NDSU NORTH DAKOTA STATE UNIVERSITY
Department of Agribusiness and Applied Economics
P.O. Box 5636

Fargo, ND 58105-5636

701.231.7441
Fax 701.231.7400
coa-econ@ndsuext.nodak.edu

April 20, 2009

Mary Nichols, Chair
California Air Resources Board
1001 1 St
Box 2815
Sacramento, CA 95812

ref. Indirect land use in the proposed California Low Carbon Fuel Standard

Dear Ms. Nichols,

I am a CO-Director of the Center for AgBiotechnology at NDSU. I work primarily in areas related to agriculture including risk, marketing and commercialization of technology (in this case agbiotechnology and biofuels). I have been heavily involved in varying aspects of commodity marketing, modeling, genetically modified crop production and commercialization etc.

I am very familiar with the issues related to data, modeling and assumptions. In recent years I have developed large scale models to simulate longer term trade, production and marketing for varying US and foreign government organization (including the Army Corp of Engineers on Mississippi River expansion and grain flow projections; Panama Canal on their expansion, and commodity flows) and firms (including the largest railroads in N. America on grain and ethanol flows and projections; and other large agribusiness corporations impacted by developments in the biofuels sector). In all cases we had to deal with some of the perplexing issues embedded in the analysis relevant to your decisions.

For purposes here we fully respect the science based rule-setting procedure, and accept the CGE model and that of GTAP as being appropriate. However, I have several concerns in some of the assumptions, notably those related to yields, growth rates and regional differences. Specifically, the analysis does not include higher yields that are coming from new technology and thus significant new land may not be needed to meet our feed, food and fuel needs during the period in question.

Background to these are outlined in greater detail in the attached.

Based on our modeling, these assumptions impact the results and longer-term equilibrium estimates for land-use. Continuation of analysis and policy recommendations based on these assumptions may lead to inappropriate decisions. Simply, the assumptions do not reflect the current and evolving technology in these industries. It is for this reason I am writing as I suggest these be considered in modifications

Decisions related to biofuels are very important. Indeed, billions of dollars have already been expended on this industry, not only on processing, but on ancillary industries including GM trait development, specialized harvesting technology, rail shipping technology, and proposed dedicated pipelines for shipping ethanol, etc. The science based rule setting is desirable, however the complexities of the issue are great and the current assumptions used in this analysis cannot be supported. Hence, this does not embrace science based decisions. However, as noted in the attached these can readily be examined in revised analysis and where appropriate, improved.

With regards,

William W Wilson
University Distinguished Professor

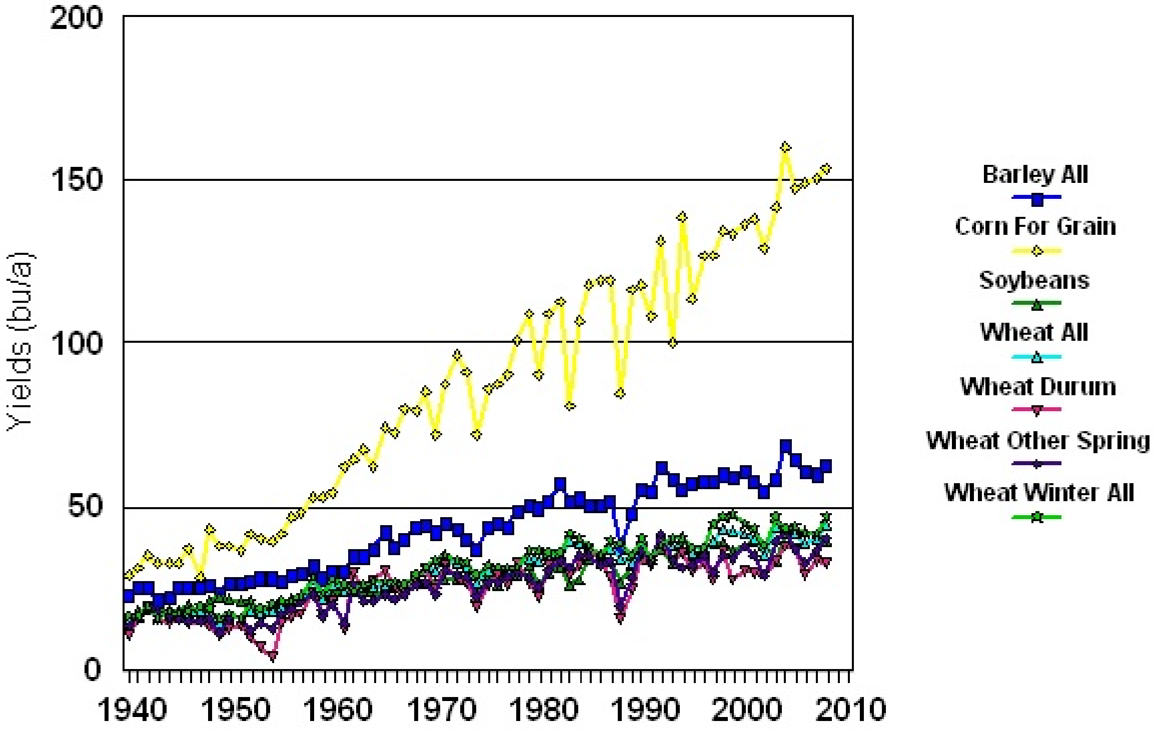
Crop Yields: Fundamental Changes in Technology and Growth Rates

There are a number of factors that are important about crop yields. Most important are yield growth rates, impacts of regional differences in yields and growth rates, and the impact of genetically modified (GM) technology on yield growth rates. Each of these has a critical impact any longer-term projection of equilibrium values about area planted, land-use etc.

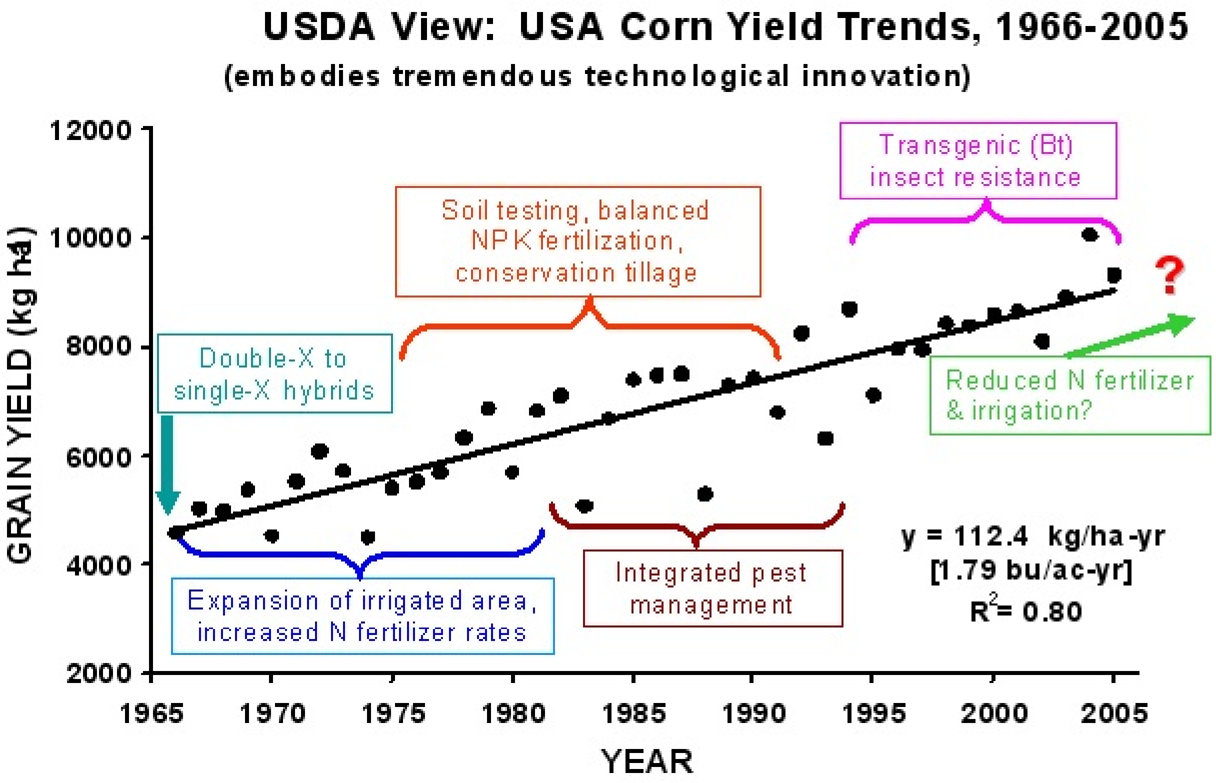
The GTAP model acknowledges the potential importance of yield growth rates, but, their base case used average yields from 2006-2008. By ignoring growth rates, and prospectively accelerated growth rates due to new technology (see section 3 below), the analysis will understate crop production and overstate land used requirements in their projection period.

1) Yield Growth Rates

There has been debate amongst analysts on the growth rate in yields for major crops. While this is being debated, the growth rate for corn is far more prominent and recognizable than virtually any other crop. See Figure below.



There is also discussion on the role of technology, and in particular GM technology (see below) on this growth rate. To put this in perspective, USDA uses the following figure to depict the factors that have contributed to yield growth rates in corn.



K.G. Cassman, CAST Renewable Energy Agriculture, In Press.

As illustrated, yields have increased at a continuous rate of growth and attributable to multiple technologies being introduced over time.

In a recent analysis, we measured growth rates in yields for crops in the US. These data were from USDA-NASS. Yield trends for U.S. corn, soybeans, barley, wheat (All, Winter, Spring, Durum) from 1940 to 2008 were evaluated.[1] Hence, for purposes here, and without being exhaustive, we interpret the linear trends. Fitted parameters are shown below.

---

[1] Several functional forms (linear, loglinear) were investigated to explore alternative growth rate assumptions.

Estimated Parameters for Linear Yield Trends (bu/a) for U.S. Crops from 1940-2008.

	Corn	Soybeans	Barley	All Wheat	Winter Wheat	Spring Wheat	Durum
Intercept	20.403	15.983	20.595	14.836	15.269	12.937	13.071
(t)	(9.644)	(29.793)	(23.580)	(23.828)	(23.300)	(14.588)	(10.309)
B*(trend)	1.895	0.355	0.652	0.429	0.460	0.379	0.345
(t)	(36.075)	(26.670)	(30.061)	(27.760)	(28.286)	(17.232)	(10.963)
R2	0.951	0.914	0.934	0.920	0.923	0.816	0.642
2008 Yields (bu/a)	153.8	39.3	63.6	44.9	47.2	40.5	32.8
% Increase	1.23%	0.90%	1.03%	0.96%	0.98%	0.94%	1.05%

These results show corn yields growing at nearly 1.9 bu/year with the lowest growth in bu/year in durum (.35 bu/yr) and soybeans (.36 bu/yr). For the wheat classes, winter wheat has the largest growth rate at .46 bu/yr, followed by all wheat (.43 bu/yr), spring (.38 bu/yr) and durum (.35 bu/yr).

Average growth was calculated on a percentage basis relative to 2008 yields. These show, corn yields growing the fastest at 1.23% per year. These results indicate corn yields are growing at a faster pace than the other crops both on a bushel basis and on a percentage growth rate/year.

2) Yields and regional differences and growth rates

Yield levels (and growth rates) vary substantially across countries, as well as across regions within a country. No doubt this is a reason the GTAP model uses 18 regions of the world. However, that model treats the geographical unit as a country, not a a region.

There are differences in yields for regions within a country. In our modeling, we have found this to be indeed challenging, but yet important. The reason for this is that the developments in biofuels ultimately are geographically concentrated, and hence, inclusion of geographical supply responses (area available, area supply response, and yield) is critical. This is particularly important in the case of the United States and Brazil, amongst others.

As example, in our work, the table below shows yields (3 year average) for corn and soybeans by region, as well as their simple growth rate from 2000-2008.

	Corn			Soybeans	
	Yield (06-08)	% Change		Yield (06-08)	% Change
Regions	bu/a	Per Year		bu/a	Per Year
Illinois	172	2.3%		46	0.9%
Indiana	157	1.2%		47	-0.3%
Iowa	169	2.3%		50	0.7%
Minnesota	157	1.6%		42	-0.9%
Nebraska	158	3.7%		49	2.8%
Northeast	138	0.1%		41	-1.4%
South	130	0.2%		35	2.6%
West	127	0.9%		34	1.2%

Discussion of these yield differentials is not intended to be exhaustive, but suggestive of their importance.

The point is there are substantial differences in both yields and growth rates across regions. Ultimately, regional crop planting decisions respond to available land and resources, supply functions, yields and returns of other competing crops. Thus, not only do relative prices impact crop choice, but, relative yields impact crop choice. And, over time, changes in these relative yields will impact changes in crop choice.

By ignoring these impacts, any equilibrium analysis will mis-represent the geographical differences in the ability of regions to respond.

3) Impacts of Genetically Modified technology on yield Growth Rates

There has been an accelerated rate of growth in yields for some crops due to the adoption of GM technology. Simply, the development and commercialization of genetically modified (GM) technology in corn, soybeans, canola and cotton, has resulted in an accelerated growth rate in yields. This varies by region, by GM trait, by adoption rate, as well as the now multiple-stacked traits available for these crops.

It is for these reasons, that we observe a faster growth rate, notably in corn yields, in the period following 1996. This is not anecdotal, but is dependent on the nature the GM technology that has been developed. As example, recently evidence has been provide to indicate that GM crops have higher yields due to both breeding and biotechnology.[2] Importantly, yield is increased by breeding and the addition of GM traits.

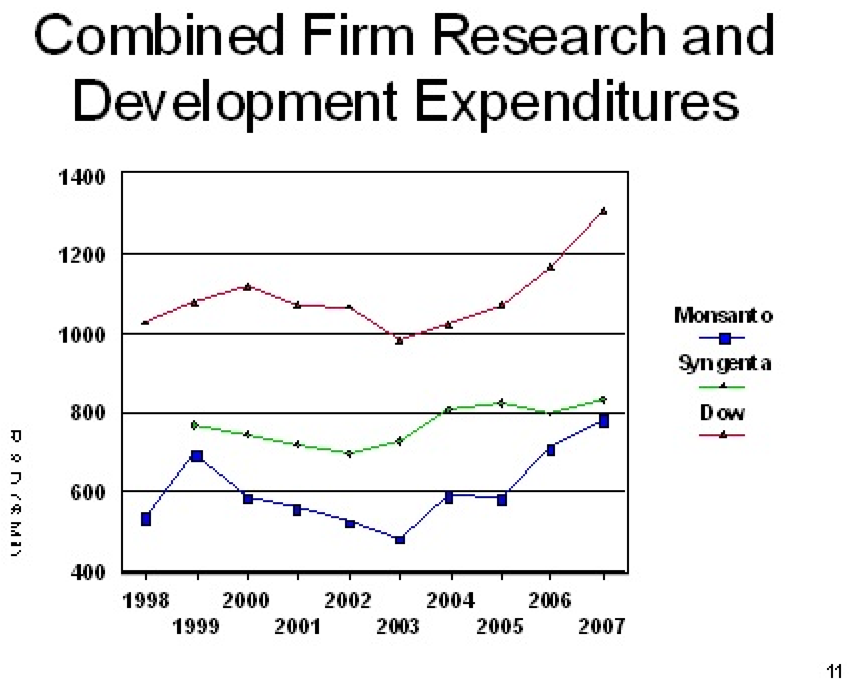
---

[2] See in particular: Edgerton, M.D., 2009. Increasing crop productivity tomeet global needs for feed, food and fuel." Plant Physiol. Jan; 149(7-13).

and also at

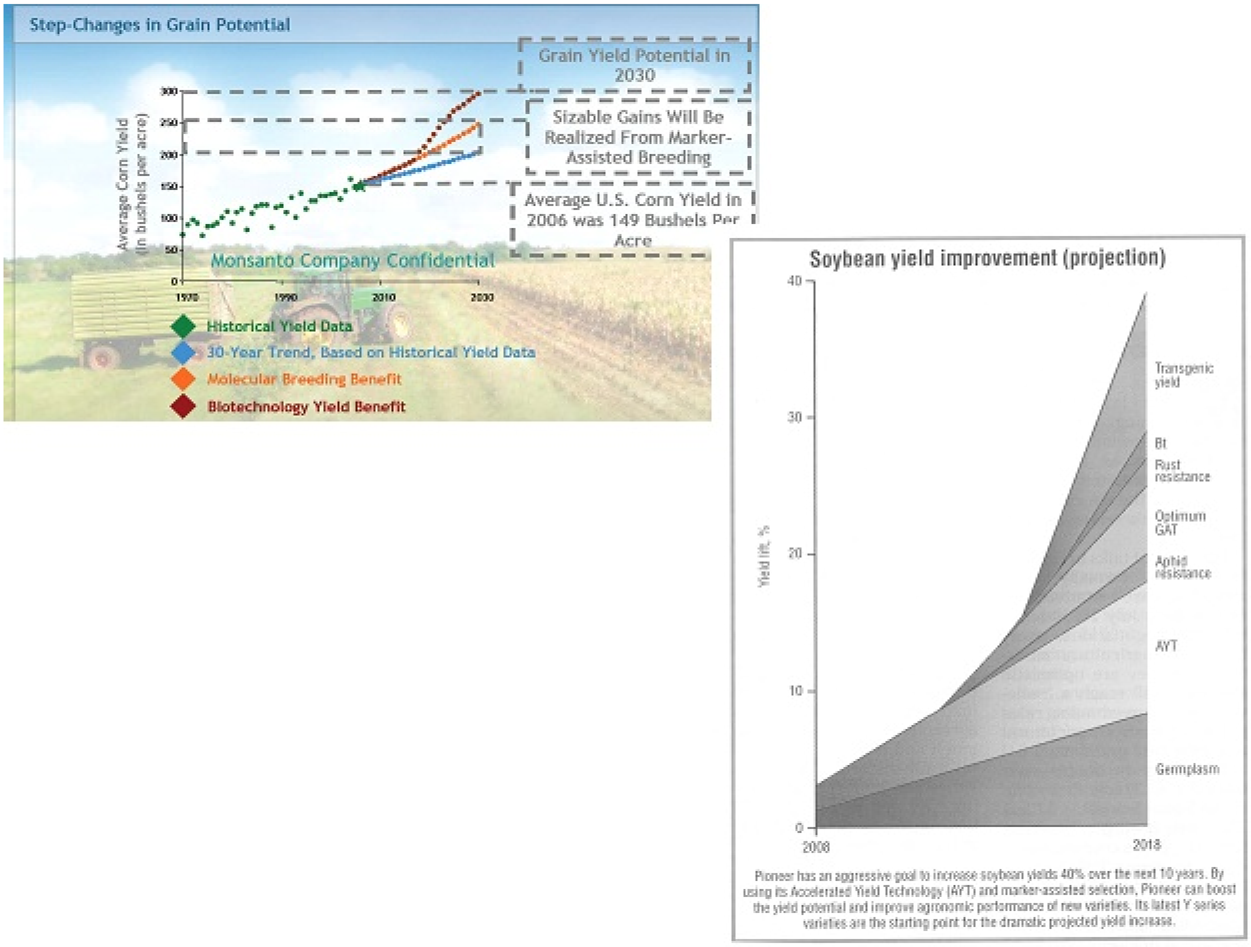
http://www.monsanto.com/monsanto_today/for_the_record/gm_crops_increase_yields.asp

Fundamentally, this accelerated growth rate in yields is really being driven by an increase in research focus and expenditures on crop development. To illustrate, the following figure shows the accelerated investment by agbiotech companies since the mid-1990s. Research expenditures have increased for each of these firms with Dow and Monsanto increasing the most. These data indicate, as example, that Monsanto increased spending from $482 million in 2003 to nearly $800 million in 2007 and this is now reportedly even greater.


Combined Firm Research and Development Expenditures

The important point is that there has been an acceleration of research expenditures, along with greater focus on different technologies of crop yield improvement that is intended to provide sustainable growth rates in the future. Based on these investments and technologies, each of the major agbiotechnolgy firms has indicated their anticipation of a much faster growth rate in yields in the coming years, than in the past.

For these reasons during the past year, each of the major agbiotechnolgy companies have indicated substantial improvements in yield growth rates in the coming 10-20 years. Specifically, Monsanto indicated it would double yields by 2030, and each of the other companies have made similar claims. The figures used by these companies are on the following page.



Pioneer has an aggressive goal to increase soybean yields 40% over the next 10 years. By using its Accelerated Yield Technology (AYT) and marker-assisted selection, Pioneer can boost the yield potential and improve agronomic performance of new varieties. Its latest Y series varieties are the starting point for the dramatic projected yield increase.

Figures Used by AgBiotech Firms to Indicate their Anticipated and Realizable Growth Rates in Crop Yields Due to Conventional Breeding, Biotechnology and Molecular Breeding

These are technological breakthroughs due to the combination of conventional breeding, biotechnology yield benefits and molecular breeding. In our empirical work, we analyzed these prospective growth rates and compared them to growth rates excluding these technologies. The results indicated the following:

Trend/Qualified	Depiction/assumption	Corn	Soybeans
		Annual % Growth Rate	
Trend line growth rates	National average	1.23	.9
Accelerated Growth Rates	Assuming GM technology growth rate (implies full adoption of GM technology)	3.4	3.3
Accelerated Growth Rates	Technology growth rate at 2007 GM adoption rates and weighted by regional area and GM adoption rates	2.14	2.53

The important point is that

- GM technology has accelerated growth rates in these crops, but, notably corn;
- The growth rate varies through time, is accelerating, and depends on adoption rates.

In all cases, by ignoring these impacts, any analysis would be understating the crop production potential and land-use requirements.

4. Implications of these Assumptions

We have conducted similar analysis that had to deal with these issues on several occasions in recent years. Our intention here is not to exhaustively present that model,[3] nor the results, but

---

[3] Specifically, our most recent analysis was a stochastic dyanmic partial equilibrium model of world production, demand and trade for corn and soybeans. The model did treat regions separately within the US and other countries, and allowed for differential yield growth rates. It was simulated through time and reported here are results for 2016.

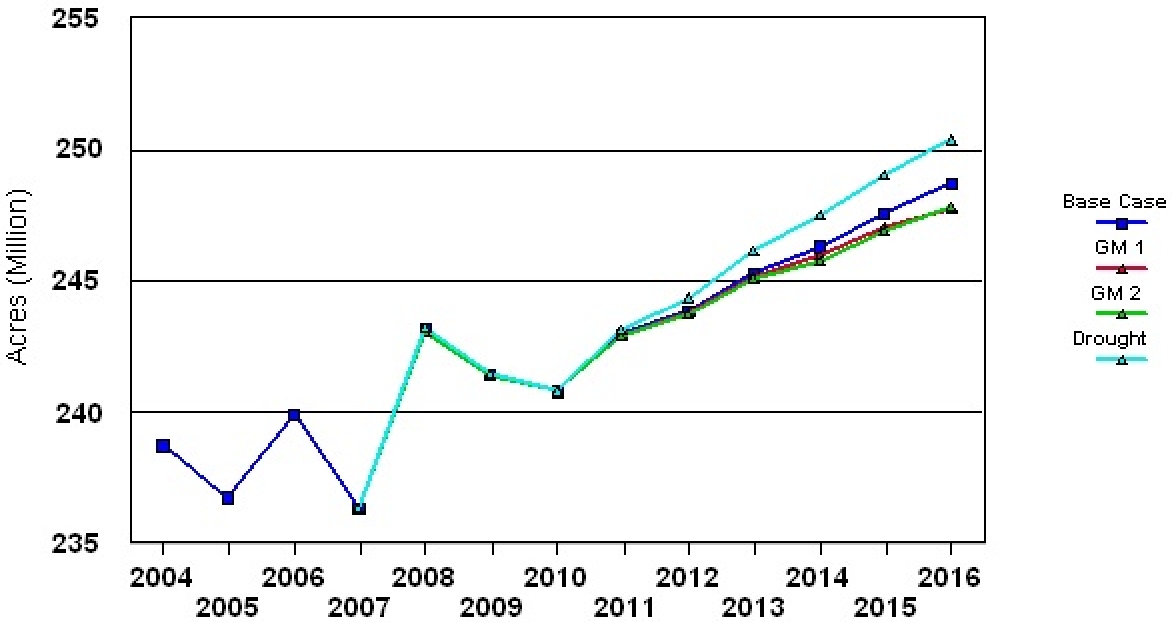
There are several important features of the model that are clarified below:

Demand : Growth varies by countries, responds to income and population growth rates and prices;
Ethanol vs. food demand: Ethanol demand for corn, depends on a complex of relations including the price of gas, ethanol, corn, DDGs, capacity utilization rates and the time lag to expand capacity. The implied elasticity of demand for ethanol is -.48, vs. about -.1 to -.15 for most food and other industrial demand. As a result: changes in corn prices will have a greater impact on ethanol demand than demands for other uses. i.e., adjustments in demand for corn for ethanol are an important feature of the output
Area planted and supply response Supply and area responds to net incomes and relative prices. In a number of important US regions and Brazil, area is at or near the limits on area available which restricts total supply response.

instead to suggest and indicate the impacts of these assumptions on crop production, area planted etc.

Some highlights of these results are (defined as equilibrium values in 2016):[4]

4.1 Changes in area planted. There is an increase in area planted to corn. The change in world area planted to corn and soybeans are illustrated below for different technology assumptions. For corn there are gradual increases to accommodate increasing demands. Corn area planted increased from 430 ma currently to 450, or 4.6%, and soybean area increases by about 5% from now to 2016. The rate of growth is highly dependent on the rate of GM adoption/release and growth rates, as well as other scenarios

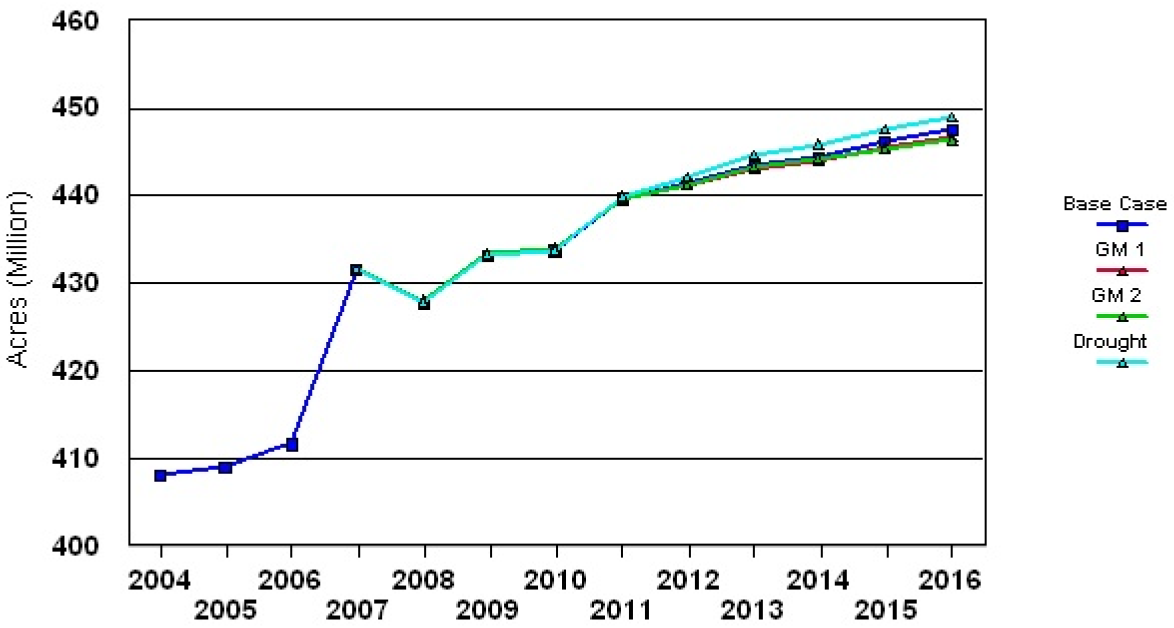


World: Area Planted to Corn Under Different Technology Assumptions

---

Argentina and several US regions are the most important regions for prospective increases in supply.
Yield growth rates Historical yield growth rates (from 1996 to 2007) are about 1.2% per year, which is the rate of growth used in most other large scale models. Proposed new GM traits would results in growth approaching 3.3-3.4%/year. These growth rate have a very significant impact on the equilibrium prices and supplies, as well as ethanol demand. However, they are only applied to regions that adopt GM production.

[4] These results reflect what we define as a scenario in which GM crops continue to be developed, ethanol price distributions were at mean values during Feb 2008 and we allowed accelerated Chinese demand for soybeans (which has been observed).



World: Area Planted to Soybean Under Different Technology Assumptions

Changes of interest in some of the important regions are:

- United States increased corn area planted to 95 ma, and area planted to soybeans remains flat.
- Argentina has reduced area for corn, and an increase in soybean area planted;
- Brazil has a decrease in corn planted area, and soybean area increases from 55 to 56 million acres.
- For many of the U.S. regions plantings are unchanged due in part due to area limitations. It is important that the majority of the increase area planted is in what we defined as "West," partly the result of the new stress traits.

These results differ from the Tyner et al model (p. 14) which indicates that most of land use change due to us ethanol production will take place outside the Untied States. Indeed, due to growth in GM technology as suggested here, at least some of this land-use change occurs within the United States.

A further concern is the interaction of external policies in the CGE model. The way in which demand will be met depends very much on external policy decisions. Indeed, removal of the EU set-aside requirement and reduction of US CRP are two important examples of external policy decisions that, to my understanding, are not included in the GTAP model. Both create large amounts of available cropland in the relatively higher yield developed countries.

4.2) Ethanol Demand for Corn. Part of our goal was to determine the equilibrium level of ethanol produced. We simulated this through time to 2016.

The results showed that in equilibrium (i.e., after all adjustments were made in demands, area planted by regions and countries in the world, etc), ethanol production would increase to 15.25 bg by 2016, with a range from 14 to 17 bg. The reason for the range is the model is stochastic, and ethanol demand is one of the more elastic (implicitly) demands in the model.

Ethanol demand for corn grows in part due to the GM technology which is an important feature of the model and analysis.

5. Summary

We fully embrace the use of the CGE model for assessing impacts you are trying to analyze. While there may be many issues in the specific application, the one of greatest concern to us is the treatment of yield. The authors recognize this issue. Our own analysis, while not exhaustive and not in the same type of model, illustrates that the impacts of assumptions around future yield growth rates have a significant impact on the results.

The discussion above can be summarized along a few key points:

- Given the growth in overall food and feed demand, combined with the growth in demand for biofuels, there is greater demand on agricultural resources, notably land use and technology;

- There are three important points regarding yields for crop production: 1) yields have had a continual growth rate over time, with that for corn exceeding other crops; 2) there are substantial differences in yields and growth rates across regions; and 3) growth rates have accelerated in the period following introduction of GM technology. Ignoring these impacts would have a drastic impact on land use and the spatial distribution of production etc.

- The projected growth rates in yields are in response to new technologies developed for crop breeding and biotechnology. Further, they are the result of a cumulative accelerated growth in funding for research, the results of which will be greater yields expected over a longer period of time.

Implication As the CARB assesses impacts of biofuels and quantifies prospective future values for land-use, requirements, etc, it is important that these impacts are accounted.

The GTAP model makes an assumption on these values and ultimately used average yields from 2006-2008. Using 2006-2008 yield averages will undoubtedly underestimate crop production in the projection period.[5] The important points are that by using a simple average without allowing changes over time, ignores the future crop production potential, and suggests a greater.

To be clear, the researchers could use methodologies similar to what we have used and could develop data similarly as it is all publicly accessible. There are a number of methodologies that could be used that would be more compatible with the CGE but would also capture these impacts. All of these would be an improvement upon what has been done with these limiting assumptions. We would hope that in future work, this is explored exhaustively.

---

[5] The authors acknowledge this issue (e.g., p. 32).