Land Use Change in Agriculture: Yield Growth as a Potential Driver

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Biofuel Feedstock Analysis

- Recent legislation and policy initiatives have made biofuel production and use a focus of the future U.S. energy system, along with lifecycle GHG emissions reductions

- For the foreseeable future, the majority of feedstocks will likely come from agricultural land, using both established and newly developed crops and production practices

- There is considerable debate as to how much, if any, additional agricultural land will be required to achieve biofuel feedstock production targets

Policy issues

- How will crop production respond to/influence biofuel processing facility location, transportation infrastructure, and land suitability?
  - Geographic distribution of production
- How will emerging dedicated energy crops influence the agricultural landscape?
  - How do crop residues fit in?
- How big a role do crop yields play in land use change?
  - Will yield growth motivate further intensification of production?
- Implications for reallocation of cropland
  - Shifting from traditional crops to biofuel feedstock
  - Reintroduction of idle (possibly marginal) land
  - Conversion of land under conservation

Farmer choices…

- Land stewardship involves choices regarding:
  - Crop/rotation
  - Tillage/soil management
  - Input use: Irrigation, fertilizer
  - Participation in conservation programs
    - Land retirement
    - Working lands

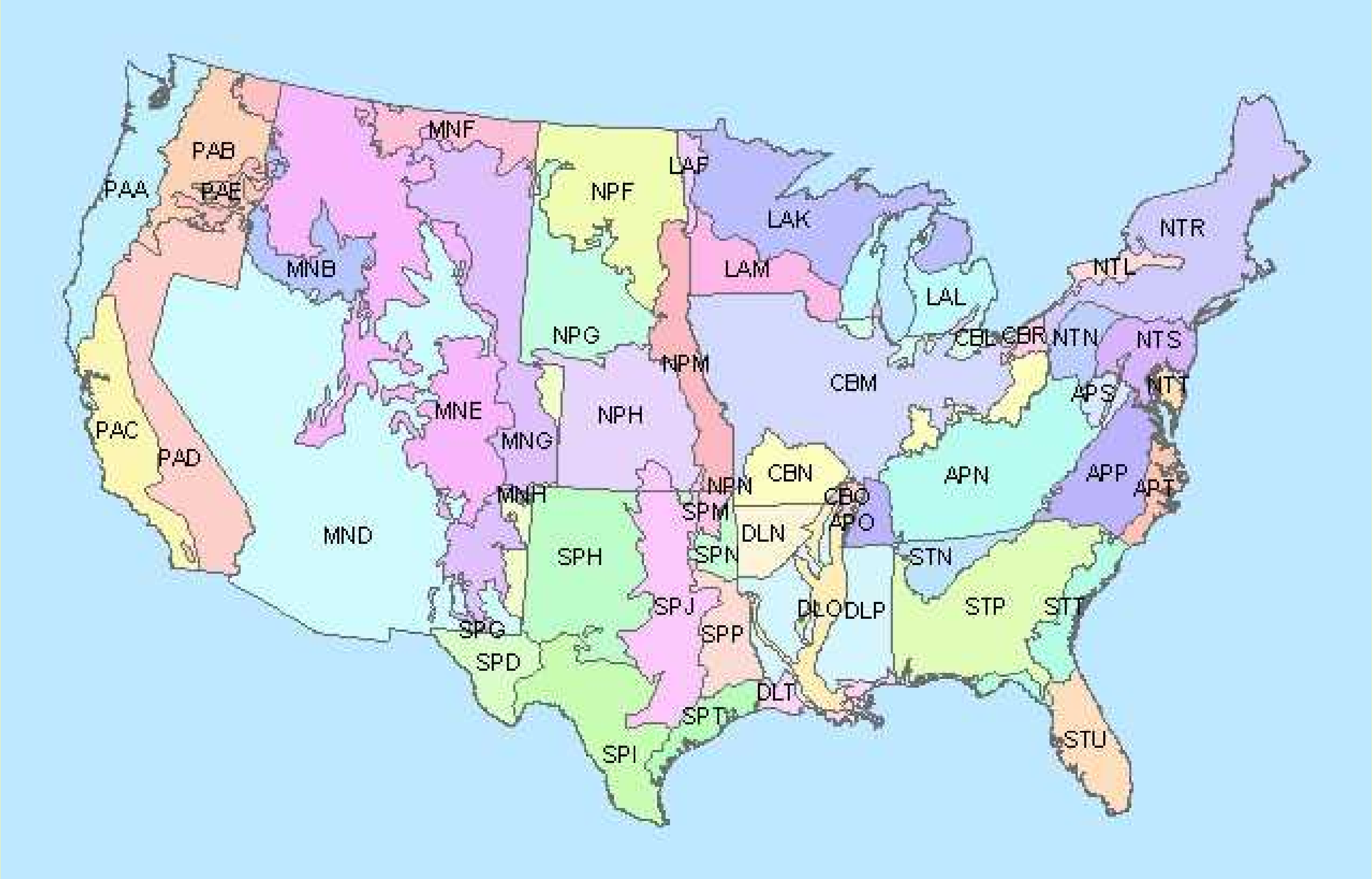
…have Consequences

- Changes in production practices lead to changes in fertilizer and pesticide use
- These changes, in turn, affect soil, water and air quality, and GHG emissions
- Shifts in demand for biofuel feedstocks and land will change the equilibrium of other (non-feedstock) agricultural markets
- Market, resource and environmental interactions highlight the need for an integrated modeling framework

Modeling framework

- Regional Environment and Agriculture Programming (REAP) model
  - 50 agricultural production regions
  - Integrated crop, livestock and agricultural product supply/demand model
  - Explicit relationship between production practice (rotation, tillage, fertilizer) and yield
  - Link between production practices and environmental outcomes
  - Calibrated to the USDA baseline projections

REAP regions



REAP structure

- Activity model
  - Identifies welfare-maximizing choice of rotation, tillage, fertilizer application in each region
- Partial equilibrium model
  - No market for energy, fertilizer, irrigation
- National demand for final products
  - No transportation between supply and demand centers
- 9 environmental indicators
- Data from a variety of sources
  - ARMS, NRI, Census, and EPIC

Cropping choices

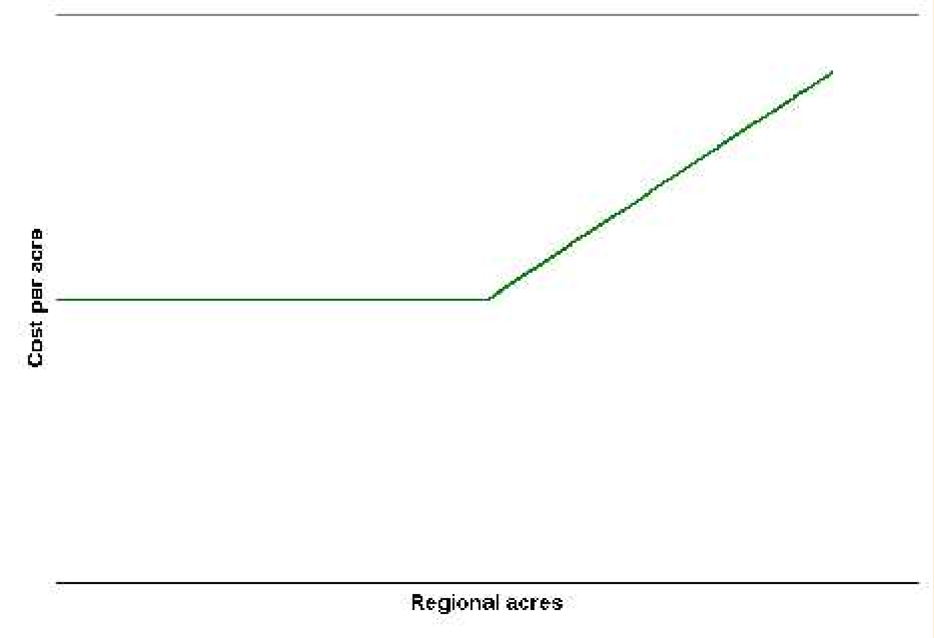
- 45 rotations
  - 10 continuous + 35 multi-crop
- 5 tillage regimes
  - Conventional, Moldboard, Ridge, Mulch, No-till
- 115 total rotation/tillage combinations
  - Range from 10 in the Southeast to 70 in the Northern Plains

Crop yields in REAP

- Crop yields are specific to each region, rotation, tillage, and fertilizer level, and land erodibility class
  - Initial values are determined by EPIC, a biophysical simulation model, under predominant soil type and climate conditions for each region
  - Yields are adjusted in the calibration process so that national average for each crop matches that given by the baseline

Land supply

- Land is modeled by two components
  - Constant cost, up to a limit
  - Increasing cost beyond the limit
- Varies by FPR
- Land supply is effectively unlimited, but at a great cost



Measuring Land Use Change

- Three categories of land
  - Cropland, pasture and CRP
    - Cropland measured at the REAP region level
    - Pasture and CRP are measured at the Farm Production Region level
- REAP can measure gross changes between categories, but it does not measure specific movement
  - e.g., we cannot say X acres of CRP was converted to corn
  - Can say CRP acres declined by Y and corn acres increased by Z

A Policy Question

- There has been much talk about policy-induced land use change being mitigated by improvements in crop yields, specifically corn
  - Other crop yields may improve as well, leading to complementary, as well as conflicting, outcomes

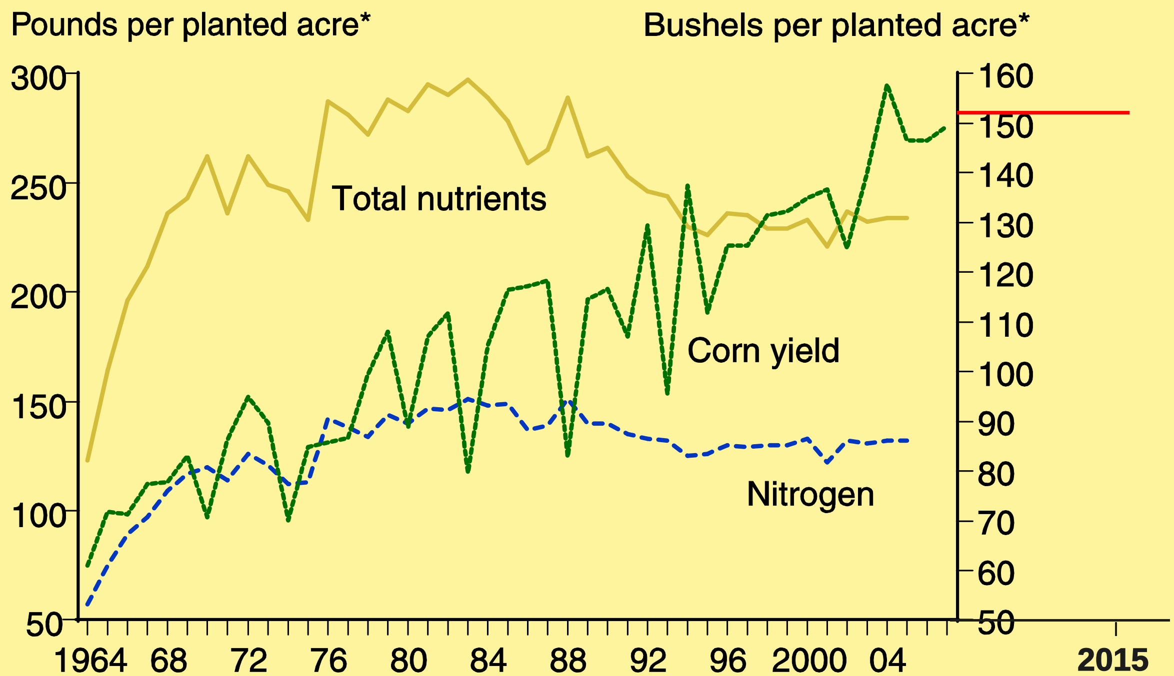
- Scientific evidence supports both high and low yield projections
  - What if yields exceed baseline expectations?
  - What if yields fall short of baseline expectations?

- What will be the joint impact on land use change of differences from expected corn and soybean yields in 2015?
  - Yield targets of +/-10% baseline values are considered
  - *All values in the following tables are million acre changes with respect to the USDA Baseline for 2015, adjusted to production of 15 billion gallons of corn ethanol*

Corn yield trend

- For corn, -10% yield (152 bu/acre) implies basically flat yields to 2015

Corn yield and fertilizer applied to corn, U.S., 1964-2007



*Excluding silage acreage.

Source: USDA, National Agricultural Statistics Service.

- Total acreage response to differing crop yield realizations

Total cropland acres in production

		Soybean yield	
		+10%	-10%
Corn yield	+10%	-3.8	-6.7
	-10%	11.0	8.3

- Corn acreage declines with increased yields, but soybean acres increase…

Corn acres

		Soybean yield	
		+10%	-10%
Corn yield	+10%	-3.5	-3.5
	-10%	2.1	2.1

Soybean acres

		Soybean yield	
		+10%	-10%
Corn yield	+10%	1.8	-1.2
	-10%	1.3	-1.4

- Increase in soybean yield moves acres into corn/soybean rotation

Corn/Soybean rotation

		Soybean yield	
		+10%	-10%
Corn yield	+10%	0.9	-0.4
	-10%	0.8	-0.8

- Regional pattern of cropping activity changes as well

Corn Belt

		Soybean yield	
		+10%	-10%
Corn yield	+10%	-0.5	-1.1
	-10%	0.8	0.3

Northern Plains

		Soybean yield	
		+10%	-10%
Corn yield	+10%	-2.3	-3.5
	-10%	6.5	5.6

- CRP participation is affected
  - Baseline CRP enrollment is 31.4 million acres
  - Demand increases as acreage is freed by increased corn yield

CRP

		Soybean yield +10%	Soybean yield -10%
Corn yield	+10%	2.8	4.6
Corn yield	-10%	-8.3	-6.5

- Crop tillage choice affected

Conventional till

		Soybean yield +10%	Soybean yield -10%
Corn yield	+10%	-3.2	-4.0
	-10%	11.3	10.3

No-till

		Soybean yield +10%	Soybean yield -10%
Corn yield	+10%	-0.1	-0.9
	-10%	0.8	-0.1

- Soil carbon sensitive to corn yield, but not soybean yield (million tons)
  - Change from farming activity only

Soil carbon flux

		Soybean yield	
		+10%	-10%
Corn yield	+10%	0.17	0.17
	-10%	-0.34	-0.31

Implications for GHG production and mitigation

- Actual GHG emissions realized will depend on how input use corresponds to changes in yield over time
- Failing to achieve promised yield growth will favor movement into conventional till systems
- Most of the “action” is in the Northern Plains region, with lower productivity and soil carbon than the Corn Belt

Room for improvement

- Productivity of land is not constant across regions
  - "new" land coming into production likely to be of lower productivity than "average" in a region
  - "Average" analysis doesn't fully capture degree of intensification
- Land "use" isn't the only GHG driver
  - Production systems
  - Other farming activities (transportation, processing)
  - Cover crops, conservation activities, etc.