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Title: Scenarios of Global Diets and the Impact on Land Resources

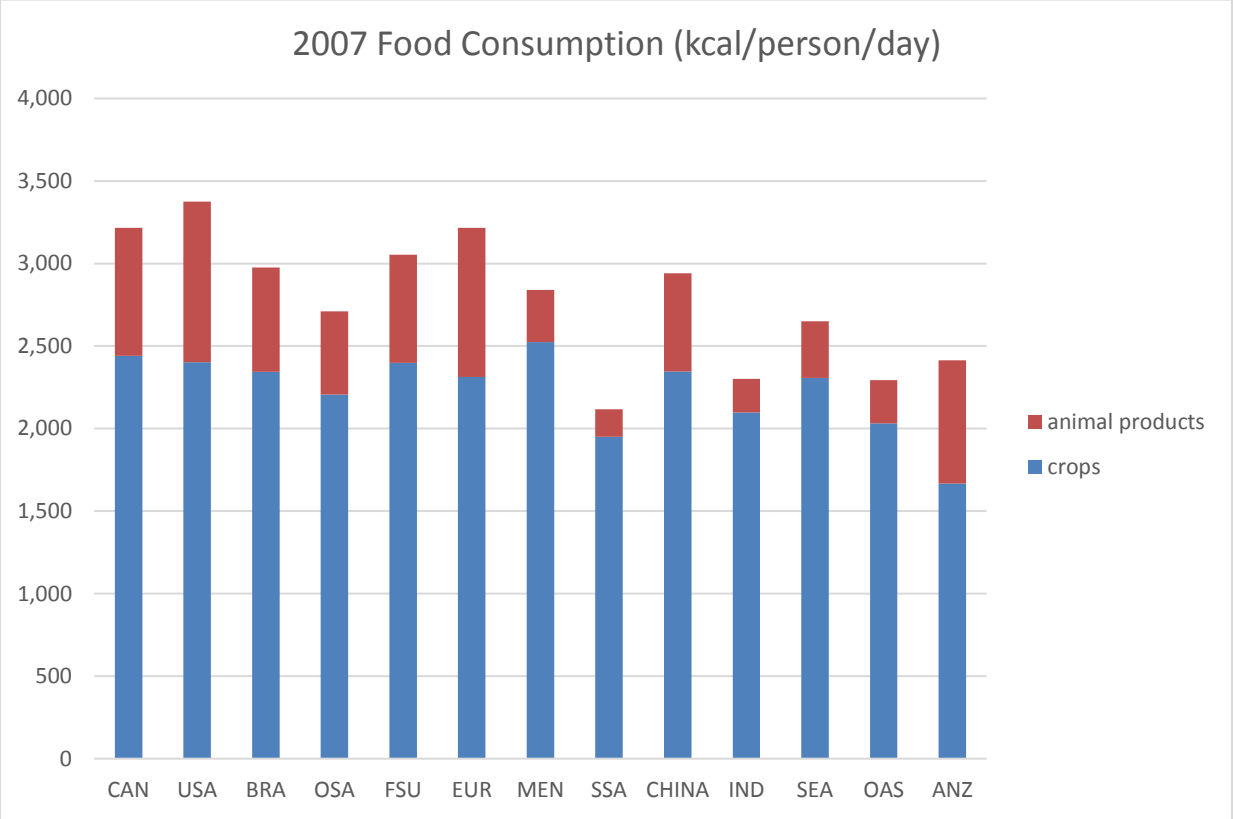
Understanding the capacity of agricultural systems to feed a growing world population with rising incomes requires projecting future food demand. The point of departure for this paper is a multi-model study of world food demand through 2050 (Valin et al., 2014), organized by the Agricultural Model Intercomparison and Improvement Project (AgMIP). Here, rising populations, rising incomes, and increased demand for animal products over time were important drivers of world food demand.

We use a global computable-general-equilibrium (CGE) model based on GTAP social accounts to simulate alternative food consumption scenarios from the present through 2050. Scenarios of future population and income are taken from the Shared Socio-economic Pathways (SSPs; O'Neill et al., 2014). There are five global SSPs with variation across income and population growth by world region. Further, the SSPs provide narrative on other aspects of development such as technological change, environmental protection, and changes in diets. This provides the scenario framework for our study.

Modeling consumer demand for food, and the impact on land, presents two theoretical challenges. First, consumer demand systems typically used in CGE models are not well suited to order-of-magnitude changes in per-capita incomes. Our approach is to break consumer demand into two stages: the first allocates consumer expenditure to large categories of demand such as clothing, transportation, and food. The second stage allocates expenditure on food to specific food categories. The second challenge is to track final consumption of food calories back through food production and livestock to calories provided by field crops. This requires revision of the input-output relationships in the social accounts to track quantities of calories. This is analogous to methods developed for tracking energy consumption, in joules, from primary production, through energy transformation, to final energy consumption.

Results show that land use change from alternative diets is comparable in scale to other drivers such as agricultural productivity. Shifts in diets away from animal products, and continuing improvements in agricultural productivity, are considered land-sparing activities. However, aggressive policies to reduce carbon dioxide emissions may create very large future demands for biomass.

Base-year (2007) per-capita consumption of calories



Tracking calories in a CGE model

Several methodological challenges need to be overcome to track calories over time in agricultural scenarios:

1. The consumer demand system must be modified so that per-capita calorie consumption remains in a plausible range. If food consumption scales with income, our model will over-feed consumers in developing countries with rising incomes.

2. Tracking calories in a way consistent with Food Balance Sheets from the United Nations Food and Agriculture Organization (FAO).

3. Parameterize alternative diets by allowing demand system parameters to change over time.

Our solution to the first challenge is to construct a nested consumer demand system. The top next is the Linear Expenditure System, which allows calculation of demand for broad consumption categories such as transportation, household energy services and food. The second stage of the nest uses the CES functional form to split food demand into food types.

To track calories, we use the full detail of FAO food balances, aggregated to 13 world regions. This is done at the reporting stage of the model, where FAO food items are matched to GTAP food categories.

Modelers have developed strategies for tracking energy consumption over time in a CGE model, based on energy balances from the International Energy Administration (IEA), mostly for assessment of alternative climate policies in CGE models.

Other applications of CGE models examine the impact of changing agricultural productivity, whether due to technical change or climate, on land use and food prices.

Analytical Framework

The Future Agricultural Resources Model (FARM) is a global computable general equilibrium (CGE) economic model with 13 world regions that operates in 5-year steps from 2007 to 2052. Land use can shift among crops, pasture, and forests in response to population growth, changes in agricultural productivity, and policies such as a renewable portfolio standard or greenhouse gas cap-and-trade. See Hertel et al. (2009a) for a comprehensive overview of modeling land use in CGE models.

The first version of FARM was constructed in the early 1990s by Roy Darwin and others at ERS (Darwin et al., 1995). By partitioning land into land classes, this model provided a unique capability among CGE models to simulate land use on a global scale. Early versions of the FARM model were used to simulate the impact of a changed climate on global land use, agricultural production, and international trade.

Data requirements include a base-year social accounting matrix from the Global Trade Analysis Project (GTAP) at Purdue University, energy balances from the International Energy Agency (IEA), land use from the Food and Agriculture Organization of the United Nations (FAO), and agricultural production from FAO.

Scenarios

We construct three scenarios for each modeling experiment, all based on SSP2, the “middle of the road” scenario. The first scenario, SSP2_CON1, uses food consumption from SSP1 but is otherwise the same as SSP2. Similarly, SSP2_CON3 uses food consumption from SSP3 but is otherwise the same as SSP2.

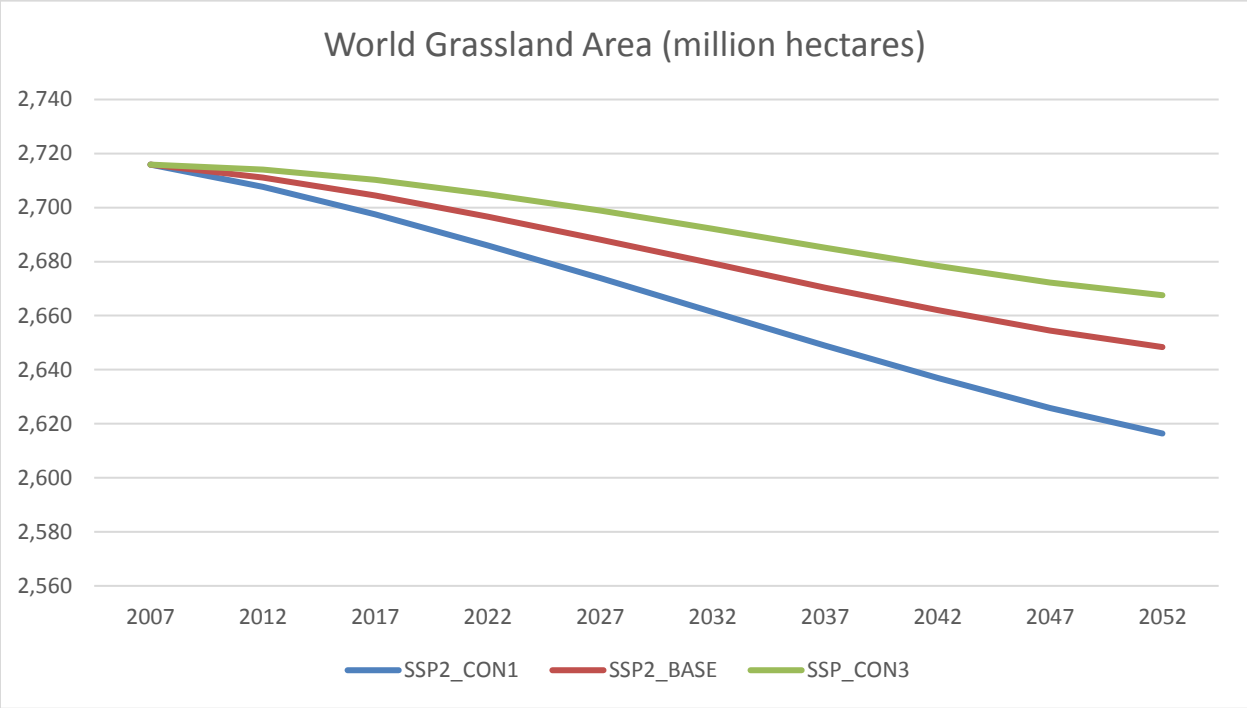
Experiment 1

SSP2_CON1: reduced consumption of animal products relative to SSP2_BASE

SSP2_BASE: reference scenario

SSP2_CON3: increased consumption of animal products relative to SSP2_BASE

The primary effect on world land use is an increase in grassland, as consumption of animal products increases. There is a compensating reduction in forest land, and the amount of cropland changes very little.



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