Modeling biofuels induced land use changes

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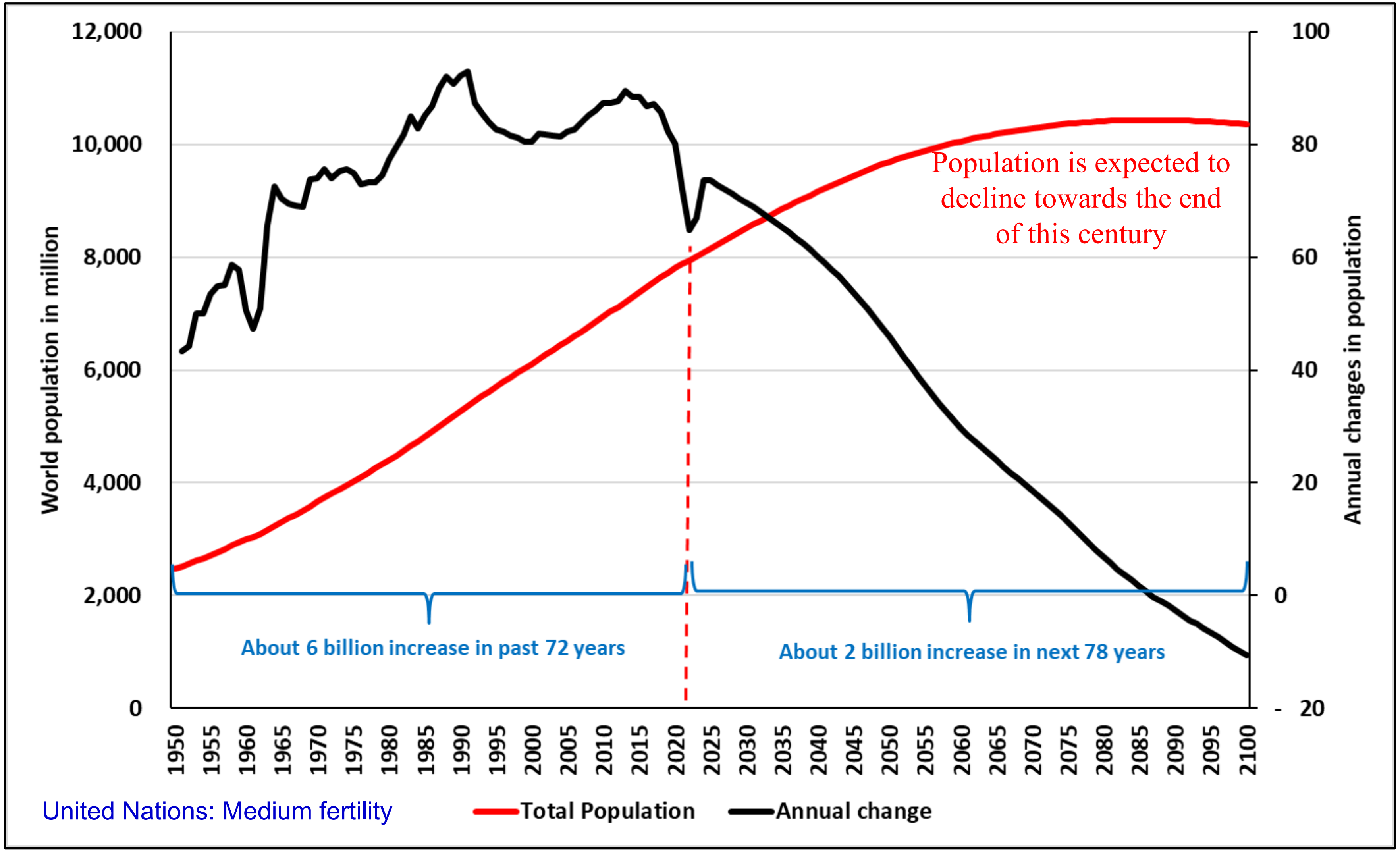
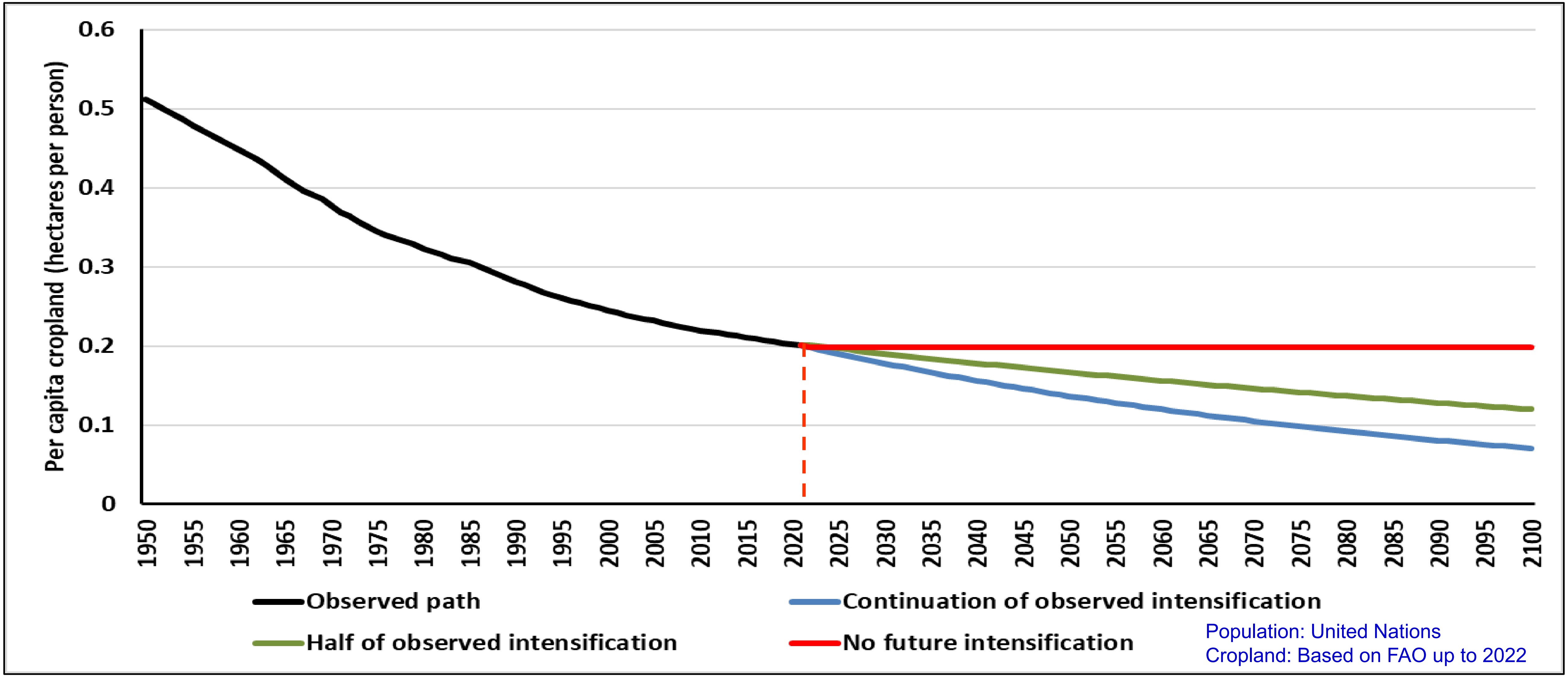
- This presentation covers the following topics:
  - Demand for cropland in a broad perspective
  - Intensifications in agricultural activities
  - Assessing unintended consequences of biofuel production and policy
  - ILUC and variations in ILUC assessments
  - Development of GTAP-BIO model and its future extensions

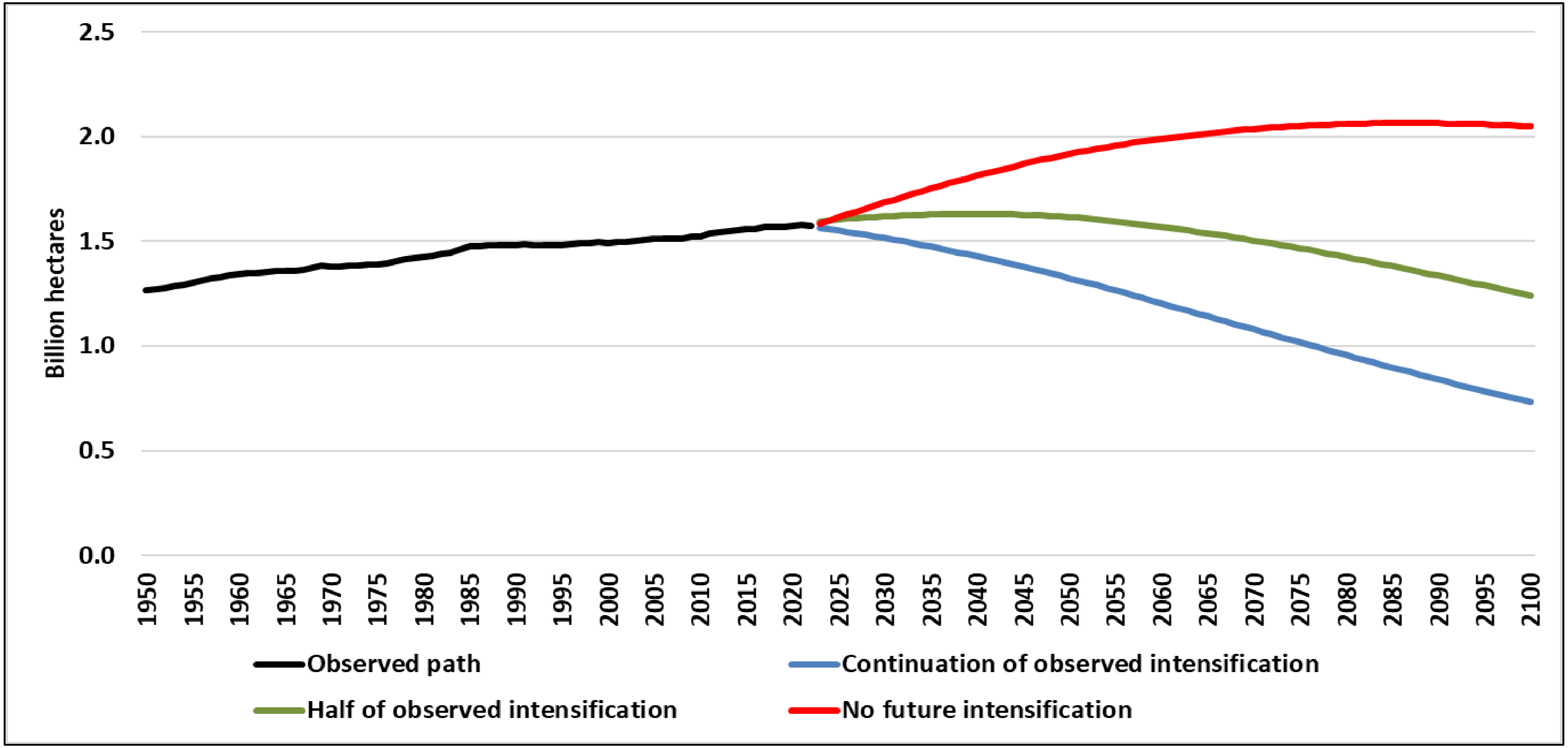
World population and its changes over time



Per capita cropland at the global scale: Historical data and a few potential future paths

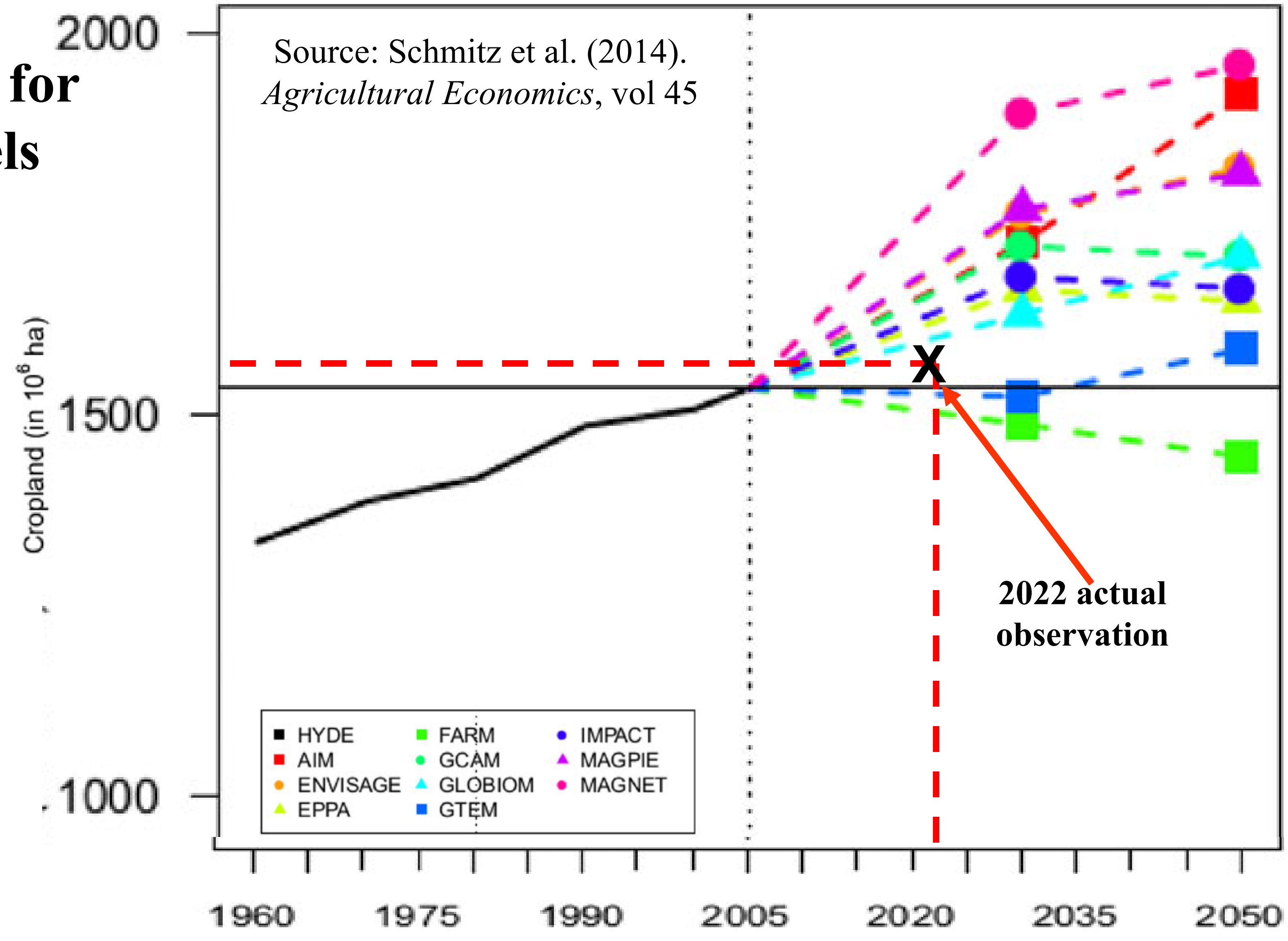


Area of cropland at the global scale: Historical data and a few potential future paths



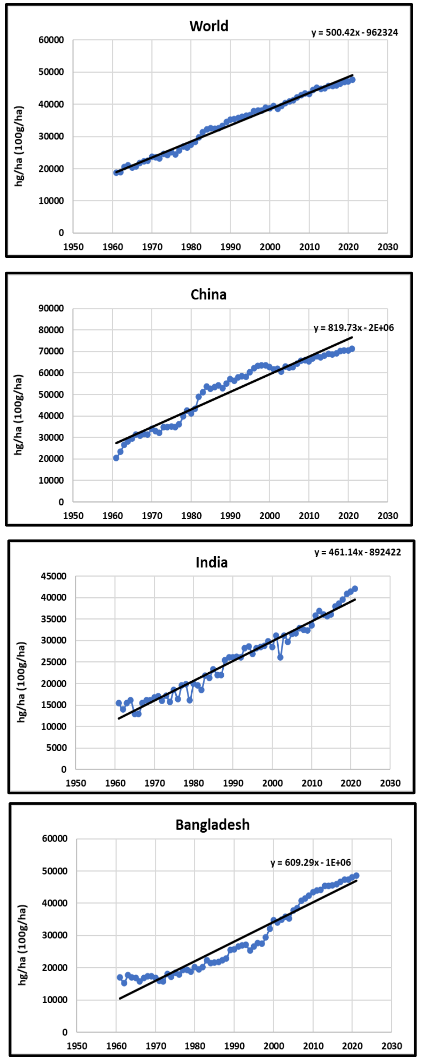
Projections of future demand for cropland with various models

- Economic models provide divers estimates for future demand for cropland
- Some of these models overestimate demand for cropland
- Models that omit the price incentive margins overpredict land use changes (Baldos and Hertel, 2013: ERL 034024)

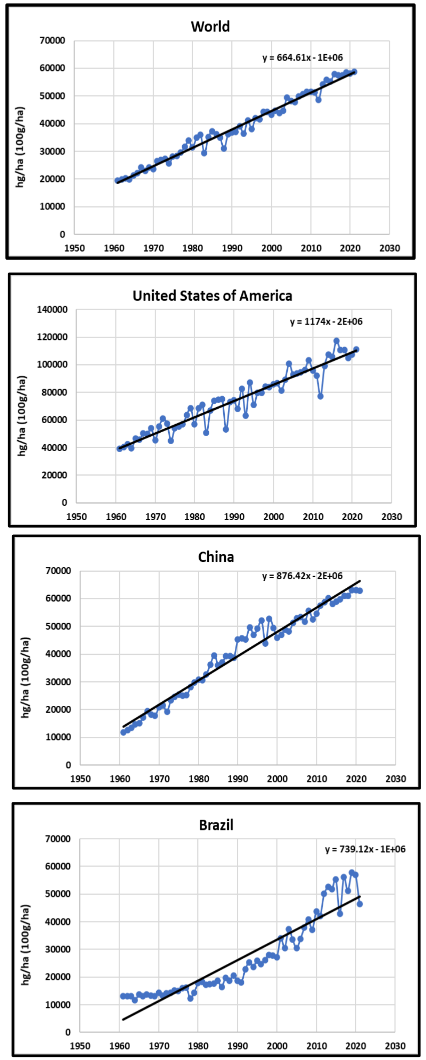


Yield growth: Review of some actual observations

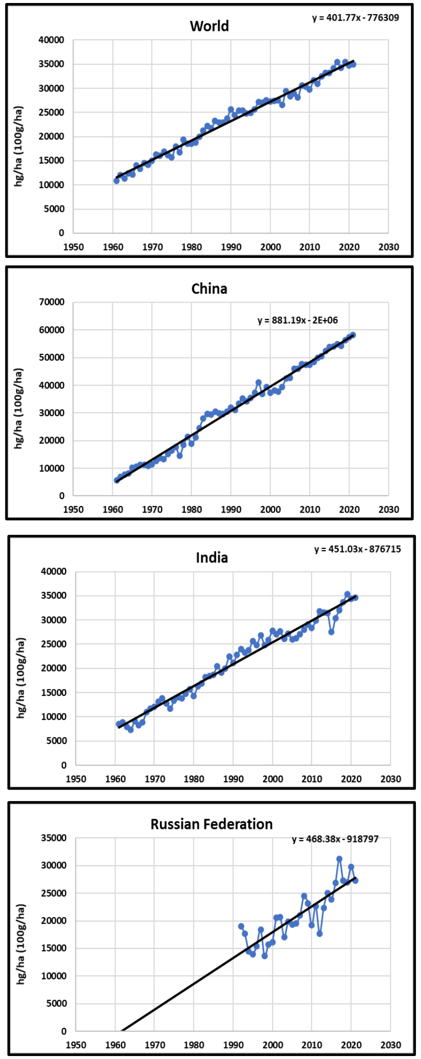
Rice yield



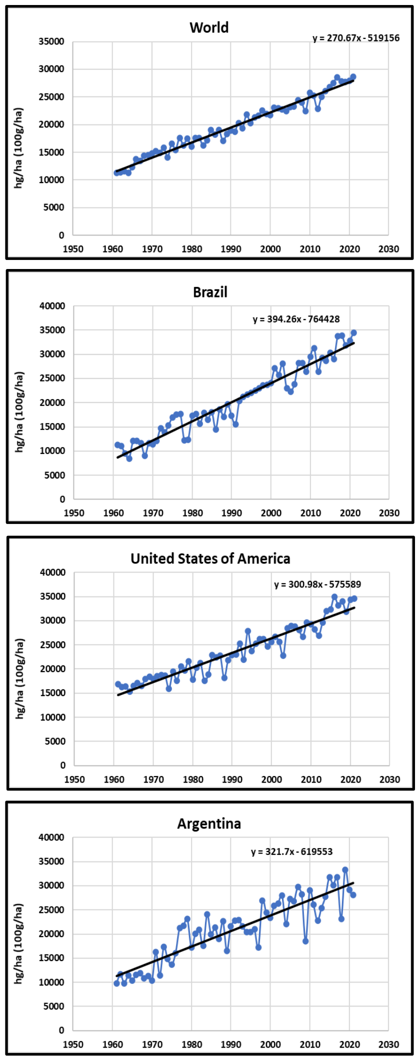
Corn yield



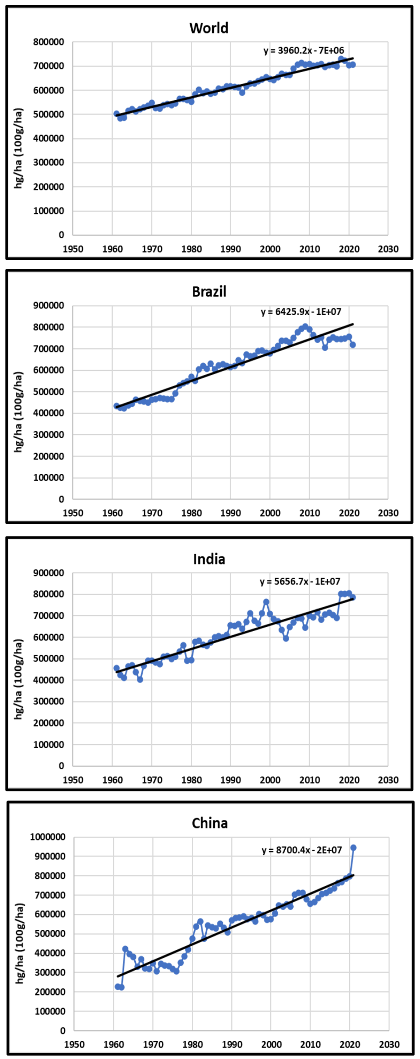
Wheat yield



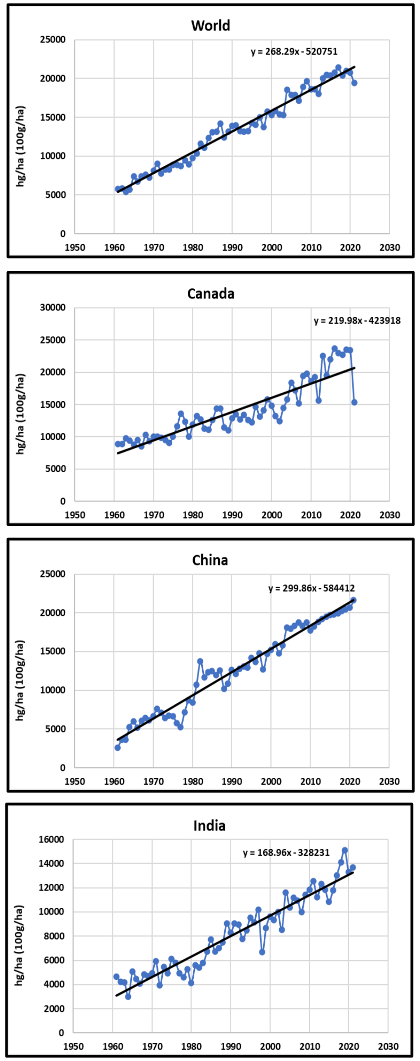
Soybeans yield



Sugarcane yield



Rapeseed yield

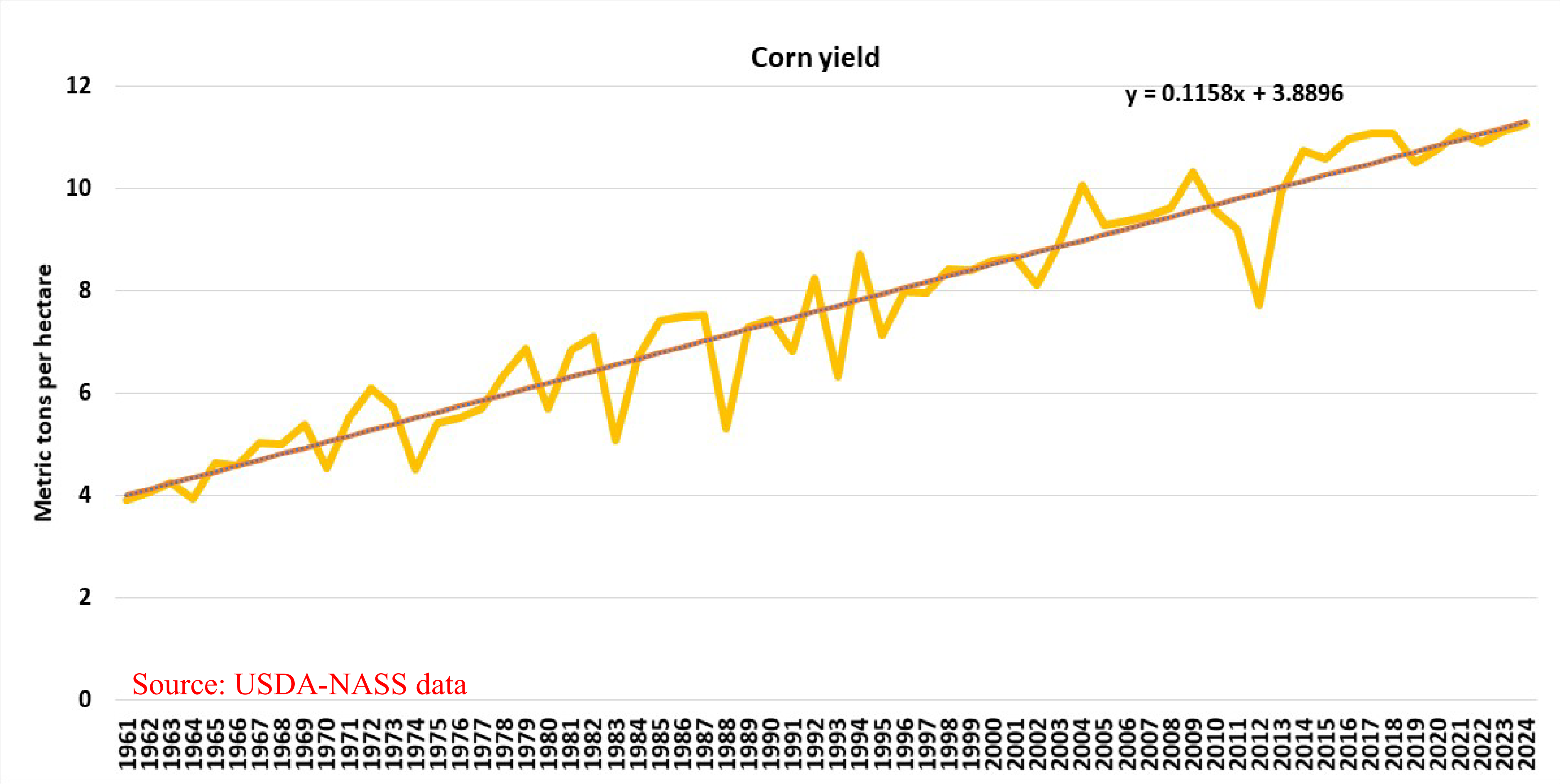


Technological progress in US agriculture

- Three phrases from a paper published 75 years ago: Salter, R. M. (1950). Technical Progress in Agriculture. *Journal of Farm Economics*, *32*(3):
  - "The last 50 years have brought a dramatic increase in physical productivity of agriculture in the United States".
  - "In last 20 years alone average crop yields have increased 50%".
  - "big harvest" will happen in the second half of 20^{th} century.
- The next slide shows what happened in the second half of the 20^{th} century and the first quarter of 21^{st} century.

Review of some actual observations

Historical data: US corn yield over time



- Corn yield has increased by 32.6% between 2000 and 2024
- This yield improvement has added 1,132 million metric tons to the supply of corn in this period

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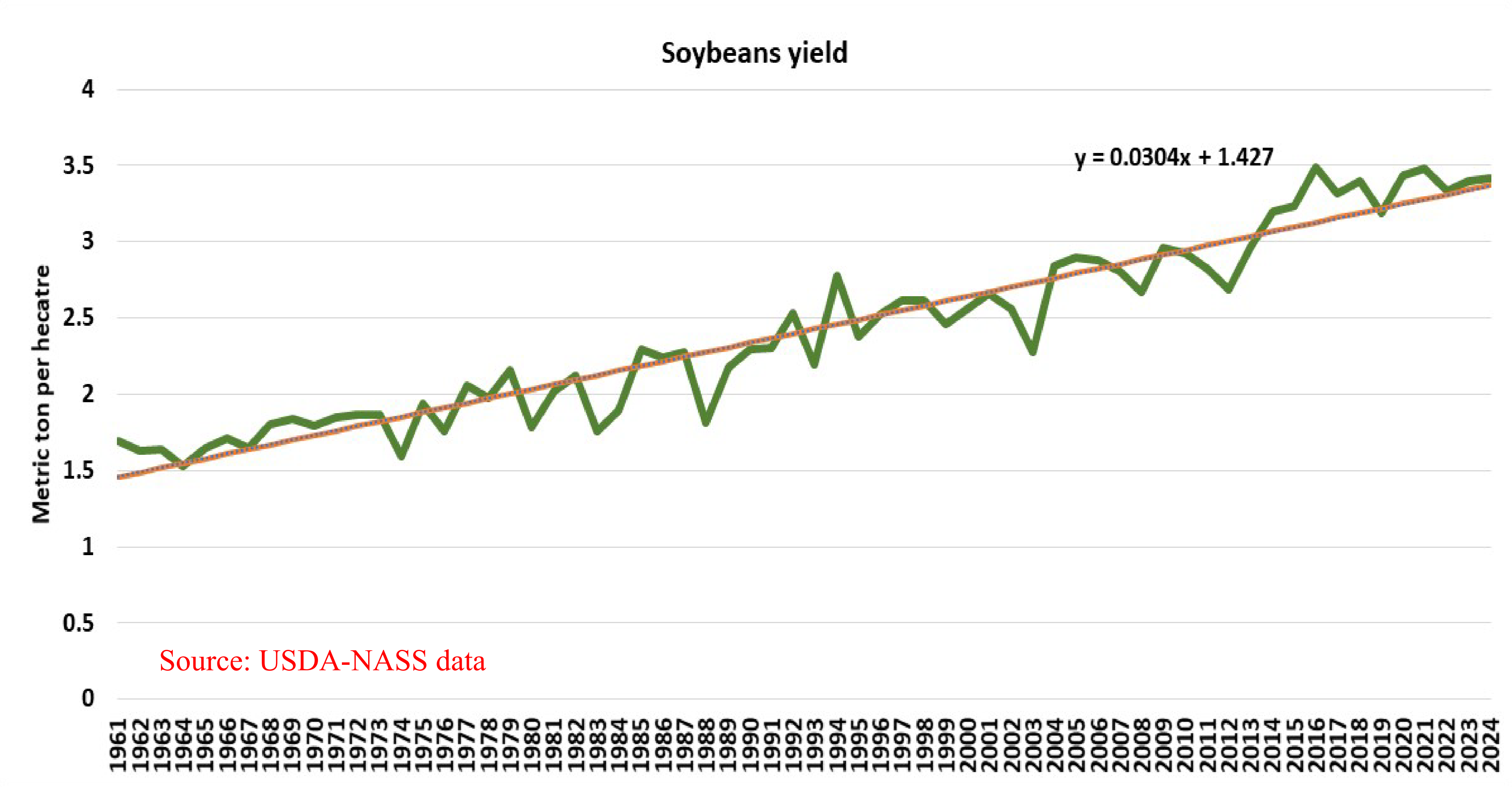
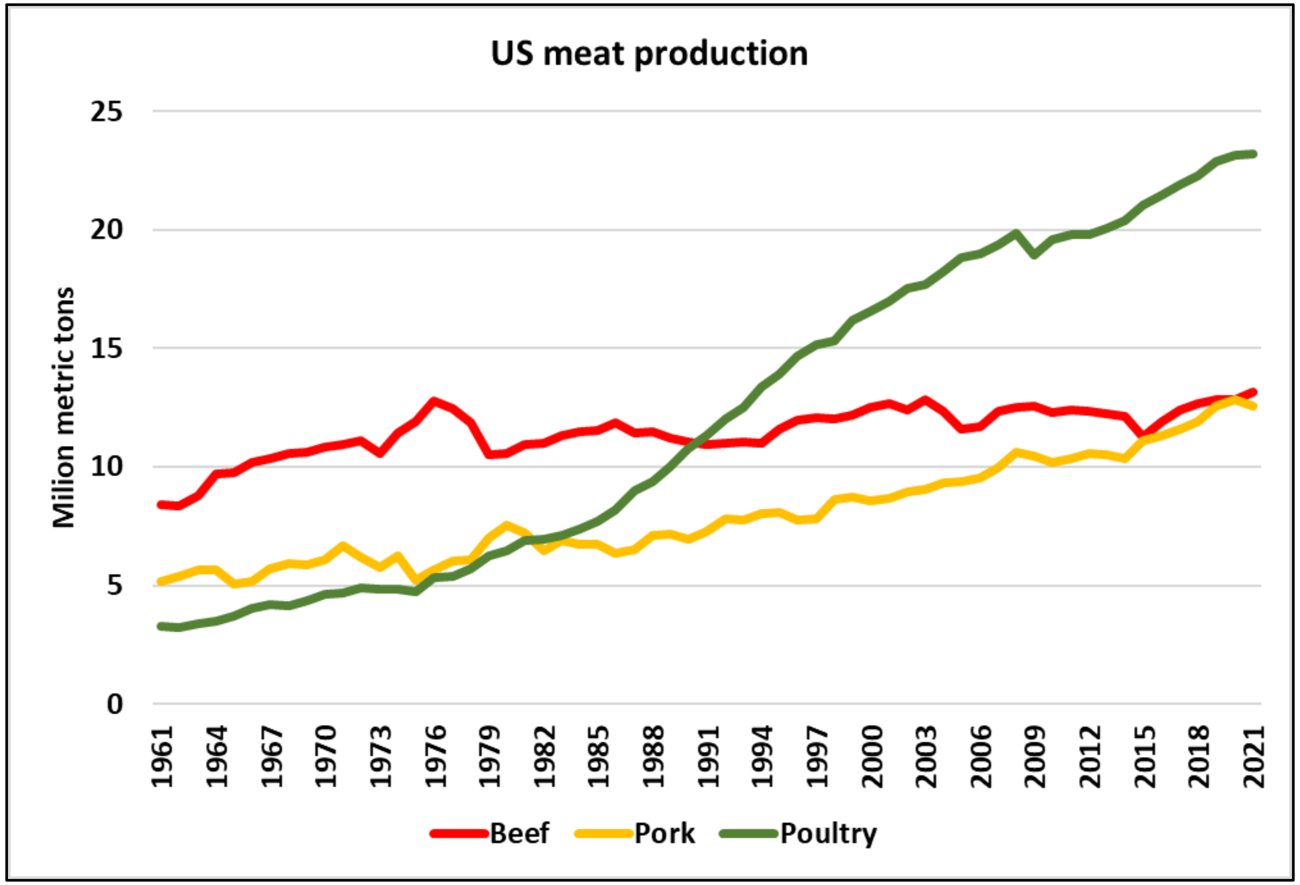
Review of some actual observations

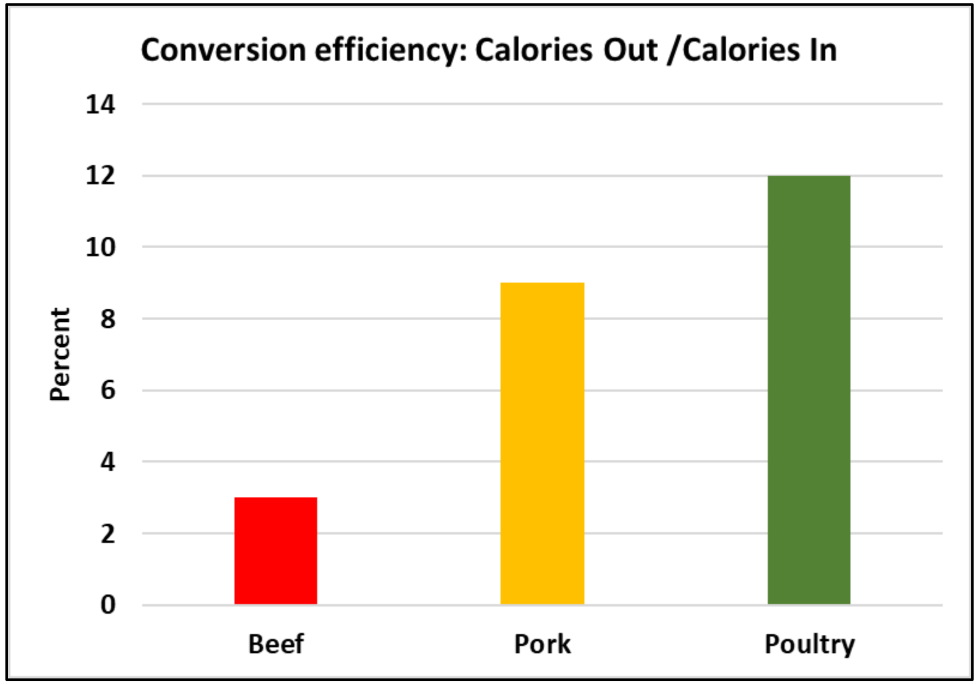
Historical data: US soybean yield over time



- Soybean yield has increased by 27.6% between 2000 and 2024
- This yield improvement has added 376 million metric tons to the supply of soybean in this period

Efficiency gains in meat production

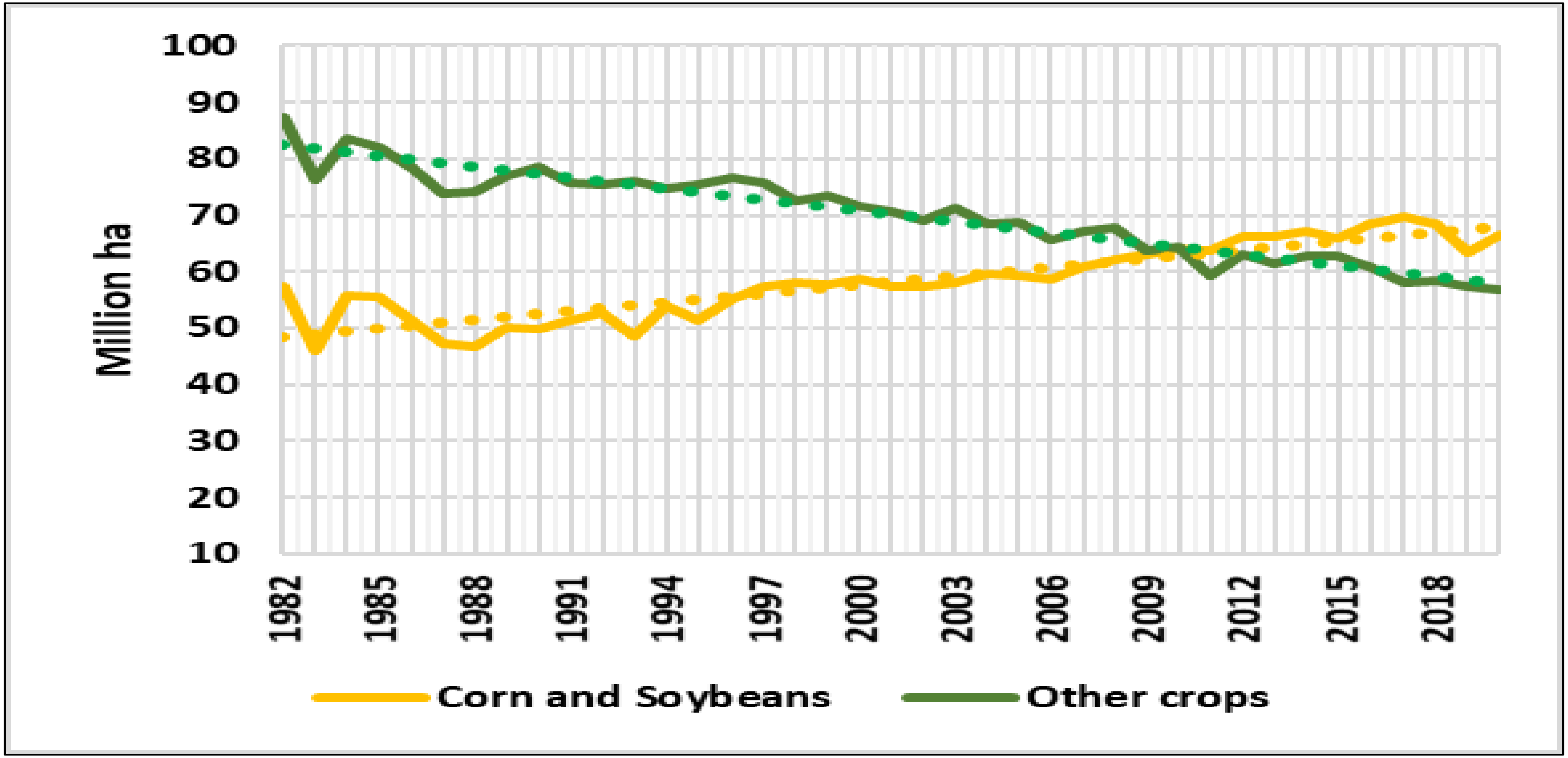




Source: Shepon et al., 2016)

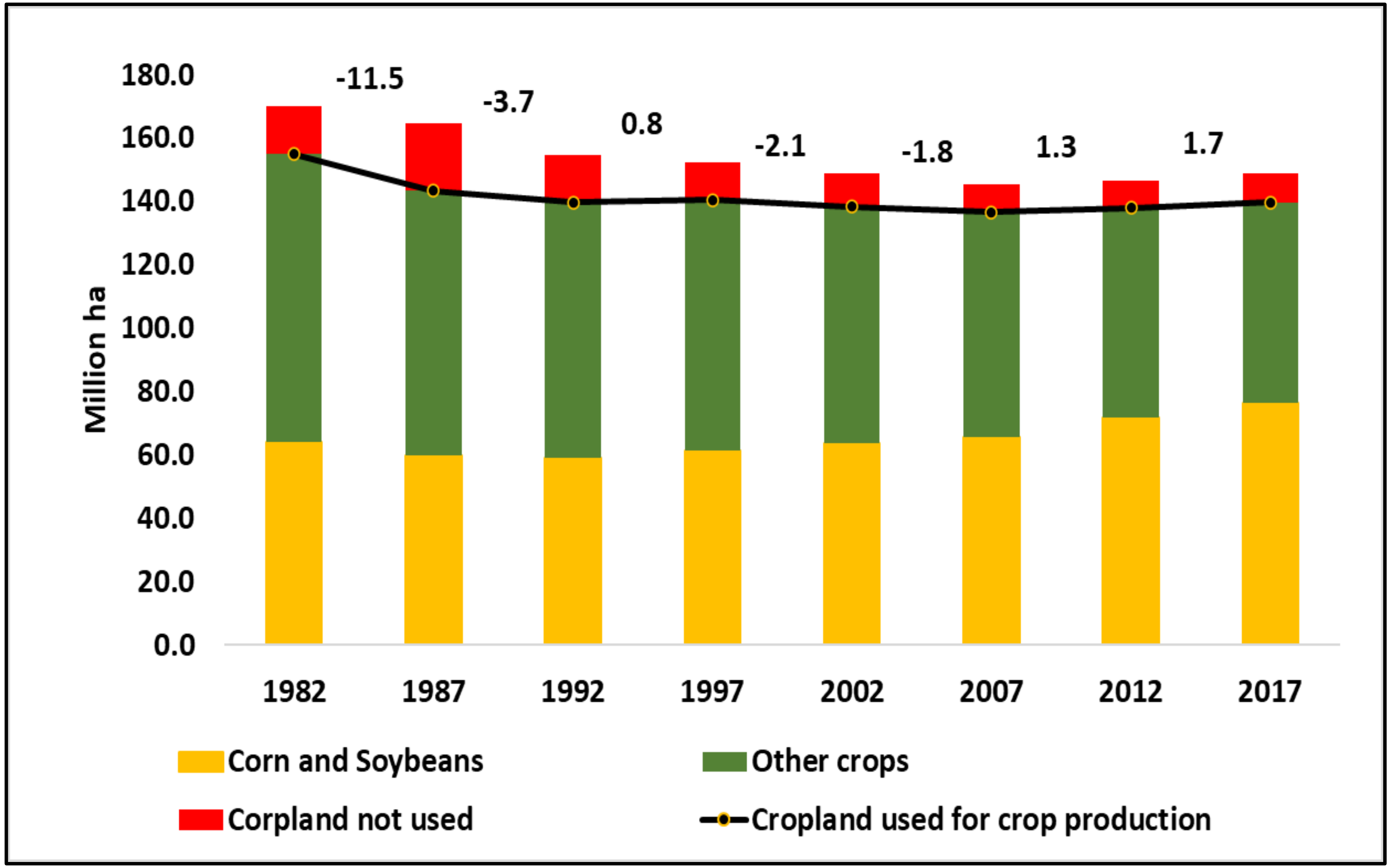
- Over time major efficiency gains achieved in livestock industry

Evolution in US harvested areas



Changes in US cropland over time

Historical data: US cropland area (NRI)



- NRI data show cropland used for crop production has changed by:
  - -1.8 Mha in 2002-07,
  - +1.3 Mha in 2007-12,
  - +1.7 Mha in 20012017.
- NRI data show no evidence of deforestation.
- NRI data show pasture land area has changed by:
  - + 0.4 Mha in 2002-07,
  - + 0.8 Mha in 2007-12,
  - - 0.6 Mha in 20012017.
- No major change in forest area has been observed over the past two decades
- But major increases have been observed in crops and livestock outputs due to yield and efficiency improvements over time.

Economic and environmental impacts of biofuel policies

- Since the surge in biofuel production in the late 2000s, various efforts have been made to study the economic and environmental impacts of biofuel production and policies
- These efforts have addressed various related topics including but not limited to:
  - 1) Techno-Economic Analysis (TEA) and feasibility studies of alternative biofuel pathways
  - 2) Supply chain and Life-Cycle Analysis (LCA) of alternative biofuel technologies
  - 3) Assessing the long-run and short-run effects of biofuel production and policy on welfare, agricultural activities, commodity markets, and energy markets at local, national, and global scales
  - 4) Evaluating Induced Land Use Changes (ILUC) due to biofuels and their corresponding greenhouse gas (GHG) emissions
  - Conventionally Carbon Intensity (CI) of biofuels are calculated using the following formula:

CI= LCA emissions + ILUC emissions

Attributional Consequential

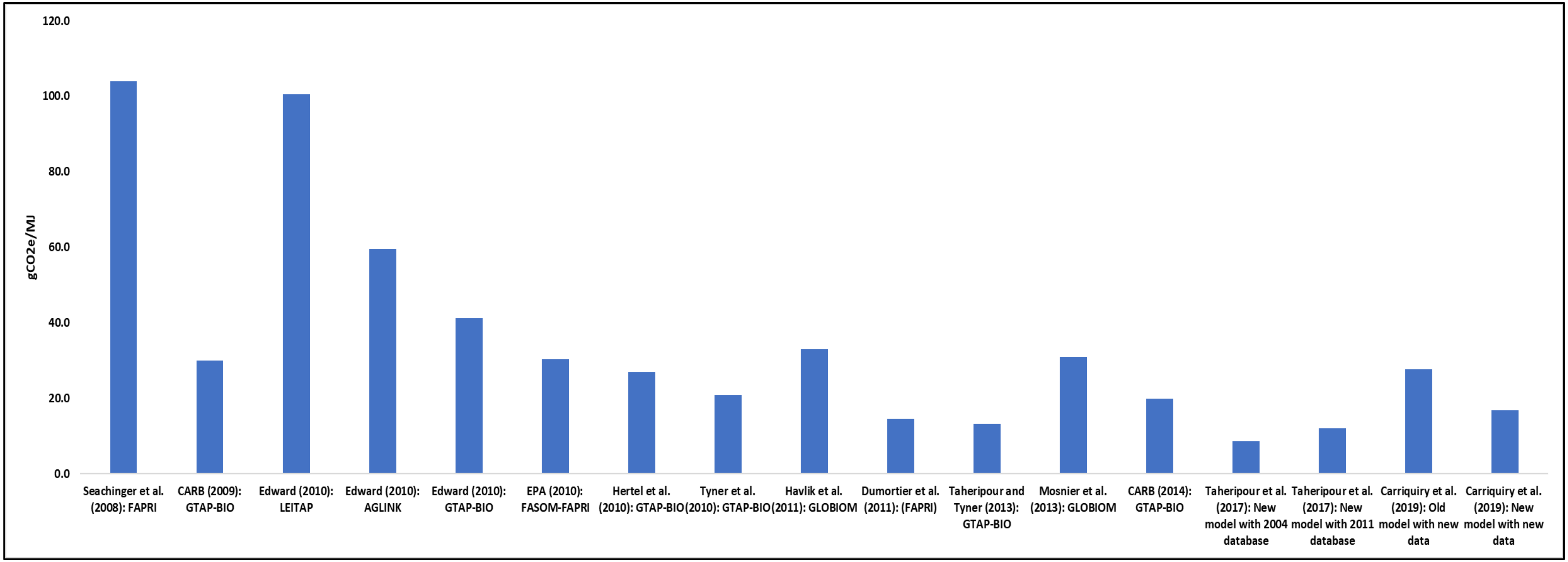
Biofuel policies and ILUC emissions

- Public policies are often used to affect market performance through fiscal and monetary policies, mandates, and/or standards.
- Regulatory mechanisms use these approaches to address market failures, enhance social objectives, and manage externalities (e.g., controlling GHG emissions)
- ILUC assessment aims at measuring unintended GHG emissions that biofuel policies (e.g., RFS or LCFs) may generate through land use changes
- The goal of ILUC assessment is not to measure performance of individual biofuel or feedstock producers
- Risk assessment approaches could not quantify unintended ILUC emissions due to biofuel policies

Measuring ILUC emissions

- Like many other unintended consequences of public policies, ILUC emissions are not directly measurable
- Typically, ILUC emissions are calculated using economic models in combination with biophysical and land use emissions factors
- Estimated ILUC emissions vary largely by modeling approach, implemented biophysical data and emission factors, type of feedstock, location of feedstock and fuel production, and conversion technologies
- The existing literature has widely noted a wide range of variation in ILUC estimates
- It is well-documented by the NASEM (2022) report that not all of this range is due to uncertainties

Uncertainties/variations in ILUC emissions: Case of US corn ethanol



Amortization period: 30 Years

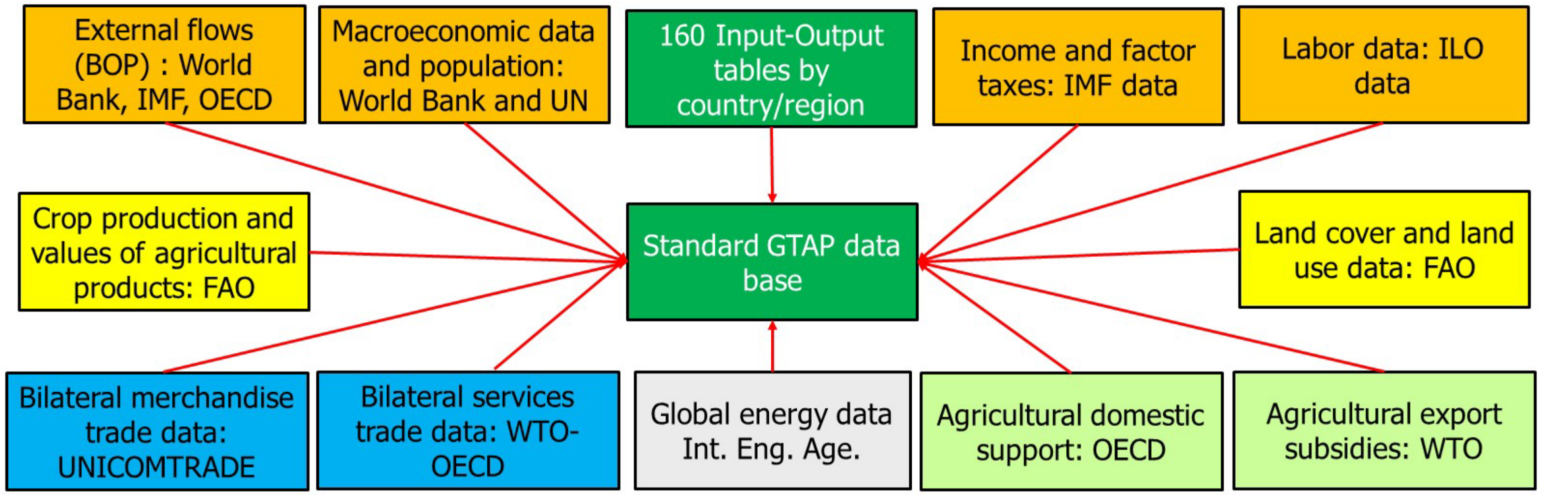
Variation and uncertainty in ILUC assessments

- Over the past two decades various efforts have been made to determine sources and drivers of variations in ILUC assessments:
  - Various sensitivity analyses
  - Some modeling comparison exercises
  - Limited validation practices
- These efforts have made significant contributions in understanding the sources and drivers of variations in ILUC assessments, see NASEM (2022) report for details
- However, no major effort has been made to develop and define required criteria, standards, and guidelines for ILUC assessment
- Regulatory entities could lead these types of efforts to eliminate the effects of ad hoc and improper factors from uncertainties in ILUC assessment efforts

GTAP center and GTAP model

- The GTAP center is the hub of a global network of more than 32 thousand researchers, scholars, academic institutions, and policy research entities that are conducting quantitative analysis of a wide range of policy issues related to trade, energy, agriculture, and climate change
- The standard GTAP is a global, comparative static, multi-commodity, and multi-regional Computable General Equilibrium model that traces production, consumption, and trade of all good and service produced across the world
- The latest published standard GTAP data base represents the 2017 global economy
- A 2023 data base will be released in the first quarter of next year
- This data base assembles and represents a wide range of data items

Main components of a GTAP data base



Economic sectors in the most recent version of GTAP data base

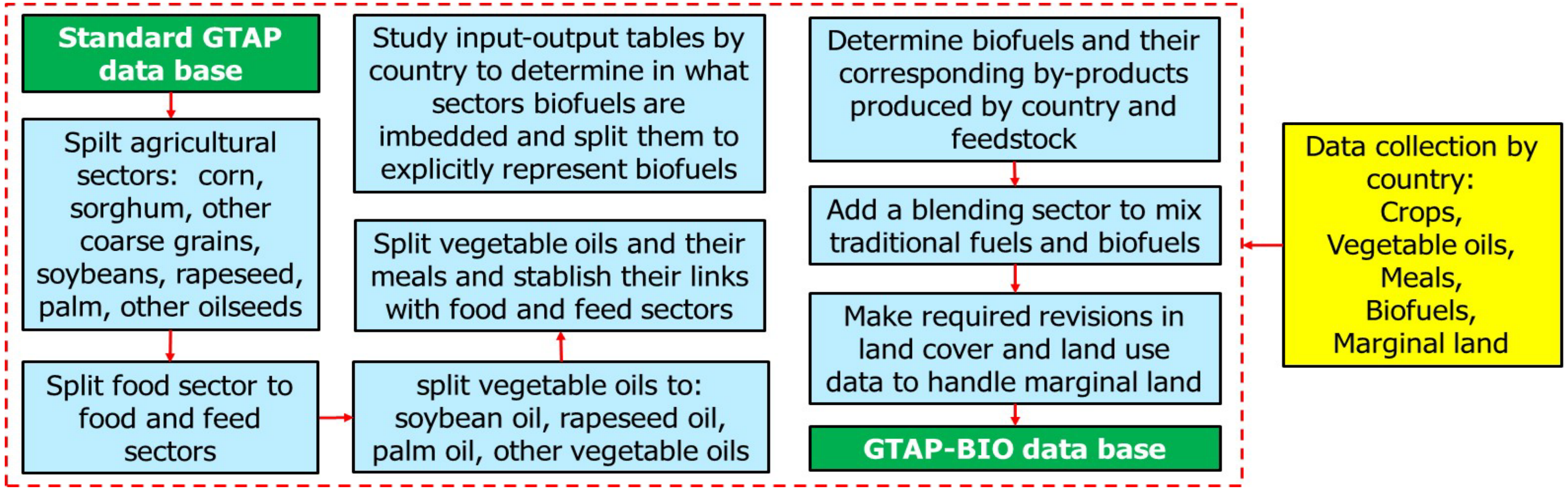
Paddy rice	Coal	Wood products	Electrical eqpt.	Communication
Wheat	Oil	Pulp, paper etc.	Other mach. & eqpt.	Financial services
Other cereals	Gas	Refined oil etc.	Other manu.	Insurance
Vegetables & fruits	Other minerals	Pharmaceuticals	Electricity	Real estate
Oil seeds	Red meat	Other chemicals	Gas distribution	Other bus. services
Sugar cane & beet	White meat	Rubber & plastics	Water	Recreation etc.
Plant-based fibers	Vegetable oils	Other mineral prod.	Construction	Public Admin.
Other crops	Dairy products	Ferrous metals	W & R trade	Education
Beef etc.	Processed rice	Other metals	Hotels, rests. etc.	Health
Poultry, pork, etc.	Refined sugar	Metal products	Warehousing etc.	Dwellings
Raw milk	Other food	Mot. vehicles & parts	Land transport	
Wool etc.	Beverages & tobacco	Other trp. eqpt.	Sea transport	
Forestry	Textiles	Electronic eqpt.	Air transport	
Fishing	Clothing			
	Leather products			

- The standard GTAP data bases do not explicitly represent biofuels, their corresponding economic activities, and other essential variables that are needed to assess biofuel production and policy

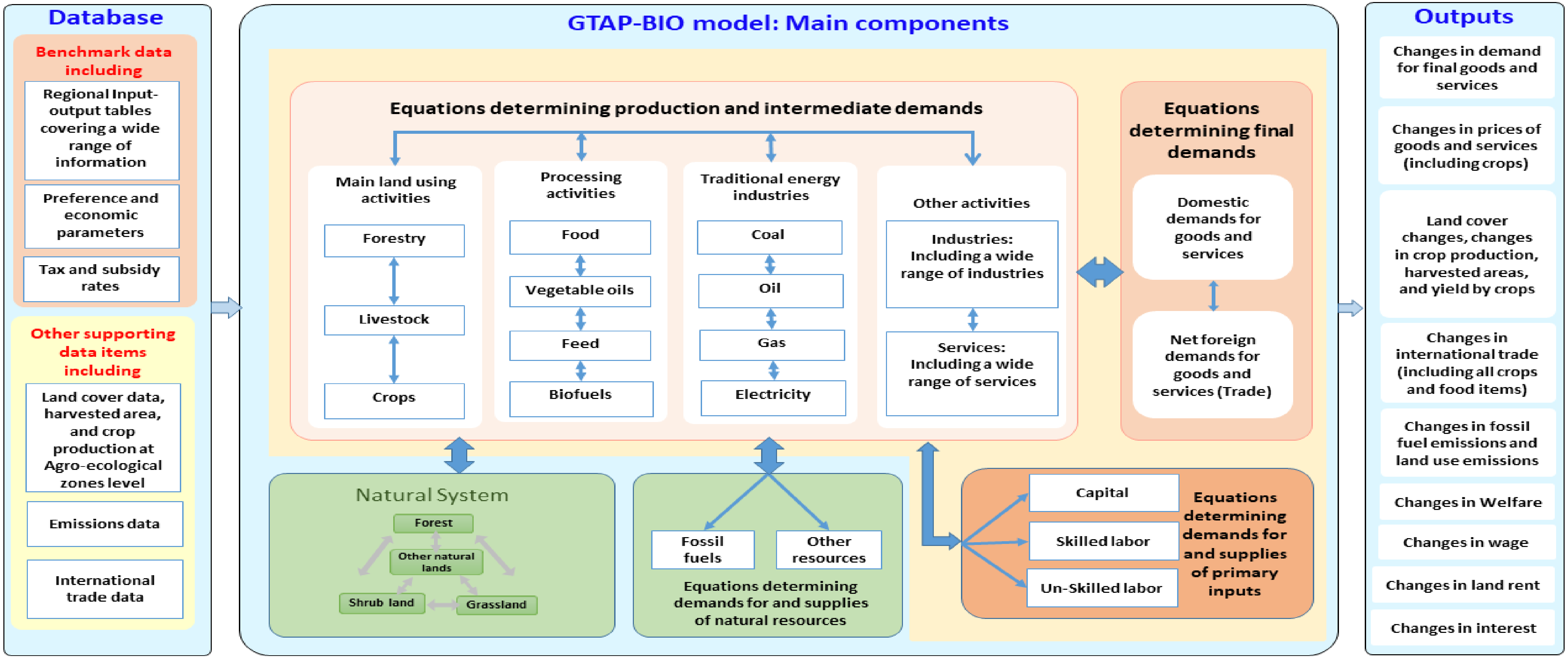
GTAP-BIO model and its uses

- Over time, a method has been developed and used to create the GTAP-BIO data bases to be able to assess the economic and environmental effects of biofuel production and policy
- The GTAP-BIO model and its data bases cover different types of biofuel including:
  - Conventional biofuels such as ethanol, biodiesel, and renewable diesel that are produced commercially
  - More advanced biofuels such as suitable aviation fuels (SAFs) that could can be produced in future using different types of feedstock using alternative production technologies
- The GTAP-BIO model has been used in:
  - Many policy analyses
  - ILUC assessment for CARB
  - ILUC assessment for CORSIA
  - ILUC assessment for 40B and 45Z

Construction process of a GTAP-BIO data base



A schematic representation of GTAP-BIO model



Main changes in GTAP-BIO model and it data bases over time

- GTAP-BIO data bases represent:
  - the global economy in 2001, used in early publications
  - the global economy in 2004, used in CARB analyses
  - the global economy in 2011 with SAF pathways, used in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) analyses
  - the global economy in 2014, used in 40B analyses
  - the global economy in 2017, used in 45Z analyses and is expected to be used for CORSIA analysis
  - the global economy in 2023, will be developed in 2026

- GTAP-BIO models: Some major changes
  - Early versions tracing biofuels and limited links between biofuels and other activities
  - Improved versions for CARB analysis:
    - ✓ Modeling links between biofuels and other sectors including crops, livestock, and energy sectors
    - ✓ Advancement in land cover and land use modeling
    - ✓ Modeling endogenous yield responses
    - ✓ Tuning model parameters to historical observations
    - ✓ Allowing conversion of marginal land (cropland pasture) to active cropland
  - Improved versions for CORSIA, 40B and 45Z
    - ✓ Modeling changes in harvest frequency
    - ✓ Handling SAF pathways
    - ✓ Other improvements in model parameters

Potential future advancements in GTAP-BIO model

- A new land cover and land use data base for GTAP-BIO is under development based on latest available satellite data sources
- GTAP-BIO has a dynamic version. This model has been used in some limited applications. This model will be improved and used in policy analyses
- GTAP-BIO operates based on accessible land. A new version of this model which considers conversion of unmanaged to managed land with costs of land conversion is under development
- There are several options to handle changes in physical areas of land in CGE models (Taheripour et al. 2021). GTAP-BIO could operates using any of these options
- GTAP-BIO currently operates at the Agro-Ecological Zones (AEZs) resolution. A new version of this model is under development to operate at a finer resolution (grid cell)

This paper has been published in response to Malins et al. (2020)

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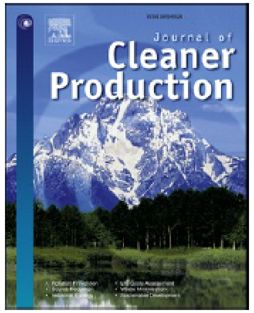

Letter to the editor

Response to “how robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?”

Check for updates

Taheripour F., Mueller S., Kwon H. (2021). “Response to “how robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?”,” *Journal of Cleaner Production*, *310*(127431), 10.

Thanks for your attention

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