Subnational Modeling of U.S. Agriculture and Biofuels

Ron Sands
USDA Economic Research Service
Washington, D.C., USA

The 30th Asia-Pacific Integrated Modeling (AIM) International Workshop
National Institute for Environmental Studies, Tsukuba, Japan

28-29 August 2024

Overview

- Objectives
  - Outline a modeling framework that links global change at the world level with subnational activities in the United States.
    - Population
    - Income growth
    - Agricultural productivity growth
    - Dietary preference
    - Climate change impacts on agriculture
    - Bioenergy and climate change mitigation
  - Describe data and conceptual challenges with a nested computable general equilibrium (CGE) model.
  - Report on progress in this modeling effort.

- GTAP data base
  - Global Trade Analysis Project (GTAP) at Purdue University
  - Up to 160 world regions
  - Up to 50 U.S. States
- GTAP-WiNDC canonical model
  - Wisconsin National Data Consortium (WiNDC) at the University of Wisconsin
  - Up to 160 world regions
  - Up to 50 U.S. States
  - Public distribution on github
  - Policy analysis usually requires model extensions.

USDA
Economic Research Service
www.ers.usda.gov

Future Agricultural Resources Model (FARM 4)

- FARM version 4
- Capabilities
  - Global CGE
    - 13 world regions
    - 38 production sectors
    - 5-year time steps from 2011 through 2100
- Activities
  - AgMIP global food demand study
  - Stanford Energy Modeling Forum (bioenergy studies)
  - USDA Economic Research Service report *Scenarios of Global Food Consumption* (September 2023)

USDA Economic Research Service
U.S. DEPARTMENT OF AGRICULTURE

Economic Research Service
Economic Research Report Number 323
September 2023

Scenarios of Global Food Consumption: Implications for Agriculture

Ronald D. Sands, Birgit Meade, James L. Seale, Jr., Sherman Robinson, and Riley Seeger
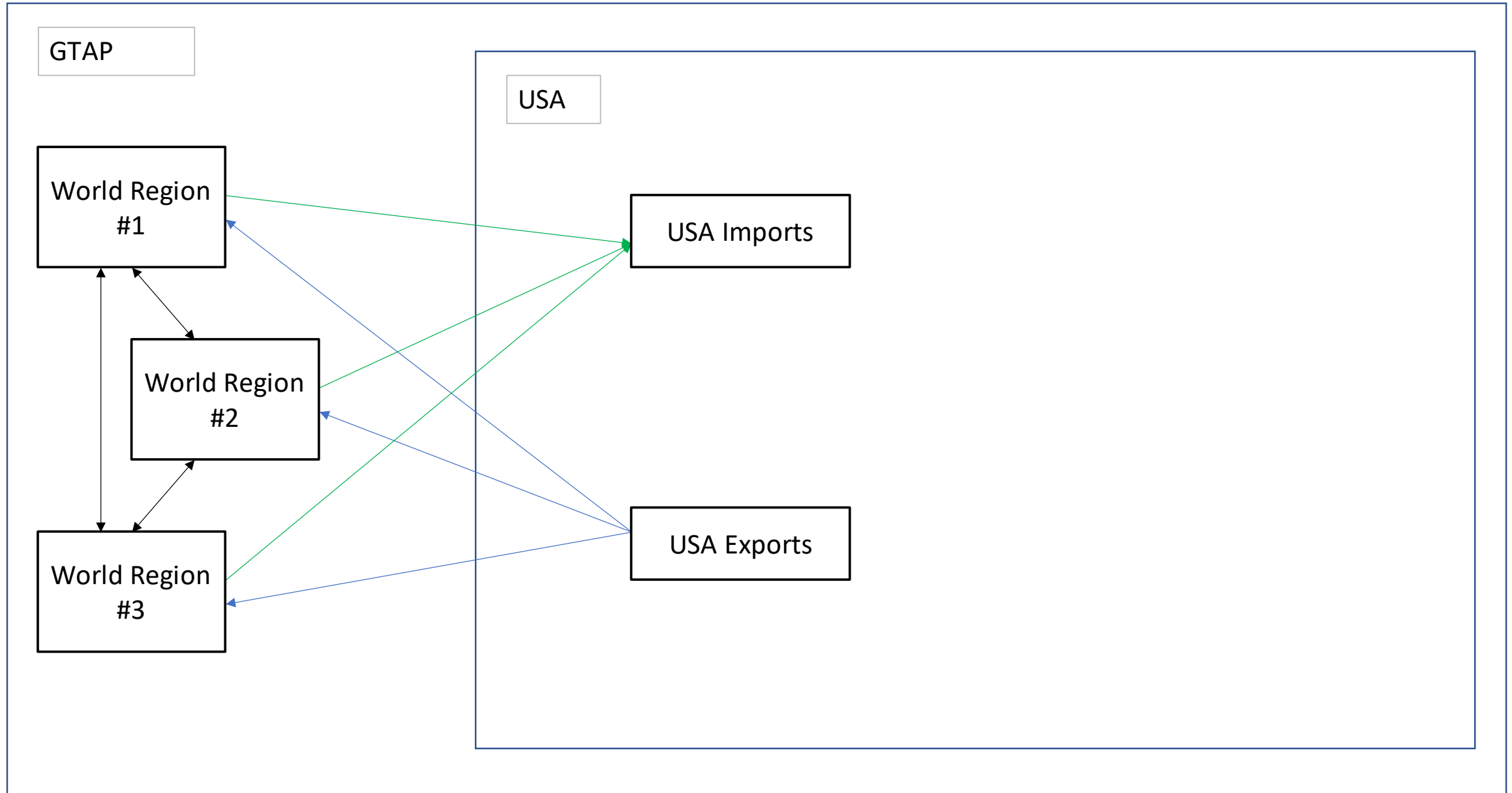
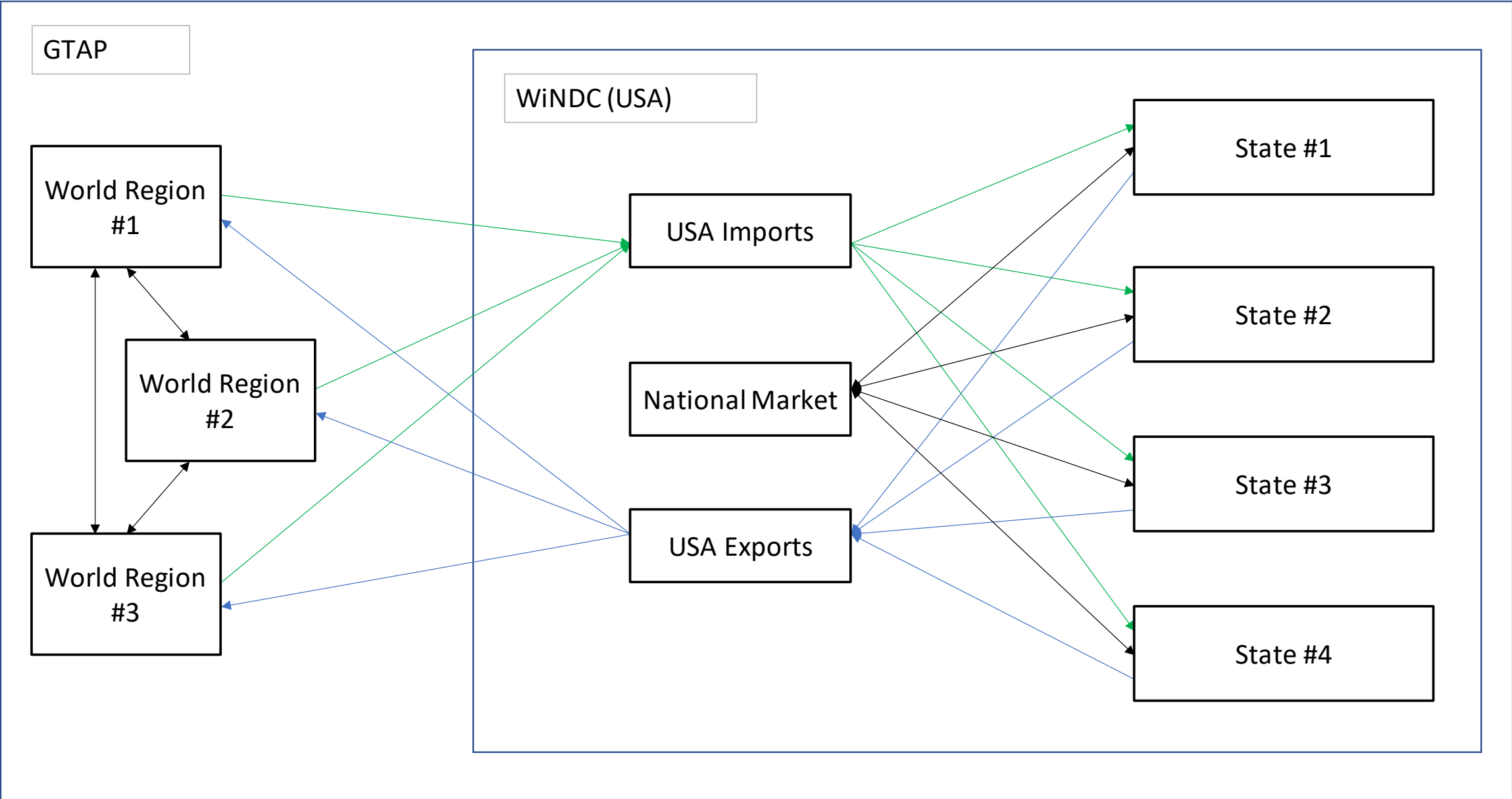# Future Agricultural Resources Model (FARM 5)

- FARM 5 in process
- Applications where subnational breakout is helpful
  - Energy crops and competition for agricultural land
  - Climate change impacts on agriculture
- Nested U.S. state-level model within global CGE model

- Within each U.S. state
  - Each state has a production function for each crop to represent spatial variation in land productivity
  - Land competition within each state
- GTAP-WiNDC canonical model helps manage complexity.
- Food balance sheets allow conversion from economic units (real dollars) to physical units (calories).

FARM 4 model with international trade

FARM 5 model with links to U.S. states

Future Agricultural Resources Model (FARM)

Global computable general equilibrium model with 13 world regions, 38 production sectors (FARM 4), and five-year time steps through 2100. FARM 5 adds three production sectors: rubber and plastic products, water, hotels and restaurants, for a total of 41 sectors.

Region name	Notes
Sub-Saharan Africa	
India	
Other Asia (south)	
Brazil	
Other South America	Including Central America, Caribbean, and Mexico
Middle East and North Africa	Including Turkey
Economies in Transition	Russia, Belarus, Ukraine, Kazakhstan, Kyrgyzstan, Armenia, Azerbaijan, Georgia, Tajikistan, Turkmenistan, and Uzbekistan
China	
Southeast and East Asia	Including Japan
United States	
Canada	
Europe	Including Estonia, Latvia, and Lithuania
Australia and New Zealand	Including Oceania

Group	Subgroup	Production Sector
Primary agriculture	Crops	Wheat
		Paddy rice
		Other grains
		Oilseeds
		Sugar (cane and beet)
		Vegetables and fruits
		Plant fibers
		Other crops
	Animal products	Cattle and other ruminants
		Raw milk
		Wool
		Other animal products
	Fisheries	Fish
	Forestry	Forestry
Food processing		Vegetable oils
		Processed rice
		Sugar
		Beverages and tobacco products
		Other food
		Meat from cattle and other ruminants
		Dairy products
		Other meat products
Energy	Production	Coal
		Crude oil
		Natural gas
	Transformation	Refined coal and petroleum products
		Electricity
Energy-intensive industries		Wood products
		Paper and pulp
		Chemicals, rubber, and plastic
		Nonmetallic minerals
		Iron and steel
		Nonferrous metals
Other industry		Other industry
Transportation		Land transportation
		Water transportation
		Air transportation
Services		Services

|	GTAP 11 data base	WiNDC data base	GTAP-WiNDC	FARM 5 (in development)
Geographical coverage	160 world regions	50 U.S. states	10 world regions 50 U.S. states	4 world regions 9 U.S. Forest Service regions
Benchmark year	2017	2017	2017	2017
Household types	1	5	5	1
Production sectors	65	43	43	41
Agricultural sectors	Rice Wheat Coarse grains Oil crops Vegetables, fruits, tree nuts Sugar crops Plant-based fibers (cotton) Other crops (hay) Ruminant meat (beef, lamb) Other animal products (pork, poultry, eggs) Milk production + 8 Food processing sectors	Rice Wheat Coarse grains Oil crops Vegetables, fruits, tree nuts Sugar crops Plant-based fibers (cotton) Other crops (hay) Ruminant meat (beef, lamb) Other animal products (pork, poultry, eggs) Milk production	Same as WiNDC	Same as GTAP 11

Testing Canonical GTAP-WiNDC Model

- Nine U.S. Forest Service regions
  - Will be useful for modeling forest production and carbon stocks
  - North Central region is a good match for U.S. corn belt

- Counterfactual: varying rates of productivity growth
  - 20 percent productivity increase in North Central U.S. (corn belt) for coarse grains
  - 10 percent productivity increase in U.S. Great Plains for coarse grains
  - No change in productivity in other U.S. regions or in other countries

Percent change in course grain output
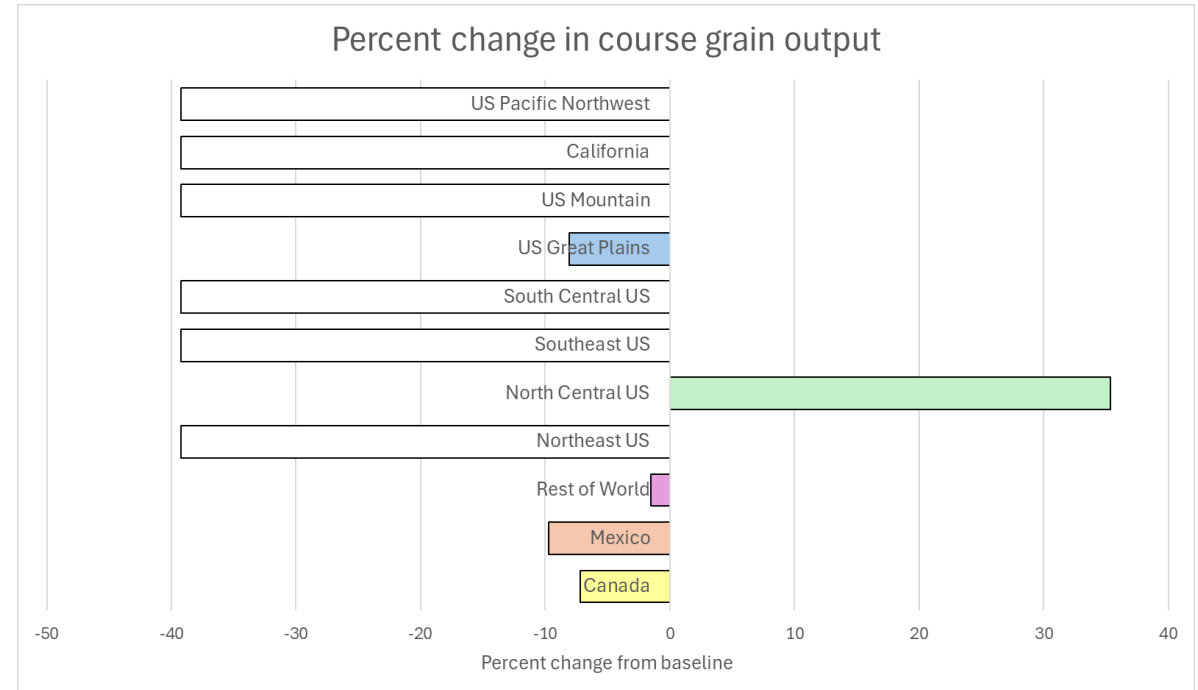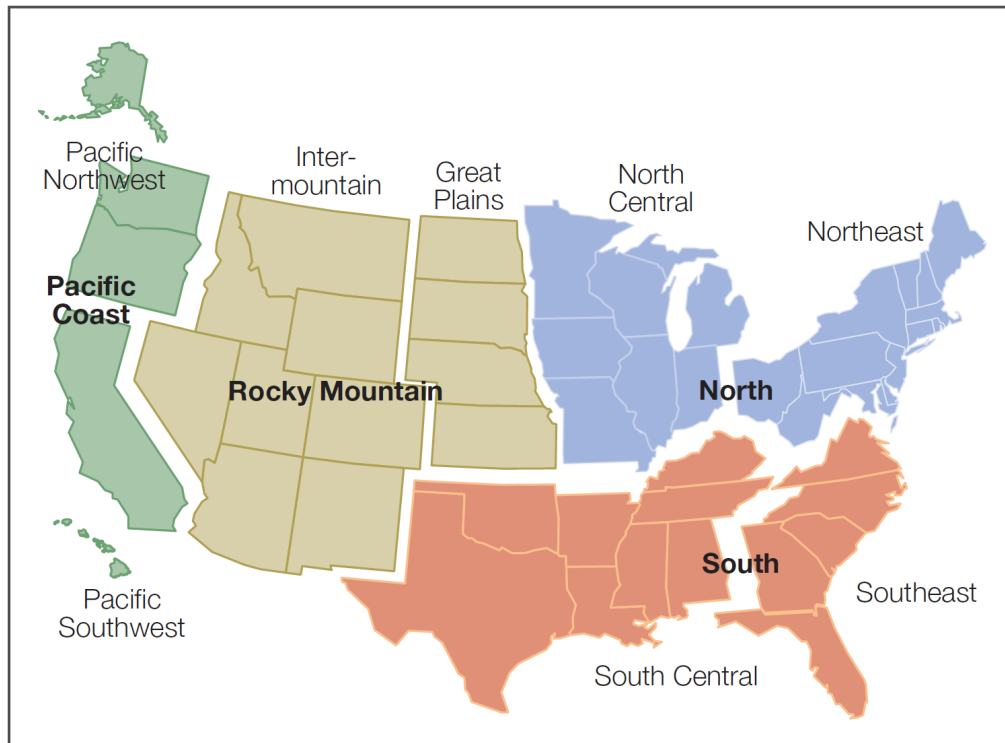
Biofuels and U.S. crops

- Historical consumption data
  - Corn-ethanol and biodiesel have been steady
  - Renewable diesel growing rapidly
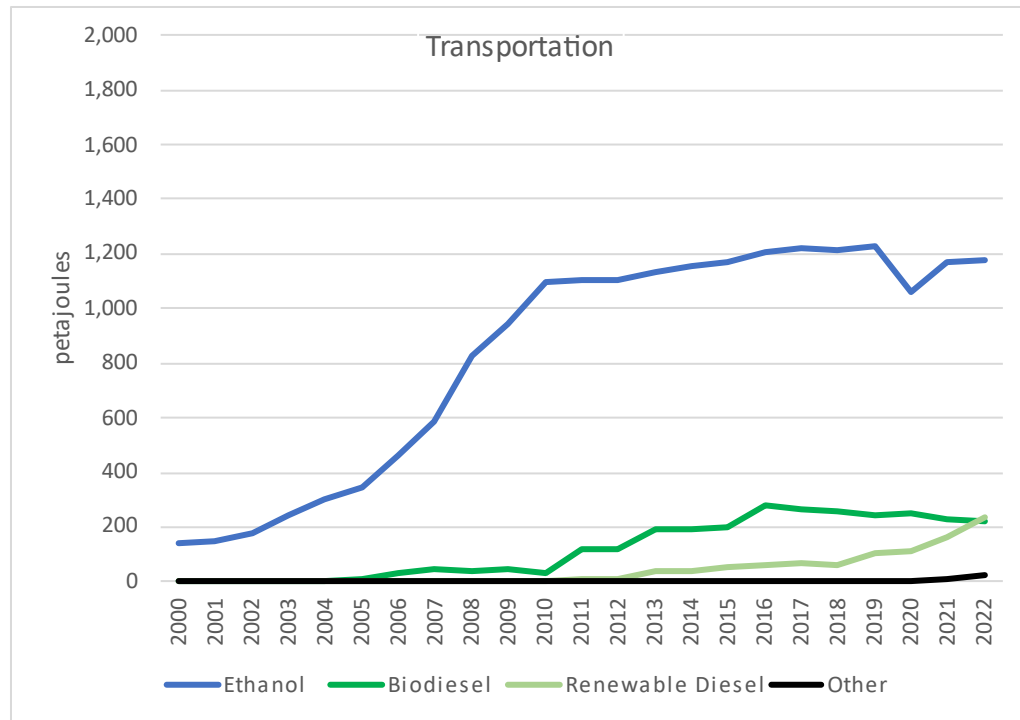

- Interest within USDA on potential of winter oil crops as a feedstock for biodiesel, renewable diesel, and sustainable aviation fuels
- Derived from similar feedstocks (vegetable oils and animal fats) but are different products
  - Biodiesel Produced through a chemical reaction called transesterification and is typically blended with petroleum-based diesel fuel in concentrations of 2 to 20 percent biodiesel (B2 to B20)
  - Renewable diesel (hydrotreated vegetable oil) contains only hydrogen and carbon. Can be used in diesel engines without modification (R100)
  - Sustainable aviation fuel Hydro-processed Esters and Fatty Acids (HEFA) fuel can be used as a substitute for fossil jet fuel
- Most renewable diesel is consumed in California
- Land use implications of U.S. biofuel expansion
  - Carbon dioxide emissions from global land use change
  - Agricultural productivity growth in U.S. and globally

2022 U.S. Biofuel Consumption by State
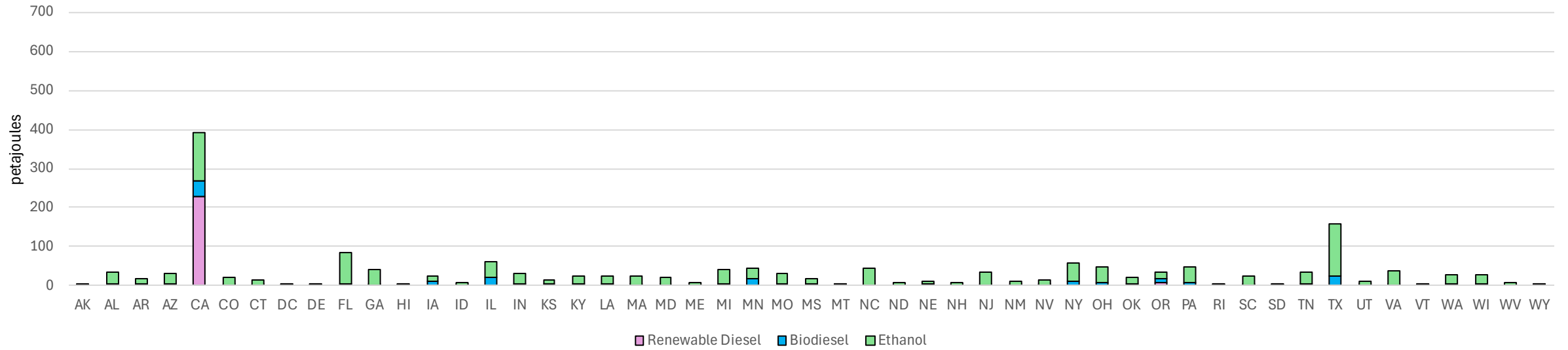
2022 U.S. Biofuel Production by State
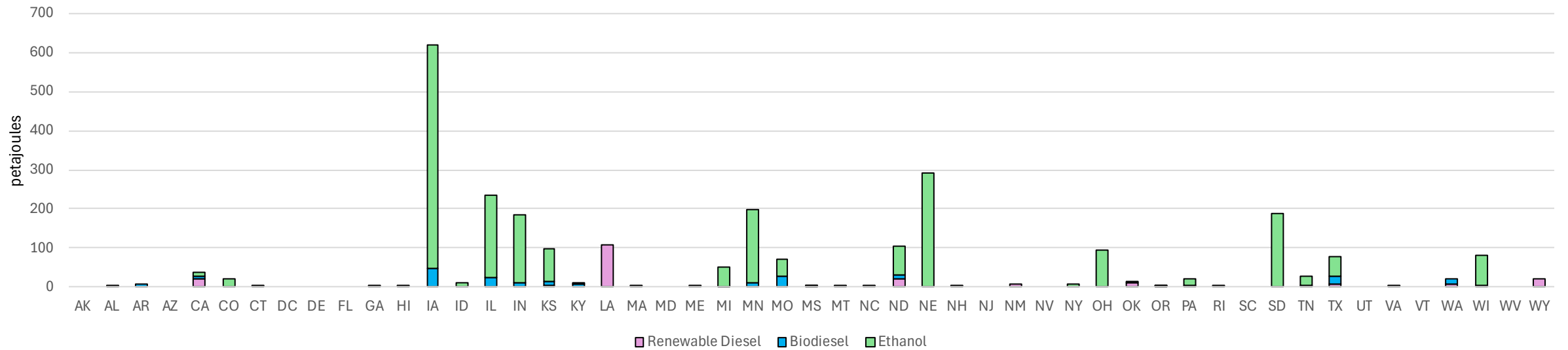
Discussion

- Status of FARM 5
  - Canonical GTAP-WiNDC model runs with 4 world regions and nine U.S. subregions
    - Subnational CGE model for USA nested within a global GTAP model
    - Full simultaneity in GTAP-WiNDC model solution
    - Units are 2017 $US
  - Extensions needed for agriculture and biofuels (in process)
    - Introduce food balances from the Food and Agriculture Organization of the United Nations (food production and consumption in calories)
    - Introduce bioenergy data from U.S. Energy Information Administration

- Requirements
  - GAMS license
  - Large models require GTAP subscription
  - GAMS code for GTAP-WiNDC canonical model https://windc.wisc.edu
- Next Steps (Move other FARM 4 capabilities to FARM 5)
  - Consumer food demand system
  - Match monetary and quantity flows for analysis of climate change adaptation, mitigation, and food security
    - Cubic meters of forestry products
    - Hectares of land in crops, rangeland, forests
    - Joules of energy produced and consumed