies to reduce ag land base in most productive places
- Policies to reduce Ag's emissions
- Regulations that deter innovations in agriculture
- Support for small-scale agriculture

Irreversibility of bad policies

- GMO bans have forestalled decades of beneficial innovations in genetic engineering
- Biofuels are a loser for society but are here indefinitely and likely that mandates will be expanded
- Land removed in the name of "conservation" is unlikely to be repurposed for production
- Ag productivity research operates with a lag of about 20 years---reduced investments today will haunt us into the future

“Sustainable” policies to expand food availability: UN FAO

- Reduce conflicts that disrupt food systems
- Address climate change/resilience
- Reduce food loss and food waste
- Change dietary patterns including reduced use of animal protein



Food loss and food waste

- UN estimates food loss (everything from harvest to retail) is 13% of potential supplies
- Food waste (retail, food service, household) is 19%
- Poor and rich countries waste similarly per capita
- UN, EU, US have goals to cut them by 50%
- “Edible food” and “marketable food” are very different
- Much of food loss and waste represents economically efficient behavior

Eat less meat and dairy?

- Animal product production and consumption is bad from both a GHG perspective and inefficient conversion of inputs to food outputs
- But people are going to want to eat more, not less as their incomes rise
- Consumption is growing and expected to grow well into the future
- Can/will policies be enacted to reduce meat consumption?

Enough food, food equity, and the environment?

We can have all three

- Eliminate policies to support products with yield-reducing credence attributes
- Stop promoting legislation and regulations that reduce ag productivity and discourage innovation
- Produce food on the most efficient land in the most efficient places using the most efficient methods
- Support consolidation of small farms worldwide

Conclusions--1

- Great uncertainty as to demand and supply growth moving forward
- Food demand will grow considerably in this century
  - Models most likely underestimate it.
- We face significant headwinds to expanding food production at rates achieved in the past
  - Declining ag productivity
  - Pest resistance
  - Climate change
  - Competition with biofuels for land
  - Expansion in yield-reducing credence attributes and standards

Conclusions--2

- Policies that reduce yields on existing farmland cannot credibly claim to benefit the environment or to be "sustainable"
- Policy-influenced decisions made today are not often readily reversible
  - Europe's, Africa's GMO policies
  - Biofuels
  - Deforestation and expansion of the agricultural land base
- But a future with enough food, good environmental outcomes, and food equity is surprisingly easy to achieve . . . If we have the will

Conclusions—3

Optimism: a good thing or a bad thing?

- Optimism as to your favorite sports team's chances in the upcoming season can be a good thing
- Relying on optimism that we'll be OK with respect to food production isn't a good thing

Further reading?