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Longer-Term Forecasting of Grain Flows and Delay Costs on the Mississippi River

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ABSTRACT

The purpose of this study was to forecast grain and oilseed shipments through the Mississippi River system and to analyze impacts of delay costs. The focus is on the world grain trade and expected changes in response to a multitude of evolving competitive pressures and structural changes. The model is a spatial optimization model of the world grain trade. Important parameters are forecasted and used to evaluate changes in flows through specific logistical channels. Projected import demands are based on consumption functions estimated using income and population and accounting for intercountry differences in consumption dependent on economic development. Each of the competing supply regions and countries were represented by yields, area potential that could be used in production of each grain, costs of production, and interior shipping costs, where relevant. Crucial in this model is the interior spatial competition between the U.S. Pacific Northwest and shipments through the U.S. Gulf, as well as inter-reach competition.

Delay costs are the additional costs associated with shipping on the barge system and result from queuing and the added costs for shipments that are delayed. These are an important feature of barge shipping, particularly when shipment volumes are greater. In several of the reaches, grain flows are near the point at which positive delay costs are accrued. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic.

The results suggest exports from the United States increase from the base period to 2010, in part due to the assumption that the maximum area for plantings would increase and in part due to the fact that China's corn exports are assumed nil in 2010 and beyond. U.S. corn exports decline the most, with a potential peak of 62 mmt to around 42 mmt. Wheat exports decline substantially, but soybeans increase through 2030. Exports from the United States are concentrated in the U.S. Gulf, which declines to 57 mmt after reaching a peak of 92 mmt in 2010. Exports from the Pacific Northwest (PNW) are 25 mmt in the base year and decline in later years. The results illustrate that the United States remains an important exporter of soybeans and this conclusion persists in other scenarios.

Expansion would result in reduced delay costs on each or Reaches 1, 2, and 4 by about \$0.44/mt, \$1.04/mt, and \$1.01/mt, respectively. Expanding lock capacity reduces delay costs, increases capacity and shipments by barge. Barge shipments increase by about +4 mmt by 2020. Thereafter, the change in barge shipments would be about +0.9 mmt to +2.5 mmt. There is substantive inter-reach competition and by 2020 shipments on Reach 1, 2, and 4 increase, but shipments on Reach 5 and 6 would decrease.

Delay costs, in aggregate, are comprised of the lower delay costs that would occur at current capacity, plus the volume effect. The impact of expansions on delay costs are in the area of \$61 million, inclusive of both direct effects. Most of this is accrued on Reach 4, followed by Reach 2 and 1. Expansion results in an increase in barge costs due to the increase in volume, a decrease in rail shipping costs, and a slight increase in ocean shipping costs. In total, the impact of expanding locks is a decrease in costs by about \$52 million.

The base case assumed Energy Information Administration (EIA 2005) projections of corn use in ethanol demand. The model was revised assuming the EIA (2006) estimates of ethanol produced from corn. Results are drastic. Exports from Argentina, Europe, and Eastern Europe increase and wheat exports from Australia increase and exports from the United States decline. Gulf exports decrease (65 to 51 mmt) and PNW changes only slightly to 14 mmt. Most of the decline is in corn and wheat shipments. In addition, there are major changes in flows within the United States. Most interesting is the increase in shipments to the Eastern and Western Corn Belts, reflecting the increase in domestic demand for ethanol use. Also interesting are the changes in flows from the Northern Plains which had previously exported most of its corn through the PNW. These are now shifted with a significant portion destined for domestic movements. The model was run assuming more stylized assumptions for some critical variables, mostly impacting the ability of corn production to expand to meet these competing demands. The results suggest the model is fairly robust in capturing these different assumptions. Most striking in making these comparisons are: 1) corn exports from the United States increase; 2) soybean exports from the United States decline to 28 mmt vs. 36 mmt for the 2010 case; and 3) wheat exports increase from each of the competitors and those from the United States decline, but by not as much as in our unrestricted high-ethanol case. There are important reasons for these differences. Most important are assumptions about the yield growth, the ability to expand corn acres, and differing assumptions on soybean production and exports from the United States vs. competitor countries.

Key Words: Barge Shipping, Grain Transportations, Delay Costs

Longer-Term Forecasting of Grain Flows and Delay Costs on the Mississippi River

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INTRODUCTION AND OVERVIEW

Agricultural commodities are one of the important products in world trade that are shipped on inland waterways. The international distribution of grains and oilseeds are influenced by many factors including agricultural production and consumption which are impacted by tastes, population, and income growth, as well as agricultural and trade policies. Relative costs of production, interior shipping, handling, and ocean shipping costs all have an impact on trade and competitiveness of the interior logistical systems. Changes in the variable costs of any of these impact the international distribution of grains and oilseeds and shipments through the U.S. waterways.

The purpose of this study is to develop a methodology and analytical model to forecast shipments through the Mississippi River system and analyze impacts of delay costs.[1] The focus is on the world grain trade and expected changes in response to a multitude of evolving competitive pressures and structural changes. Emphasis is on the competitiveness of the U.S. grain and oilseed sector that is tributary to the Mississippi River system and to assess impacts of critical variables on its competitiveness.

A spatial optimization model of world grain trade was developed to analyze these effects. Important parameters were forecast and used to evaluate changes in flows. Projected import demands are based on consumption functions estimated using income and population and accounting for intercountry differences in consumption dependent on economic development. Each of the competing supply regions and countries were represented by yields, area potential that could be used in production of each grain, costs of production, and interior shipping costs. Crucial in this project is the spatial competition between the U.S. Pacific Northwest and shipments through the U.S. Gulf, as well as inter-reach competition.[2]

River System Issues

Numerous studies focused on issues related to the Mississippi River and grain transportation (see summary of studies below). In addition, there are a number of recent initiatives to expand various components of the river system. This study, however, was

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[1] This report is a summary of a project by the authors and the U.S. Army Corps of Engineers. It summarizes the results of a model and multiple simulations. These are published and available at: http://www.nets.iwr.usace.army.mil/docs/LongTermForecastCommodity/06-NETS-R-12.pdf.

[2] This contrasts with other studies focusing on grain exports through the U.S. Mississippi river system. Without being exhaustive, some of those used historical data from U.S. production and/or exports to make projections into the future. The distinction here is that we make projections in demand, by country worldwide, and use these to determine the most efficient flows and production activities to meet those demands.

motivated in part by the National Academy of Sciences (2004). In their review, the National Academy of Sciences noted:

> *Such scenarios will always contain a degree of uncertainty, and uncertainty alone should not justify the delay of investment decisions. But the magnitude and the potential effects of investments being considered in the feasibility study require scenarios that are consistent with the key drivers in global and national grain markets, that are supported by credible model results, and that are consistent with the knowledge of credible and independent experts.* (p. 9).

In commenting on the issues related to the analysis, the National Academy of Sciences indicated:

> *Model development efforts have not adopted, for example, realistic assumptions regarding spatial variation in grain production and shipping costs, the range of ports that might be accessed by regional grain production, domestic processing demands and the location of these demands, or global grain supplies and demands. The restructured study also assumes that the division of grain exports among available ports will not change, which is an unlikely assumption. As lock congestion builds on the U.S. inland waterway system, domestic markets and alternative ports and routing become increasingly feasible and likely ...Moreover, since 80 percent of U.S. corn production is domestically consumed, some dimension of this demand should be explicitly modeled. With some improvements and adjustments, existing spatial grain models could be adapted to give superior insight to the approaches currently considered by the Corps. ...Our committee has not sufficiently studied the Panama Canal transportation demand model to be able to recommend it specifically for use in the UMR-IWW study; however, it is a fully developed model that goes a long way toward incorporating the elements of a full spatial equilibrium model and it merits investigation by the Corps.* (p. 15)

Finally, in suggesting issues that should be considered if the Corps develops its own spatial price model, they suggested:

> *...forecast the amount of grain grown in the upper Midwest, which will be a function of the cost of growing grain and other commodities compared to prices at which grains and alternatives commodities could be sold. Another module should examine grain production in other grain-producing regions around the world (especially Argentina and Brazil) and associated prices. Another module should focus on world demand for grain, which is a function of population, income , domestic production, and global market prices of meat import.*

Summary of Underlying Data

The analysis identified a number of important factors that will be impacting barge shipments. These are summarized below.

Growth Markets: The most important and fastest growth markets, in terms of consumption, are for corn and soybeans in China, North Africa, South Africa, and the Former Soviet Union (FSU) and the Middle East. Growth in wheat is less and is dominated by South Asia, Southern Africa, China, and Latin America. The larger traditional wheat markets of Japan and the European Union (EU) have near nil growth rates.

Grain Production Costs and International Competition: Data on grain production costs were obtained from Global Insights (2004b) and combined with forecast yields to estimate production costs per metric ton. Results indicated there are substantial differences in variable production costs across countries. In particular: 1) the United States is the lowest cost producer of corn and soybeans; 2) most U.S. regions' production costs for soybeans are less than those in Brazil and those in Brazil South are less than those in Brazil North; and 3) other countries have lower costs for producing wheat than those in the United States. However, the United States and Canada have quality advantages which are not shared by some of these other wheat-producing countries. Results are shown in Figures 1 through 3.

The cost advantage for U.S. producing regions diminishes over time. Increases in production costs for U.S. regions rise at similar rates to that for major competing exporters. However, the rate of increase in yields is less than competing exporters. Hence, the cost advantage for U.S. producing regions diminishes over time. Increases in production costs for U.S. regions rise at similar rates to that for major competing exporters. However, the rate of increase in yields is less than competing exporters. In competing countries, the rate of increase in yields is comparable to that of production costs. But yield increases are less than competing exporters and are less than production cost increases. The impact of these is very subtle but when extrapolated forward, results in a changing competitive position of the United States relative to competing countries.

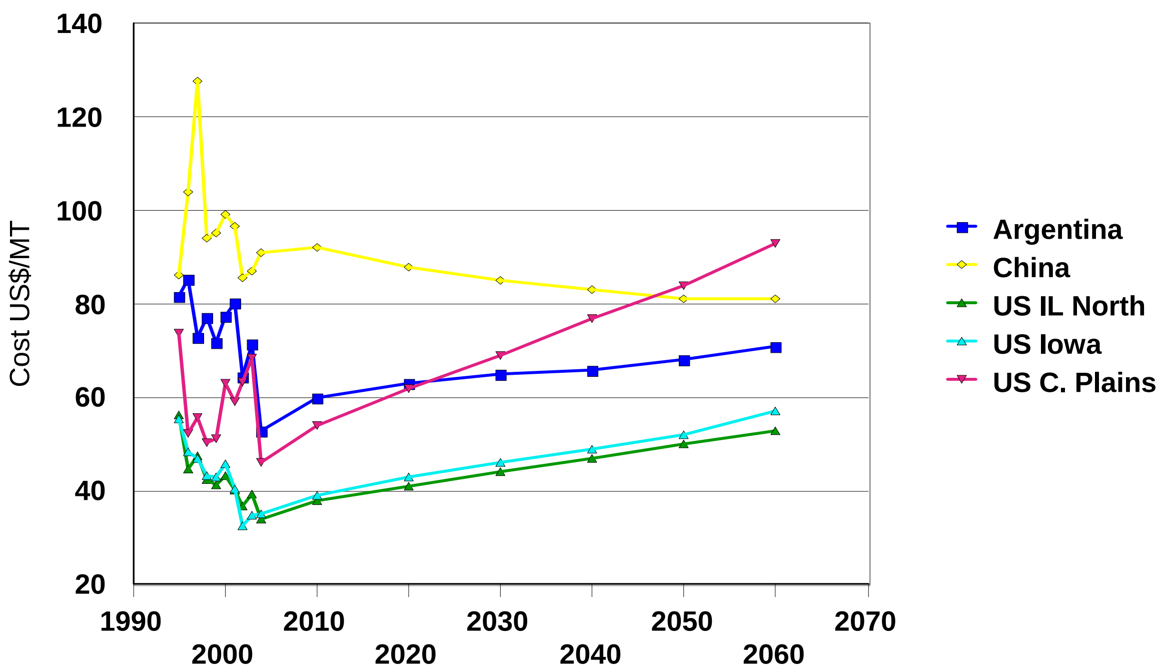

Figure 1. Corn Cost of Production

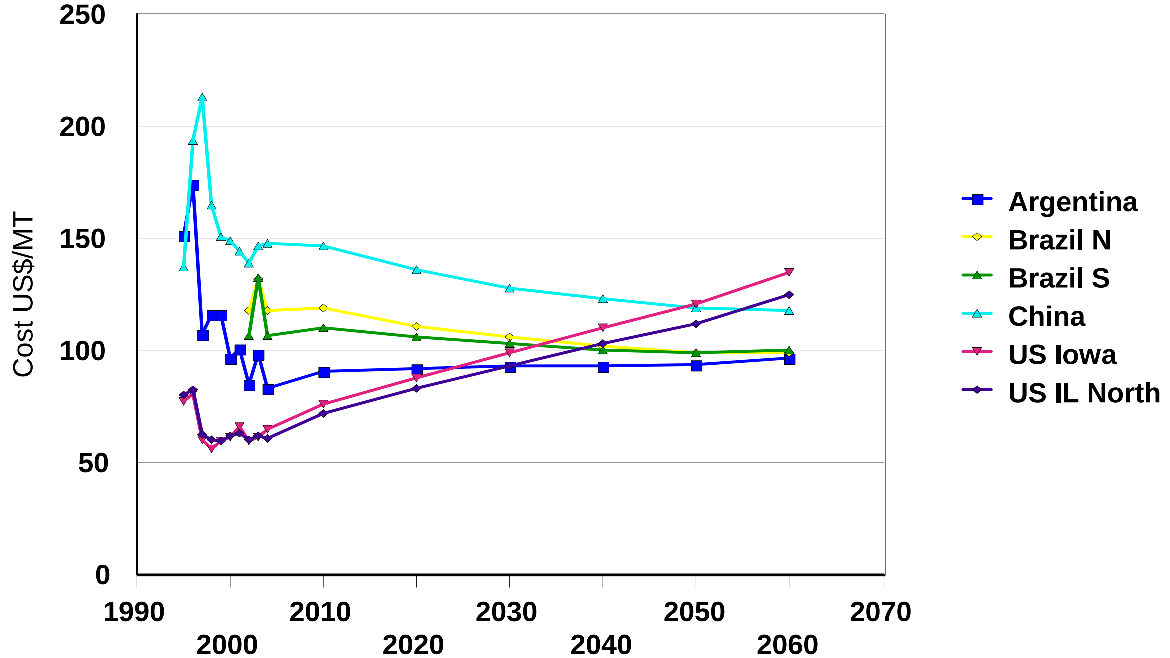

Figure 2. Soybean Cost of Production

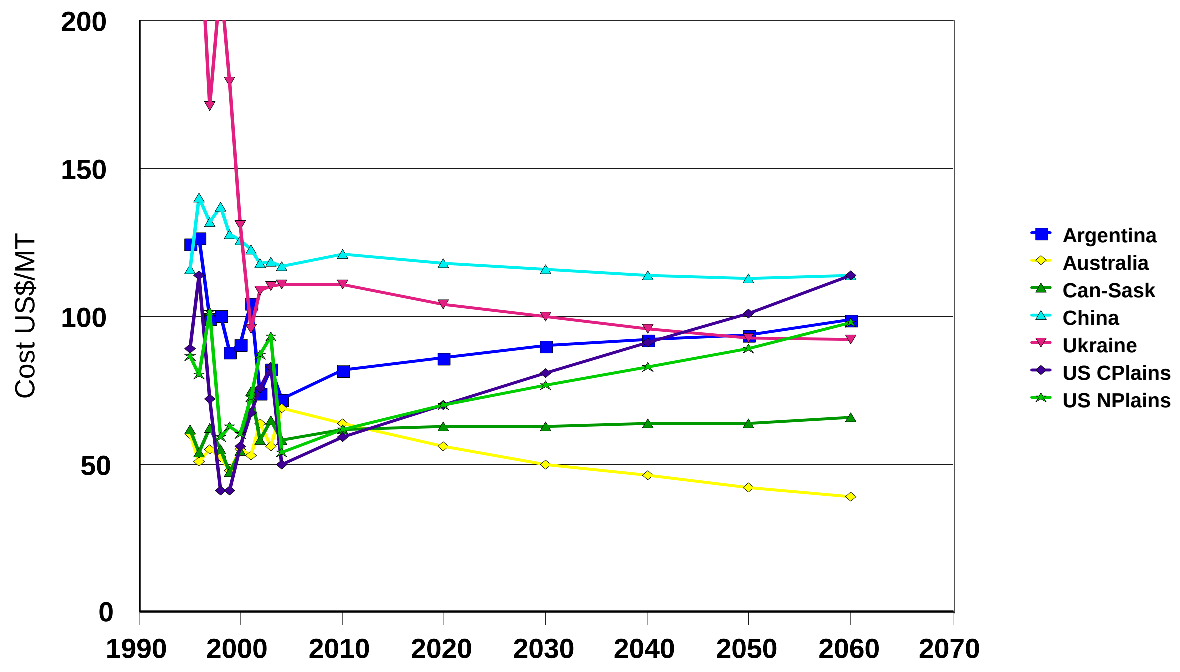

Figure 3. Wheat Cost of Production

Development of the U.S. Ethanol Industry

An important change in U.S. grain consumption is corn use for ethanol. This industry has been expanding during the past decade and its rate of expansion is expected to accelerate in the coming decade. This will impact demand for domestic consumption of corn in the future and reduce exportable supplies.

For perspective on growth and changes in this sector, in 2003 the indications were that the demand for corn for ethanol was projected to increase by one billion bushels in the next 10 years (Feltes 2003) and the United States will need another 40 or 50 ethanol plants and that would divert another one billion bushels of corn to match the same billion bushels devoted to ethanol production today (ProExporter 2004). And, "more than one billion bushels of corn will be used to produce ethanol in 2003/04, and this approaches two billion bushels by the end o f the decade" (USDA-ERS 2003). These assertions were made prior to the specifications in the recent Energy Bill which expanded the future role of ethanol and biodiesel. The Energy Policy Act of 2005 established the Renewable Fuel Standards (RFS) at 4 billion gallons in 2006, increasing to 7.5 billion gallons by 2012.

There are numerous aspects of the growth in demand for ethanol production. One is the location of new ethanol plants. In the analysis, corn demand was split into that for ethanol and that for all other domestic consumption. Then, assumptions and transformations were used to derive ethanol demand by region. A map of current ethanol plants (including planned plants) is shown in Figures 4 and 5, and the results of this transformation are shown in Table 1.[3]

Though ethanol production was earlier concentrated in the Eastern Corn Belt, the recent expansions have concentrated in the Western Corn Belt which now has about 42% of the capacity. The Central Plains is the third largest region. Earlier plants located away from the Mississippi River system, but a number of the more recent plants are located more near the Mississippi River.

Existing plants comprise 4,490 million gallons of capacity and when taken together with planned plants, total capacity would be 6,715 million gallons. (Figure 4).

Projections have changed recently on ethanol targets and mandates. Both the EIA 2005 and 2006 report projections to 2015 in ProExporter (2006d). The EIA 2005 more consistently coincides with our base case parameters and generally has ethanol from corn production at just less than 4 billion gallons. The EIA 2006 estimates reflect current notions of ethanol production as reflected in the EIA projections and reflective of the President's policy goals. In this case, corn used in ethanol production increases from 4 billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons in 2020 forward. In the period after 2015, a minor portion of this will be met by ethanol from cellulose (EIA 2005). These are fairly drastic changes. Demand growth should taper off beginning in about 2020. These levels of ethanol consumption suggest the growth in demand for corn for ethanol to increase from about 1.4 billion bushels in 2005/06 to about 4 billion bushels by 2020.

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[3] These plants and planned projects were taken from Renewable Fuels Association (2006).

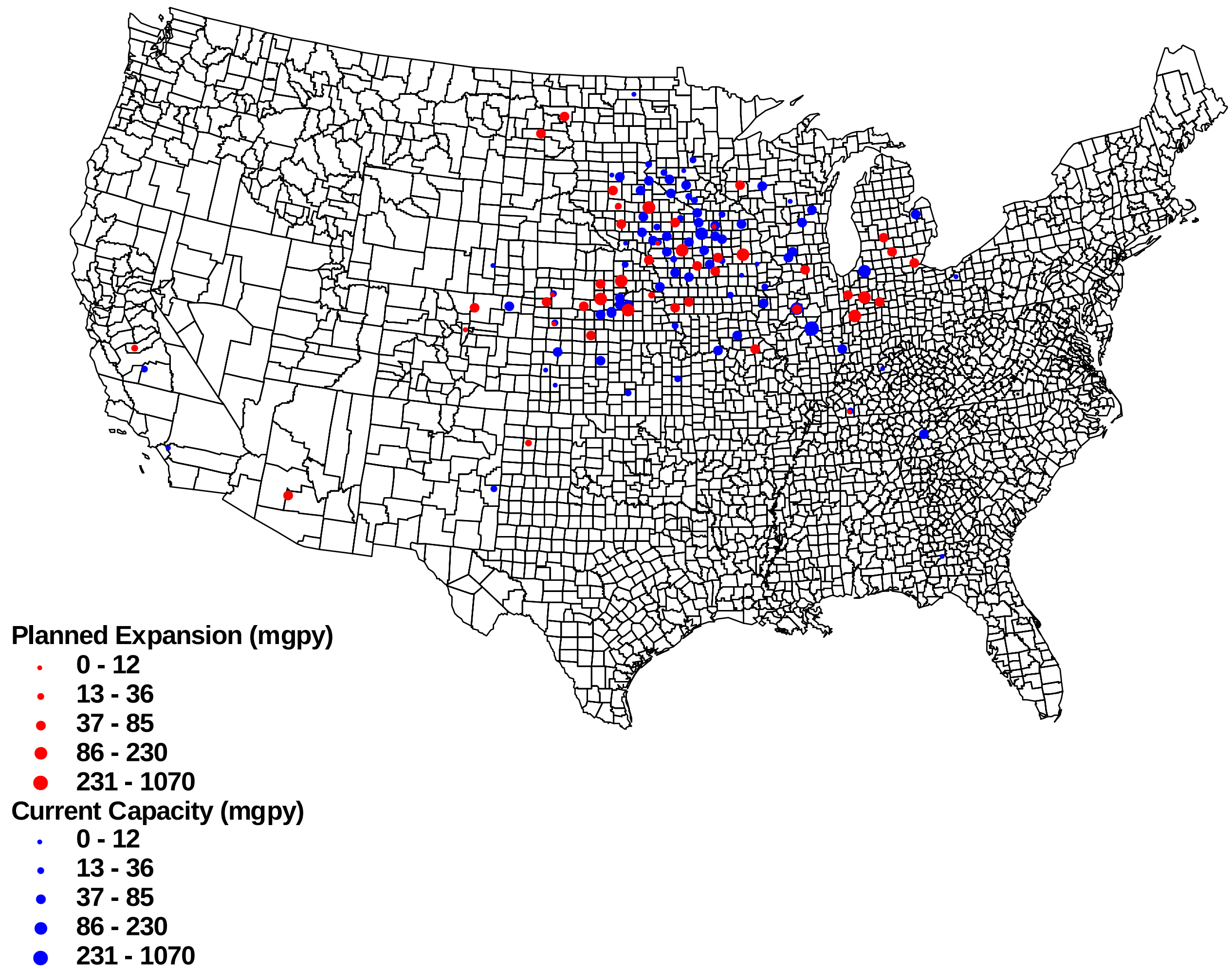

Figure 4. Location of Current and Planned Ethanol Capacity, 2006

Table 1. Percent of U.S. Consumption by Crop and Region, 2003-2005

Region	Total Corn Demand	Corn Demand for Ethanol Use	All Other Demand
US Central Plains	14%	17%	13%
US Delta	4%	0%	5%
US Eastern Corn Belt	21%	26%	21%
US North East	5%	0%	6%
US Northern Plains	4%	12%	2%
US Pacific North West	2%	0%	2%
US South East	15%	2%	17%
US Southern Plains	8%	0%	9%
US Western Corn Belt	24%	42%	20%
US West	4%	0%	5%

The principal byproduct from ethanol production is referred to as distillers dry grains (DDGs). Wide-scale use of the byproducts is just evolving and there is much to be known about its feeding value and shipping characteristics. A smaller amount is expected to be exported due in part to its lower value and higher cost of shipping. For our purposes, the impact of using corn for ethanol is to reduce the supply of corn available for domestic feed use and to reduce the domestic demand for feed corn which is displaced in part by DDGs.[4]

There are numerous issues and views on the prospects of there being enough corn to meet demands for both the growing world market and the U.S. ethanol market. For discussion here, these include the ethanol processing projections and impacts on demand, yields, and the ability to increase production, impacts on longer-term equilibrium, and impacts on grain flows. Each is discussed below.

Ethanol Processing Projections and Impacts on Demand

Development of the ethanol industry is one of the most dynamic changes in U.S. agriculture in numerous decades. Most important is the very rapid increase in ethanol processing and the concurrent impacts on demand. Using the above geographical depiction of the industry as of mid-2006, there are numerous changes occurring. These are highlighted below and taken from varying sources:

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[4] The maximum amount that can be used in rations varies by animal type and composition of herds. The value used is similar to that used by ProExporter (2006) averaged over the period 2000-2004. The rate of adoption of DDGs for corn is less than the rate of substitution in corn rations (i.e., more corn could be displaced with wider adoption of DDGs for livestock ratios). The substitition rate of DDGs for corn in livestock is 40 lbs. of corn is displaced by 400 lbs. of DDGs and for swine and poultry, 177 lbs. of corn is displaced by 200 lbs. of DDGs (Urbanchuk 2003). An article covering the effect of ethanol on Iowa indicated DDGs are largely fed to cattle and that swine and poultry are largely untapped markets (Otto and Gallagher 2003).

» Plans for new plants and expansions continue to change. Current expansion plans suggest that south central Minnesota and Central Nebraska will soon be corn deficit (Proexporter 2006e). Recently, the state of Illinois indicated that there are seven operating plants, and 30 plants in various planning stages, and 24 operating units in Iowa (as reported by the Associated Press (2006), and citing statistics from the Renewable Fuels Association, Iowa Renewable Fuels Association, and Illinois Corn Growers Association). The state of Nebraska has 12 plants running and about 22 ethanol plants in the planning stages, and 4 projects were under way in North Dakota including plants in Hankinson, Richardton, Spiritwood, and Underwood (*AgWeek*, 2006b) and an additional one was to be announced in Williston on July 7, 2006.

» The state of Iowa exported 803 million bushels in 2003, but by 2008 would be deficit 400-500 million bushels with existing plants running at rated capacity (Wisner, 2007);

» ProExporter recently estimated there were for 5.3 billion gallons of capacity currently operating and another 6 billion under construction. In addition, they indicated there were an additional 369 projects on the drawing boards representing an additional 24.7 billion gallons of ethanol capacity (as reported in Mann Global Research, 2006c). They indicated the ethanol margin in 2005 was 152 c/bu of corn processed, and this has declined to 44 c/bu which was more than attractive to justify additional investment.

» In contrast, Goldman Sachs (as reported by Red River Farm Network, 2006c) expressed worry about high corn prices indicating that rising corn prices threaten profitability of ethanol. Biomargins have been hurt by a 55% increase in corn prices and the price of ethanol has risen by 8%. Without producer incentives and tax credits, Goldman believes many biofuel plants would be unprofitable.

» By 2012, using data from the Renewable Fuel Association, corn demand for ethanol would be 2.7 billion bushels. ProExporter (2006e) indicated by this period, ethanol production would be 13.8 billion gallons and require nearly 5 billion bushels of corn.

Yields, CRP and the Ability to Increase Production: There is much debate and discussion about the ability of U.S. agriculture to respond to this change in demand. There are two areas of importance. One is the growth rate in yields, and the other is the source of additional acres that could be shifted to corn. View on these are summarized below:

» Schlicher indicated "Improvements in corn yields and the ethanol process will allow the number of gallons of ethanol produced per acre to increase from 385 gal in 2004 to 618 gal by 2015. The historical average annual corn yield increase was 1.87 bu/a; and is now averaged at 3.14 bu/a over the past 10 years...which shows the impact of ag biotech." ...with such improvements, she said, 10% of the country's gasoline can come from corn ethanol within a decade without sacrificing corn use elsewhere.

» Meyer indicated that corn yields in past 10 years have increased from 126 bu/a in 1996 to a projected 153 bu/a in 2006. The gains substantially over trend line per year are possible due to genetic modification as these adopted by growers. Stacking of traits in the next 3-5 years could result in corn production in 14-15 billion bushels per year on the same acres as 1996.

» Analysis conducted by Wisner and Hurd as summarized by Smith (2006) are most recent. They expressed caution on the potential to shift enough acres to corn to accommodate growth in ethanol, the prospects of a drought and concerns for the draw-down in stocks. In particular, Wisner analysis indicated: the increase in corn acres to meet these demands would be in the area of 11-12 million acres of corn by 2012, and, if China were an importer this would be 14 million acres. The added planted area could be taken from soybeans, other small grains or from the Conservation Reserve Program (but, with a majority coming from soybeans). Both he and Hurt emphasized that a corn supply crunch was on and the impacts of these will be reduced stocks after which each marketing year will be fraught with uncertainties about supplies.

» In response, the National Corn Growers Association indicated

...We can easily foresee a 15 billion corn crop by 2015...That's enough to support production of 15 to 18 billion gallons of ethanol per year and still supply the feed industry and exports, with some room for growth. (as reported by Zdrojewski, 2006).

This view is largely attributed to prospective advances in corn genetics and some acreage increase. Further, the NCGA indicated that corn use for fuel will not take away from food. This is "patently false, as US producers will continue to adequately supply all markets with high quality corn." Instead, their view is:

» The United States could produce 15 billion bushels to produce 15 billion gallons of ethanol by 2015. They indicated historic yield trends by 2010 would be 162 bu/a and 173 by 2015. Planted area would need to be about 90 million acres, up from 71 this year, which would be the highest plantings on record (the previous high was 75 million acres in 1986). The difference would come from CRP.

» And Rob Fraley (Chief Technology Officer at Monsanto), indicated corn yields double in 25 years, reaching 300 bu/a in 25 years which was a reasonable goal (Sosland Publishing, 2006). New technology includes traits influencing yields, drought tolerance, fertilizer use and pest resistance. Yields on dryland conditions could increase 8-10%. GM technology would also allow the redesign of corn to increase starch content. With this, he indicated it would be possible to increase ethanol production to 50 billion gallons, based on a corn crop of 25 billion bushels from 90 million acres in 2030.

Corn production could also be increased by changes in rotations. Fatka (2006b) reporting on a study by Hart (2006b) indicated that if Iowa and Illinois shifted to a 2:1 rotations for corn for soybeans, they could each add 3 million acres which would move the national total to 90 million acres. And, if all states shifted similarly, the acres available for corn planting would be 97 million.

A major policy concern is the role of CRP in expanding area available for planting. For perspective, there are 37 million acres in CRP. In 2007 there were 16 million acres scheduled to come out. USDA had earlier offered reenrollments of these acres. By mid-November, higher prices were not enticing landowners to move land back into production and USDA was expecting an 81% retention rate. There are 3 million acres in CRP that would be available for

2008 and USDA has made offers for CRP contracts expiring in 2008-2010 totaling 12 million acres. Preliminary estimates are that only 15% would be accepted (Kovers, 2006).

The ability to release area from CRP for this purpose is not as easy as posed. Fatka (2006a) indicated the industry was looking for 4-8 million acres of corn for next growing season. However, releasing these acres may end up costing the government money. Secretary of Agriculture Johannes has made no decision about paring down CRP to allow more planting for biofuels, and said plans to kick out acreage are baseless. Further, land in CRP would face steep penalties if ended before the contracts expire and there are substantial costs to getting land prepared and ready for cropping. Mann Global Research (2006c) reported that the trade is fully aware that up to 3 million CRP acres could be available in 2007. However, they noted that this CRP land is of questionable agricultural value, with the biggest chunk in Texas, Kansas and North Dakota. Some of this could be switched into wheat, but corn would be unlikely. The crop land coming out of production in the Corn Belt is limited, with Minnesota and Iowa at about 300,000-500,000 acres. Though USDA had hinted that a plan has been formulated to increase the amount of acres from the CPR, any further details were merely speculation.

While farmers with CRP could opt out of the contracts, they would incur penalties to do so (Pates, 2006). Specifically, though there are ideas of early opt-outs, this is unlikely without a change in the rules. Under exiting rules, anyone wanting to opt out of a CRP contract would have to pay back all the money they had received in that contract, plus liquidated damages, a penalty equal to 25% of one annual payment, amongst other costs. Taken together, this is the reason that it is unlikely than much CRP area would be returned to production without a change in the rules.

Longer-term Equilibrium Impacts of Ethanol: In mid-2006, analysts have begun to caution on the potential impacts of ethanol on corn supply and demand.[5] At the heart of this issue is the resulting change in supply and demand, and issues related to food vs. fuel. As Dr. Thompson suggested, the US ethanol policy may work for the next decade but continued rapid growth in corn used for ethanol will set the stage for a collision of "food vs. fuel" when US agriculture productivity growth is no longer able to meet needs of fuel, export and domestic food sectors.

More recently, at a National Grain and Feed Association conference (as reported by Mann Global Research 2006c), Tierney indicated that considering growth in international oilseeds (growth=8-12 mmt/year), the decline in U.S. soybeans, and increasing Chinese corn demand, the area planted in Brazil would have to increase by 50% in coming years. This would be an increase to 27 mill acres to offset U.S. lost acres and growth in soybean demand.

One study modeled the U.S. corn industry with emphasis on the industrial uses of corn, especially ethanol (Taylor, et.al. 2006). The model is a partial equilibrium econometric

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[5]Issues related to ethanol have also become topics in some of the more popular business press. *Business Week* (August 14, 2006, p. 56) noted "Facilities that can turn kernels into clean fuel seem to be sprouting up faster than the corn itself. There are 101 ethanol plants in existence, more than 42 new facilities and expansions in the works, and another 100 in the planning stages....Investors are wowed by the combination of short supply, surging demand, and government subsidies that top $2 billion annually (Green). And, in a recent *Fortune* article (Brown, 2006), indicated that Iowa had 25 ethanol plants operating, four are under construction and another 26 are planned, and Wisener indicated "if all those plants are built, distilleries would use the entire Iowa corn harvest. Finally, Hurt indicated "There is a 'gold rush' occurring now in building ethanol plants" (as reported by Wulf, 2006).

simulation model and contained behavioral equations for production, domestic consumption, import demand and U.S. carry-over stocks. The world is divided into two regions, the United States and the rest of the world. The model increases (decreases) price until production increases (decreases) equals the decreasing (increasing) levels of consumption. The results showed that with expanded ethanol, production increases about 100 million bushels, feed use falls about 500 million bushels, exports fall about 80 million bushels and other industrial uses fall 20 million bushels. Price increases from $2.32 in 2014 under the base case to $2.46 under scenario 1 which has the effects of increasing production, reducing exports, other industrial uses, and feed uses.

FAPRI indicated that by 2010, 32% of the U.S. corn would be used in ethanol production (Schuff, 2006 a, b or c) and that due to the price increase, by 2010, corn acres would increase by seven million. Some of this (three million acres) would come from soybeans and the remainder from the CRP or other crops. USDA's most recent statement (Collins, 2006) indicated that ethanol plants will be able to bid corn away from a variety of other uses and that the United States will need substantial increases in corn acreage to prevent reductions in exports. He indicated corn acres would have to increase by 10 million acres more than during 2005 and 2006 (assuming ethanol increases to 10 billion gallons). Finally, he suggested the CRP will likely be examined during the 2007 Farm Bill process and that 4.3 to 7.2 million acres currently enrolled in the CRP "could be used to grow corn or soybeans in a sustainable way" (as reported by Schuff, 2006b). In recent Congressional testimony the point was made that "there could come a time in years ahead when U.S. agriculture may not be able to meet the increased needs of ethanol and biodiesel while continuing to supply feed needs of the poultry and livestock sectors" (Schuff, 2006c referring to testimony of processors to the House Agriculture Committee).

A recent CARD study modeled the potential impacts of ethanol on corn and international trade (Elobeid, Tokgoz, Hayes, Babcock and Hart, 2006). That analysis modeled returns in ethanol, and determined the corn price at which it would no longer induce investment in new ethanol capacity. It then introduced this price and demand in a multi-commodity international equilibrium trade model. The results indicated the long-run break-even corn price is 405c/bu. At this price, corn based ethanol would increase to 31.5 billion gallons by 2015. To support this industry, the U.S. would have to plant 95.6 million acres of corn (vs. 79 million in 2006) and produce 15.6 billion bushels (vs. 11 billion today). Most of the acres would come from reduced soybean acreage. Corn exports would be reduced substantially and the study even suggested the U.S. could become a corn importer. There would be a 9 million-acre reduction in soybean area and a change in rotation from corn-soybean to corn-corn-soybean. Finally, wheat prices would increase 20%, and there would be a 3% reduction in wheat area with wheat feed use increasing. Wheat exports decline 16%.

ProExporter (2006e), in their *Blue Sky* model indicated a permanent shift in corn prices to the 350-400c/bu on-average area into at least 2015 based on ongoing expansion in ethanol demand. He suggested there would be origination wars in Minnesota, Iowa and Nebraska as shuttle shippers for feed to California and the Southwest, and the Pacific Northwest (PNW) have to compete with ethanol. However, due to superior margins in ethanol, the latter would set the price and force others to pay more. Stocks would be drawn down, reduced exports and there would be greater volatility in prices and supplies.

Much of these issues revolve around assumptions on future supply and demand (e.g., as done by analysts in this area, (ProExporter 2006d). In many of these cases, the analysis makes assumptions about critical variables, namely about increased yields, increased conversions from corn to ethanol, and increased area planted to corn. With adjustments in these values, by drawing down stocks, and assuming no risk or crop shortfalls, one can demonstrate there would be adequate supplies to meet the increased demand for ethanol, though, typically, exports would decline.

Impacts on Grain Flows: Ethanol is already having an impact on grain flows and barge demand in particular. Informa Economics indicated that:

> *... ethanol expansion is changing the grain flow landscape. In Illinois, the representatives share of its corn production that would have gone to ethanol production in 2004 totaled 13%. For the 2005/06 crop year, it is anticipated that ethanol's share of the Illinois' production harvest will be 18% increasing to more than 25% of this coming fall harvest. In South Dakota, ethanol's share is teetering on nearly half of the state's corn harvest expected for 2006, up from 30% two years ago. This is a similar situation for many corn belt states, especially those in the western Corn Belt where there is a surplus supply of corn. As more ethanol plants are built, this will have implications on the availability of surplus grain for various markets whether for export moves to the PNW or feed markets into the Southeast and Southwest.*

Barge Shipping Costs and Delay Functions

An important element of the analysis is barge shipping costs. These are comprised of the barge rates which are represented as functions and delay costs which are defined below . Six origins were defined on the Mississippi river system. These were defined as Reaches and encompassed all origins within that geographic region. These are defined below and illustrated in Figure 5:

Reach 1 Cairo to LaGrange (St. Louis);
Reach 2 LaGrange to McGregor (Davenport);
Reach 3 McGregor to Minneapolis (Mpls);
Reach 4 Illinois River (Peoria);
Reach 5 Cairo to Louisville (Louisville); and
Reach 6 Cincinnati

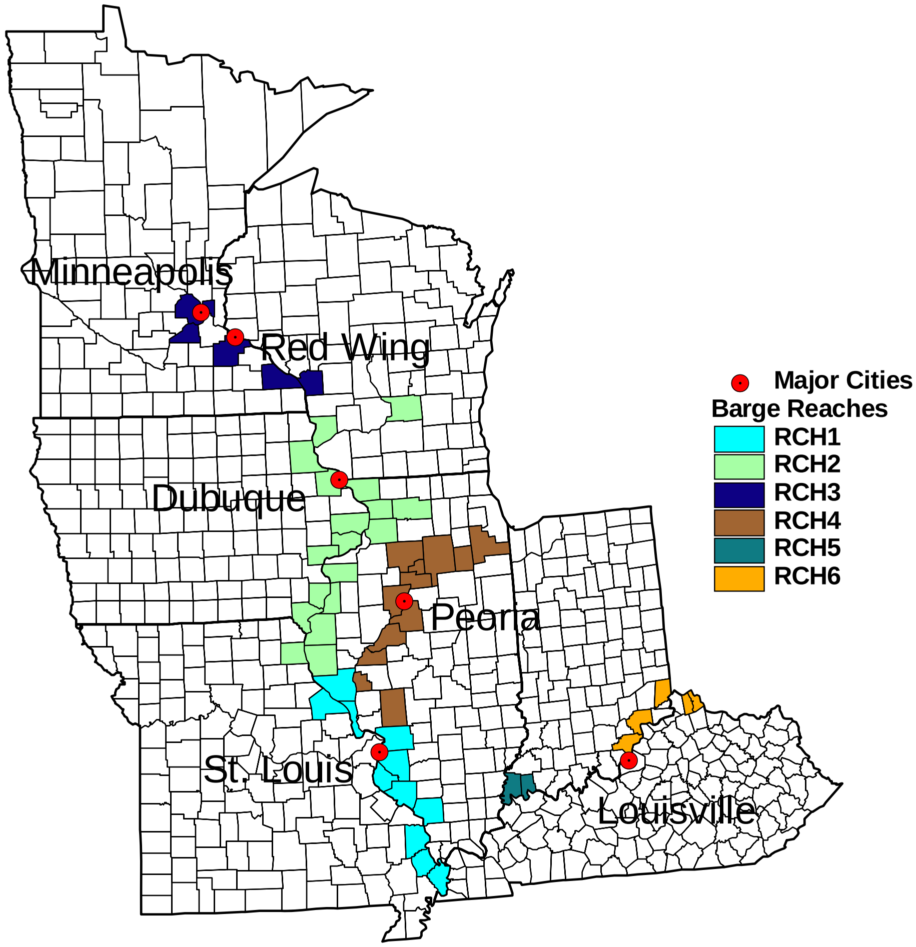

Figure 5. Barge Reach Definitions.

Barge shipping costs were represented as a rate function. In addition to this value, a delay cost was added to the rate if the volume shipped resulted in a volume sufficient to cause delays.

Barge rate functions were derived for each Reach (Figure 6). Reaches 5-6 had the highest slope indicating a higher rate sensitivity to volume shipped. Reach 4 had the lowest slope, followed by Reach 2, 1 and 3.

Delay curves were derived for Reaches 1-4. For Reach 5 and 6, it was assumed that traffic would remain relatively low compared to lock capacity. Consequently, changes in delay costs were assumed to be insignificant. Delay costs were derived through simulation assuming normal levels of other traffic (Oak Ridge National Laboratory). These were derived for current capacity, as well as for the expanded lock system capacity.

These delay costs reflect the relationship between total tonnage moving over the Reach and expected delay costs. Grain originated on Reach 3 contributes to the traffic and delay in Reach 2 and in Reach 1. Shipments on Reach 1 would not contribute to traffic in Reach 2 or 3. Traffic levels for grain and non-grain during the base period (2000-2004) were used to calibrate the curves. The base assumption is for nil growth in non-grain traffic and a sensitivity is used to illustrate the impacts of this assumption. Finally, the delay costs were derived for both the existing capacity, as well as for an expanded lock system. It is anticipated that any expansion would take 13-14 years, so, the impact of an expansion is expected in 2020.

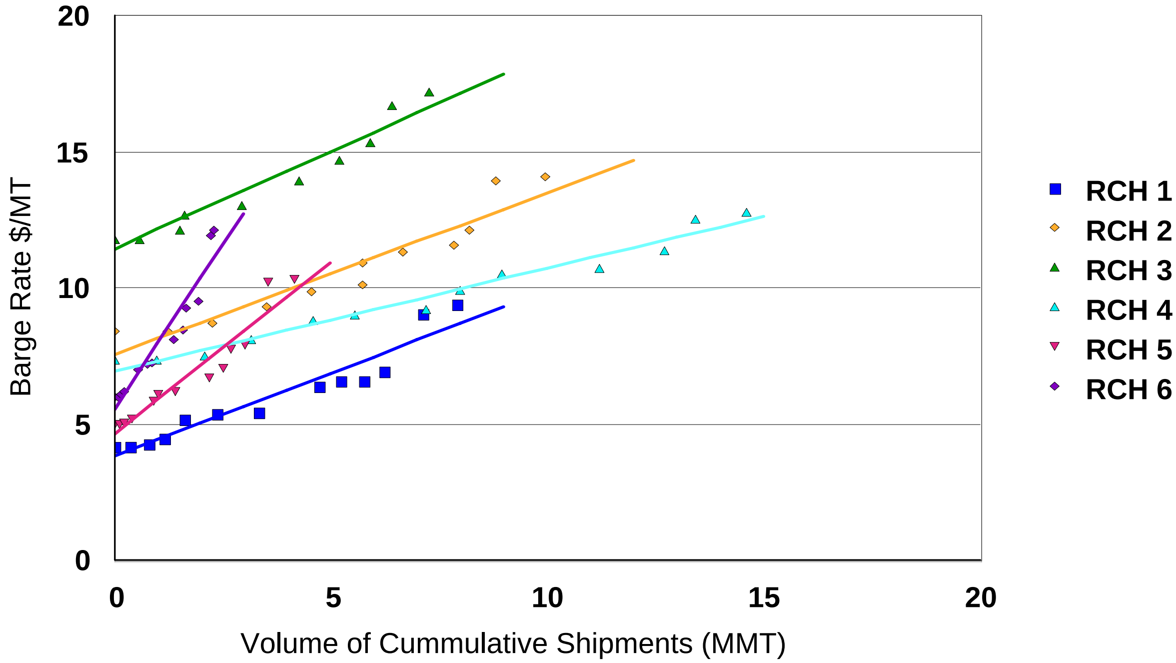

Figure 6. Estimated Barge Rate Functions

Figure 7 shows the delay costs and how they are impacted by grain volume. The impact of non-grain volumes in addition to grain on delay costs (grain + non-grain) are shown in Figure 8. Over a fairly wide range of tonnage that includes current traffic levels, delay costs are not particularly sensitive to changes in volume. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic. For most Reaches, current volume is less than the level at which delay costs would begin to escalate sharply. In addition, in some cases there is a very slight negative delay cost.[6]

For Reach 2, the increased costs associated with delay for traffic less than about 28 mmt of grain traffic is near nil. Costs increase very sharply for traffic greater than about 30 mmt. In addition, there are slight negative delay costs for volumes less than about 18 mmt. For Reach 1, which reflects the cumulative traffic of grain entering in either Reach 1 (above lock 27), 2 or 3, costs begin to increase for volumes greater than about 38 mmt. At grain traffic of about 38 mmt, the increase in delay costs is very sharp. Finally, at Reach 4, delay costs are near nil up to about 28 mmt and then increase sharply. For movements greater than these values, the increase in

[6] To clarify, the solution for existing barge system occurs at lower values than the 5 year average. Thus, negative values should be interpreted relative to a reference point, and the change derived. The reference is the base period, 2000-2004, which imputes a certain level of delay cost. In the results, these are compared to alternative solutions and differences derived.

delay costs becomes exponential which occurs at different levels for each Reach. It is this value that would reflect the maximum capacity in the model.

The delay curves would change if there were an expansion, as proposed. In each case the proposed improvements would have the impact of shifting the delay function rightwards meaning that near-nil delay costs would exist for a broader range of shipments. In addition, the value of the negative delay costs for lower volumes are slightly greater than in the previous case.

The total cost of shipping by barge comprises the rate generated from the barge rate function and the delay costs. These are shown in Figure 9 for each Reach. As volumes increase, there is an increase in barge rates corresponding to the barge rate function. Thereafter, at some level, the delay costs begin to have an impact and further increases occur due to the delay costs**.**

Rail Rates on Selected Barge Competitive Routes

Rail rates used in this study are from the U.S. Surface Transportation Board (STB) rail rate data. There has been a notable change in rail pricing that occurred within the time period of this study. In particular, rail rates declined and in some cases are lesser than rates on barge movements.

The data used in the study were combined to make comparisons of some of the critical rail and barge rate relationships for illustration. The results are summarized in Tables 2-4. For each commodity comparisons are made between rail and barge costs using the average of the rates over the period 2000 to 2004. In each case the least cost movement is identified.

Some of the important relationships are noted below, particularly as they impact spatial competition amongst modes:

Corn: Shipments from Northern Illinois favor direct rail to the U.S. Gulf, followed by shipments via Reach 1. From Minnesota the least cost is by barge through Reach 2 and from Minnesota River regions the least cost is by barge from Reach 3;

Wheat: The least cost movement from Northern Illinois is direct rail (by nearly $7/mt); direct rail to Texas Gulf from Minnesota (by over $2/mt); and for shipments from the Minnesota River to Reach 3 and then barge to U.S. Gulf;

Soybean: Shipments via Reach 4 from Northern Illinois is least cost. Barge shipments via Reach 1 from Minnesota and from Reach 2 from Minnesota River are least cost. The advantage of Reach 1 versus Reach 3 is about $6/mt; and of Reach 2 versus Reach 3 is about $3.50/mt.

These relationships have a critical impact on commodity flows. However, there are a number of differences in the empirical model. First the model also allows for truck shipments to the Reaches. Second, handling costs and the differentials are important. Third, the model uses barge rate functions to determine volumes and rates

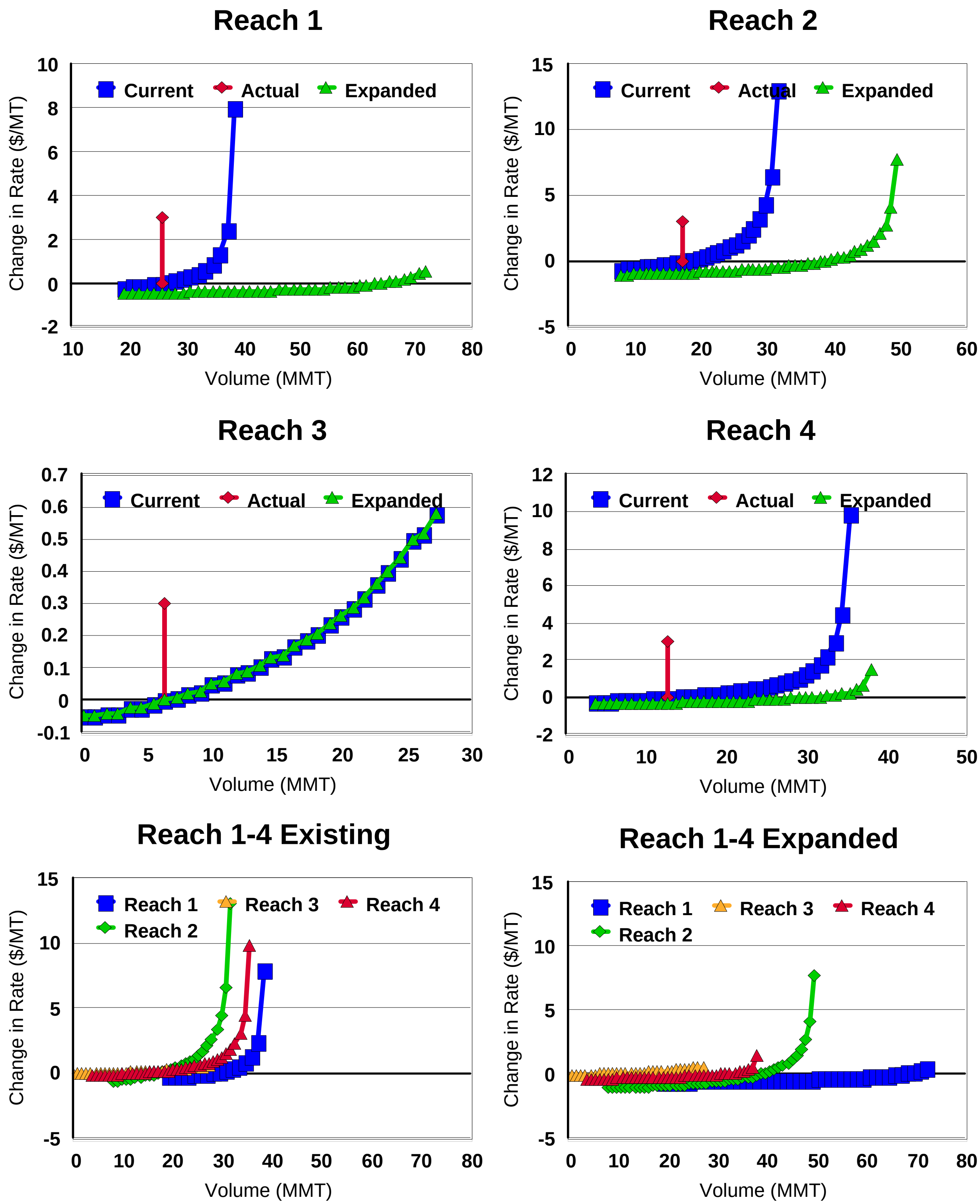

Figure 7. Delay Costs and Actual Volumes, Existing and Expanded Capacity: Grain Volumes Only

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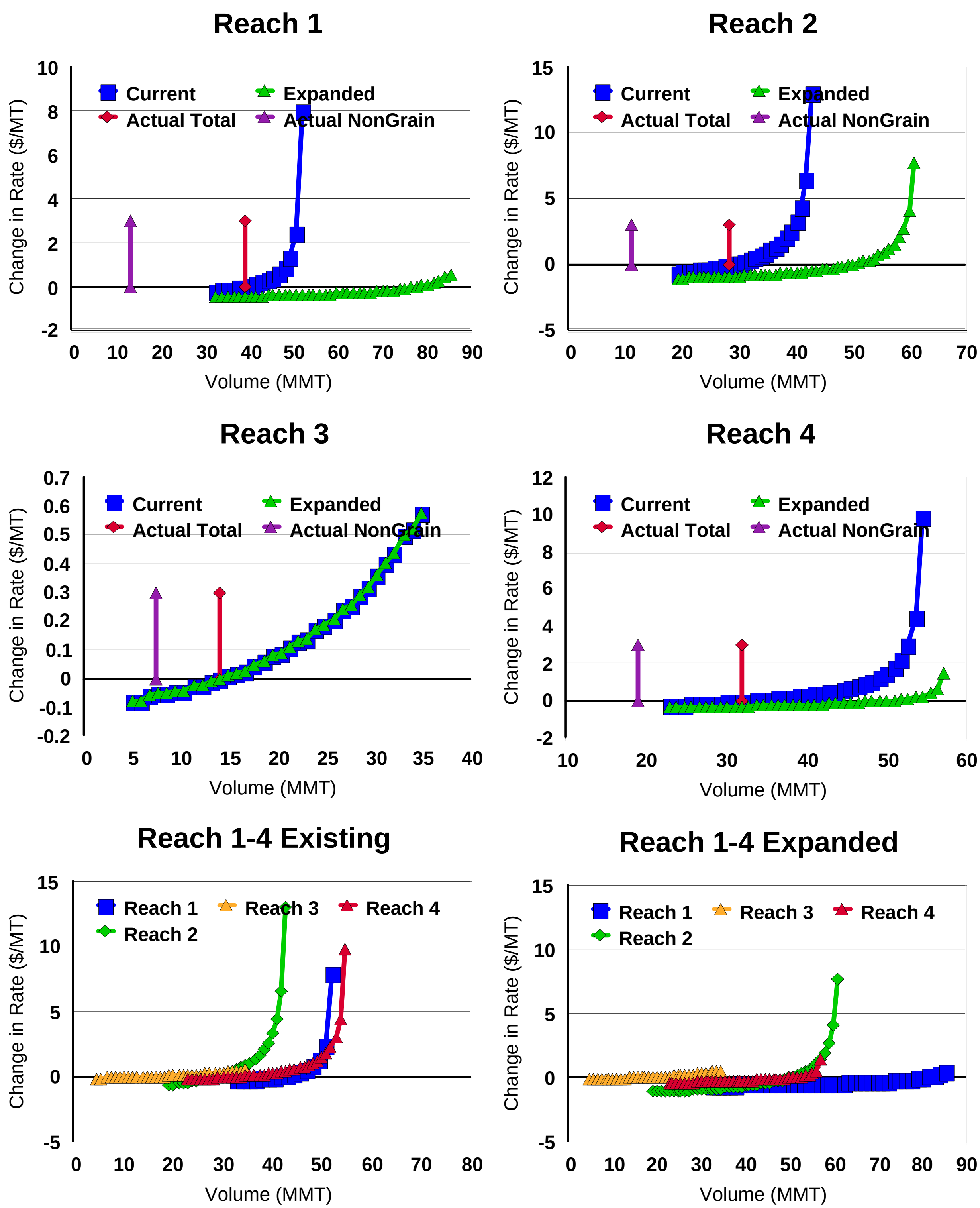
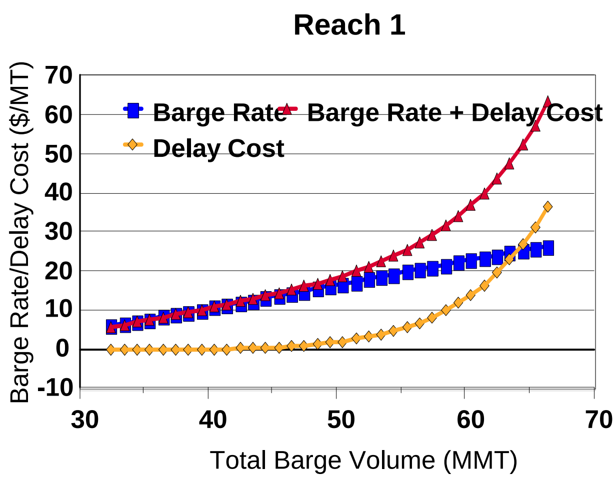
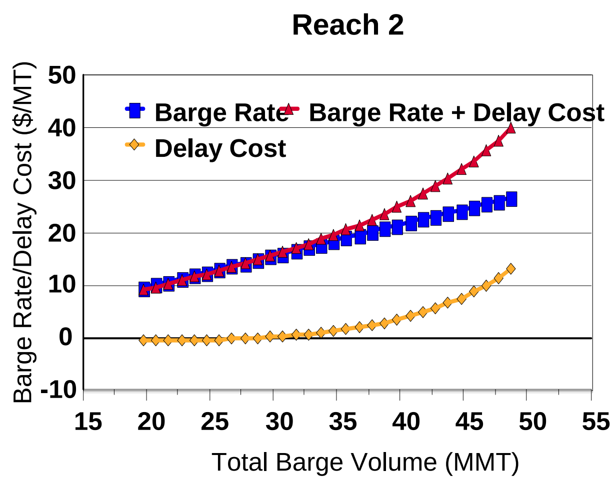


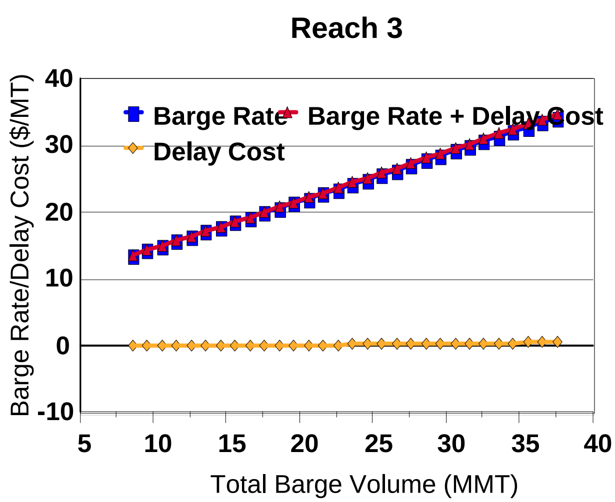
Figure 8. Delay Costs and Actual Non-Grain and Total Volumes, Existing and Expanded Capacity



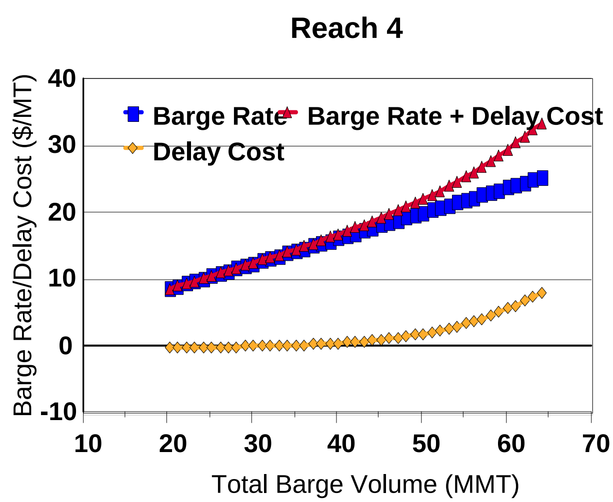
* Assumes NonGrain Volume=13.426 mmt
and Reach 2 +3 = historical average (18.96 MMT)



* Assumes NonGrain Volume=11.340 mmt
and Reach 3 grain at historical levels (7.62 MMT)



* Assumes NonGrain Volume=7.620 mmt



* Assumes NonGrain Volume=19.232 mmt

Figure 9. Barge Rates, Delay Costs and Total Barge Cost for Cumulative Barge Volume (Total Flows through Reach including Non-Grain Traffic), by Reach, Current Capacity

Table 2. Corn: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	6.55	5.81	12.36	
RCH4	3.95	9.97	13.92	
NOLA Direct	10.69		10.69	**
Minnesota				
RCH3	8.36	14.03	22.39	
RCH2	10.16	10.71	20.87	**
RCH1		6.51		
NOLA Direct	24.23		24.23	
TXGulf	24.12		24.12	
Minnesota River				
RCH3	5.53	14.03	19.56	**
RCH2	9.23	10.71	19.94	
RCH1	13.99	6.51	20.50	
NOLA Direct	25.21		25.21	
TXGulf				

Table 3. Wheat: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	12.16	6.51	18.67	
RCH4		9.97		
NOLA Direct	11.75		11.75	**
Minnesota				
RCH3	16.48	14.03	30.51	
RCH2	23.61	10.71	34.32	
RCH1	23.21	6.51	29.72	
NOLA Direct	36.85		36.85	
TXGulf	28.16		28.16	**
Minnesota River				
RCH3	7.52	14.03	21.55	**
RCH2		10.71		
RCH1	18.46	6.51	24.97	
TXGulf	50.60		50.60	

Table 4. Soybeans: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	10.01	6.86	16.87	
RCH4	2.54	9.60	12.14	**
NOLA Direct	13.19		13.19	
Minnesota				
RCH3	13.22	14.03	27.25	
RCH2	15.22	10.71	25.93	
RCH1	14.77	6.51	21.28	**
NOLA Direct	24.56		24.56	
TXGulf	27.79		27.79	
Minnesota River				
RCH3	7.89	14.03	21.92	
RCH2	7.87	10.71	18.58	**
RCH1		6.51		
NOLA Direct	23.62		23.62	
TXGulf	35.07		35.07	

These results indicate the intermodal competitive rivalry. In recent years, the railroads are pricing to encourage grain to bypass the northern regions of the river with direct shipments direct to the US Gulf in some important movements. Indeed this is true in one of the most competitive markets in Illinois North both in terms of volume and its diversity of markets to which it can ship.

EMPIRICAL MODEL

To analyze competition and future trade implications, a large scale spatial partial optimization model of world trade in grains was developed. The model is not described here due to its volume. It is summarized briefly and a detailed representation is described in Wilson, Devuyst, Taylor, Dahl and Koo, 2006. The model, along with the data inputs and transformations, and more detailed results are available online [www.nets.iwr.usace.army.mil].

Briefly, the objective of the model is to minimize production costs of grain and oilseeds in major producing countries and marketing costs from producing regions to consuming regions, subject to meeting import demands at importing countries and regions, available supplies and production potential in each of the exporting countries and regions, and currently available shipping costs and technologies. The model includes agricultural production and export subsidies commonly used as production enhancements means in exporting countries, import tariffs as trade impediments in importing countries and other trade relations that may affect international competition.

The logic to the objective function is that it reflects what would be considered a longer-term competitive equilibrium whereby spatial flows are determined by costs, technical restrictions and other relationships. Under these conditions, trade flows of agricultural commodities would be determined by demand, production costs in exporting countries, marketing costs from exporting countries and trade interventions. Demand is projected and the least cost means of meeting that demand is derived. This differs from econometric models that use functional relationships to project equilibrium trade levels, but generally are incapable of capturing spatial elements of competition. Given our objective is to make longer-term forecasts and the greater emphasis on spatial and modal distributions, a model based on longer-term competitive equilibrium was developed. However, this class of models is not without problems. Most important is that there is no direct link between the grain sector and the rest of the economy. There are indirect links between consumption and population and incomes, and between production costs and exchange rates. However, these are not directly linked in the model. As a result, this is a partial spatial optimization model and subject to these restrictions.

The model is solved jointly for each of the 3 grains. Costs included in the model are direct production costs for each grain in each exporting country and region less production subsidies, interior shipping and handling cost for each grain in each exporting region less export subsidies and ocean shipping costs plus import tariffs. Transportation modes include truck, rail and barges for inland transportation and ocean vessel for ocean transportation. The model includes 6 reaches on the U.S. river system. Four of the six reaches have delay functions (names withheld) which reflect the possible river congestion costs which could delay flows and increases costs.

The objective function is optimized subject to a set of constraints. Some of these are arable land constraints in exporting countries, demand constraints for each type of grain and oilseed in consuming regions in both exporting and importing countries. In addition to the restrictions implied above, some selected restrictions were imposed on the model to calibrate it to current trade patterns. These were applied in order to capture some of the peculiarities associated with world grain shipments and summarized in Table 1.

The model was ultimately used to make projections. To do so, the following logic was used. Demand is projected for each country and region based on income and population projections from *Global Insights (2004a)*. Yield and production costs for each producing region are derived. Production potential is determined in each country/region subject to the area restriction. Modal rates were derived for the base period. Ocean shipping cost projections were based on oil, trend etc. Using these, the model was solved for each year in the projection horizon. The model determines quantity produced in each country and region, import demand, and trade flows from origins to destinations. The model was defined in GAMS and included 12,979 variables and 742 constraints.

Model Overview

A base case is defined and used for comparison with results from alternative scenarios. The base case is interpreted as a likely (current) scenario and uses data for the period 2000-2004. The model was used to make projections. The base case assumptions are defined in Table 5. The following logic was used to generate the projections:

- Demand is projected for each country and region based on income and population projections from Global Insights;
- Yield and production costs for each producing region are derived;
- Production potential is determined in each country/region subject to the area restriction;
- US modal rates were derived for the period 2000-2004 and it was assumed that their spatial relationship was the same during the projection period.

- Ocean shipping costs were projected based on oil, trend etc.

Using these, the model was solved for each year in the projection horizon which was defined in 10 year increments for 50 years.

Table 5. Assumption for the Base Period and Projection Period

Model Assumption	Base Period 2000-2004	Projection Period	Sensitivities during projection period
US rail car capacity	Restricted rail capacity		Restriction expanded
Modal rates	Rail from 2000-2004 average; barge rates represented as rate functions by Reach; ocean rates derived from a regression	Assumed same as base case	

US area restrictions	3 restrictions imposed:
	minimum total area=100% of recent 3 year average;
	maximum total area=100% of base;
	maximum area that can be switched among crops was 7% from the base period.
		Maximum changed to 107% in 2010 forward	Relaxed to allow expanded production as required

Rest of World (ROW) area restrictions	3 restrictions imposed: minimum total area=100% of recent 3 year average; and minimum area for any one crop=88% of base; maximum total area=107% of base; maximum area that can be switched among crops was 7% from the base period.	Maximum changed to 107% in 2010 107% in 2020 115% in 2030 115% in 2040 121% in 2060	Relaxed to allow expanded production as required
Ethanol production	EIA 2005 projections	EIA 2005 projections	EIA 2006 Projections and 7.5 billion gallons
China corn trade	Exports subsidized to 8 mmt	China exports=0	Relaxed restrictions on China imports and exports
Other Trade policies	Retained as in Appendix Table 2.1	Retained	

RESULTS

Base Case

The model generates numerous results. These include area devoted to each crop in each region and country; yields, production and consumption in each country; and export supplies and import demand for each country. In addition, it provides trade flows from each country, and within the United States provides optimal shipments through each port area, by each mode, and through each Reach. Since our concentration is on the flows through the barge system primarily, we report the flows on each Reach. In addition, the export levels by port area and grain are reported.

Model results are compared first at the world trade level, then at US export ports and finally for Reach shipments. In each case, model results were compared to actual results over the base period.

The model replicates well the total quantity of exports from the United States as well as most competitor countries. See Table 6. The level of exports by country and region suggest these are very comparable to levels that existed during the base period. Total US exports are 101 mmt and comprising 44, 30 and 27 mmt for corn, soybeans and wheat respectively. World trade in these grains is 83, 61 and 119 mmt respectively, for a total of 264 mmt.

Comparing model results to actual exports suggests these are very similar. A few clarifications are in order. Canada exports as shown here exclude the shipments to the US by rail which are interpreted (in the model) as domestic flows and are three mmt, which, when taken together are about equal to their total exports. Europe (as defined above to include Eastern Europe) exports corn which includes shipments from these other countries.

Table 6. Base Case Exports by Port and Region, Total and by Crop, (000 MT)

	Total	Corn	Soybeans	Wheat
Argentina	28,962	11,122	7,997	9,842
Australia	19,817	17	0	19,799
Brazil N	11,147	0	11,147	0
Brazil S	9,904	1,432	8,472	0
Can EC	512	0	0	512
Can WC	11,912	0	0	11,912
China	8,000	8,000	0	0
Europe	44,631	19,000	0	25,630
Latin Am.	3,696	0	3,696	0
Mexico	0	0	0	0
South Asia	24,721	0	0	24,721
US EC	2,554	0	0	2,554
US Gulf	65,215	32,767	19,924	12,524
US PNW	24,594	9,923	6,101	8,570
US Mex Dir	8,234	1,005	3,995	3,234
Grand Total	263,899	83,266	61,333	119,299
US Total	100,597	43,695	30,020	26,882

* Note the export number in this and future tables and figures do not include the direct rail shipments from U.S. to Mexico.

U.S. Port Shipments: See Table 7. Results from the model are very comparable to actual shipments. Export volumes from the US are comparable by grain type as are interport exports. The exception is East Coast exports which as discussed above should be sightly greater than generated from the model. Otherwise, interport shipments are very comparable.

Table 7. Comparison of Historical U.S. Export Shipments by Port Area and Crop to Base Case Results (000 MT)

Historical U.S. Export Shipments (2000-2004)				
	Total	Corn	Soybeans	Wheat
East Coast/Lakes	5,960	1,507	2,049	2,405
Gulf	67,774	33,952	19,908	13,915
PNW	20,663	6,521	3,749	10,393
Internal	4,426	1,878	1,991	557
Total	98,823	43,858	27,969	27,269
Base Case - Current Capacity				
	Total	Corn	Soybeans	Wheat
East Coast/Lakes	2,554	0	0	2,554
Gulf	65,215	32,767	19,924	12,524
PNW	24,594	9,923	6,101	8,570
Internal - Mexico	8,234	1,005	3,995	3,234
Total	100,597	43,695	30,020	26,882

Note: Internal Shipments to Mexico Added to U.S. Export Numbers to be Comparable to Historical.

Reach Shipments: Reach shipments are shown in Tables 8 and 9 with comparisons to the actual shipments average over the period 2000-2004. Actual shipments were 47 mmt, and varied from 43 to 51 mmt with sharp declines commencing from 2002. Shipments decreased from 51 mmt to 43 mmt over this period.

Reach shipments are also fairly reflective of historical shipments during the base period. The model results compare very favorably with a total of 51 mmt. These are concentrated with about 15 mmt soybeans, 33 mmt corn and 3 mmt wheat. These are generally comparable when aggregating across Reaches, as well as within Reaches. Important differences are that the model overestimates the amount being shipped from Reach 4 and underestimates that being shipped from Reach 2. Upon further experimentation, there are very close interrelationships among shipments from Illinois and Iowa to Reach 2 and Reach 4, as well as to shipments in the Western

Corn Belt and the South East for domestic shipments. The model also has greater shipments through Reach 3 than observed in practice. However, the sum of shipments on Reach 2 and 3 are comparable[7]

Table 8. Comparison of Average Barge Reach Loadings and Base Case (Corn + Soybeans + Wheat)

Reach	Average 2000-2004	Base Case	Difference
	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,909	7,154	(755)
Reach 2	10,626	3,781	(6,845)
Reach 3	7,450	12,235	4,785
Reach 4	14,608	21,771	7,163
Reach 5	4,169	4,184	15
Reach 6	2,317	2,050	(267)
Total	47,079	51,175	4,096

[7] Upon further examination, the model has about 12 mmt from Minn. River to Reach 3. This exceeds observed volumes of 7.5 mmt. We were unable to reconcile this difference. There is sufficient supplies and demand to rationalize this shipment, and historically, shipments occur on this node which is all corn and soybeans, by truck to Reach 3.

The only way to reduce this within the model would be to increase truck rates (see below), or increase barge rates. We did neither. However, to explore this issue further, we adjusted truck rates to Reach 2, 3, and 4 to better capture the observed inter-Reach allocation. In this case inbound truck rates to each Reach would have to change as follows: Reach 2 -3$/mt; Reach 3 +$6/mt; and Reach 4 +$5/mt. Again, this was only explorative and are explained here for interest, however, these truck rate adjustments were not used in the model.

Table 9. Comparison of Average Barge Reach Loadings and Base Case by Grain

Reach	Total	Corn	Soybeans	Wheat
Avg. 2000-04	(000 MT)	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,909	4,144	2,227	1,538
Reach 2	10,626	7,483	3,007	136
Reach 3	7,450	5,384	1,680	386
Reach 4	14,608	10,853	3,557	199
Reach 5	4,169	2,758	982	430
Reach 6	2,317	1,214	985	118
Total	47,079	31,836	12,438	2,805
Base Case	(000 MT)	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,154	2,834	2,556	1,764
Reach 2	3,781	3,781	0	0
Reach 3	12,235	8,657	3,578	0
Reach 4	21,771	14,463	6,945	364
Reach 5	4,184	2,625	1,283	276
Reach 6	2,050	408	804	838
Total	51,175	32,767	15,166	3,242

Dominant US Domestic and Export Shipments: Domestic and export flows within the United States are shown in Tables 10-11. All of the movements generally coincide with expectations. Shipments to domestic consumption are as expected and comprising both rail and trucks. There are large barge flows from each of the Reaches to the points of export and by rail to the PNW.

There are a couple of notable shipments. Much of Illinois North is shipped to Reach 4, though as noted in Table 2, the relative rates favor rail direct to NOLA. Thus, if there is adequate rail capacity, this is the optimal shipment which displaces barges. The other is that Iowa River ships to Reach 2, as well as to the Western Corn Belt. This is as expected and verified in the STB data.

Table 10. U.S. Shipments from Production Regions to Export Reaches, Base Case (All Grains, Rail and Truck Movements, 000 MT)

U.S. Production Regions	U.S. Export Reaches										
	RCH1	RCH2	RCH3	RCH4	RCH5	RCH6	Toledo	Duluth	New Orleans	PNW	TX Gulf
USCP							407				4,900
USCPR									2,447		
USD									863		1,046
USIAR		3,781									
USILN				21,771							
USILS	1,571										
USINR					4,184						
USMN										2,656	
USMNR			12,235								
USMOR	3,505										
USMOW	1,321										340
USNP								2,147		14,328	138
USOH	758					2,050			1,448		
USPNW										1,798	2,858
USSE											
USSP										1,608	
USW											
USWIS											
USWIW											
USWNP										4,204	

Table 11. U.S. Shipments from Production Regions to Domestic Consumption Regions, Base Case (All Grains, Rail and Truck Movements, 000 MT)

U.S. Production Regions	US Consumption Regions									
	USCPC	USDC	USECBC	USNEC	USNPC	USPNWC	USSEC	USSPC	USWC	USWCBC
USCP	31,186						1,175			
USCPR	7,175	6,277				3,165			4,927	2,622
USD		8,297								
USIAR										13,428
USIAW										43,781
USILN			14,255				702			
USILS			5,125				15,583			
USINN			22,565							
USINR			1,423							
USMI			9,082							
USMN								3,832	3,593	1,790
USMNR										6,785
USMOR										234
USMOW			2,466					7,511		696
USNE			615	7,722						
USNP			2,662		10,229					
USOH				4,576			8,544			
USPNW						2,151			2,000	
USSE							18,515			
USSP								10,696		
USW									2,188	
USWIS			7,488							356
USWIW			3,006							15
USWNP					215					

Base Case Projections

The model was used to make projections on shipments through the river system. The logic of the analysis involves first projecting demand, along with costs and yields and then the model was solved to determine optimal flows. Consumption is estimated based on income and demographics and using projections for these variables from *Global Insights (2004a)*. Yields were projected based on nonlinear trends and production cost projections are those from *Global Insight (2004b)*. Modal rates are assumed at base period values and relationships. Projections were made in 10 year increments for 50 years.

The model was first simulated assuming existing capacity on the barge system, then with expanded capacities. The other critical assumption is about China. Here China is restricted to export eight mmt in the base period, and thereafter their exports and imports were restricted to nil. In a sensitivity we relax this assumption.

In some cases it was necessary to make adjustments to maximum area allowed to be planted in order to get a solution, i.e., so supplies exceeded demand on a world level. To do this, we retained the base case assumptions as much as possible, and then made adjustments for this purpose. In each case the adjustment was increased until a solution was attained. This is interpreted as a percentage of base total projected area, which varies through time (see model overview). For some countries there have been gradual reductions in area planted (e.g., US, EU and China) whereas in others there have been increases (e.g., Argentina and Brazil). The percentage adjustment was made relative to that projected area and in all cases was treated as a maximum restriction. For each simulation we report these. Those for the base case projections are shown below. The strict interpretation of this is that in order to produce adequate supplies to meet demand, and with the US maximum area fixed at 107%, the area devoted to these crops in the row would have to increase by these values.

Maximum Area Limit Relative to Projected Base Area to Achieve a Solution (%)						
	Base	*2010*	*2020*	*2030*	*2040*	*2060*
US	100	107	107	107	107	107
ROW	107	106	107	119	115	123

Projections with Existing Capacity: The model was first solved assuming existing capacity. Results are shown in Figures 10 to 12.

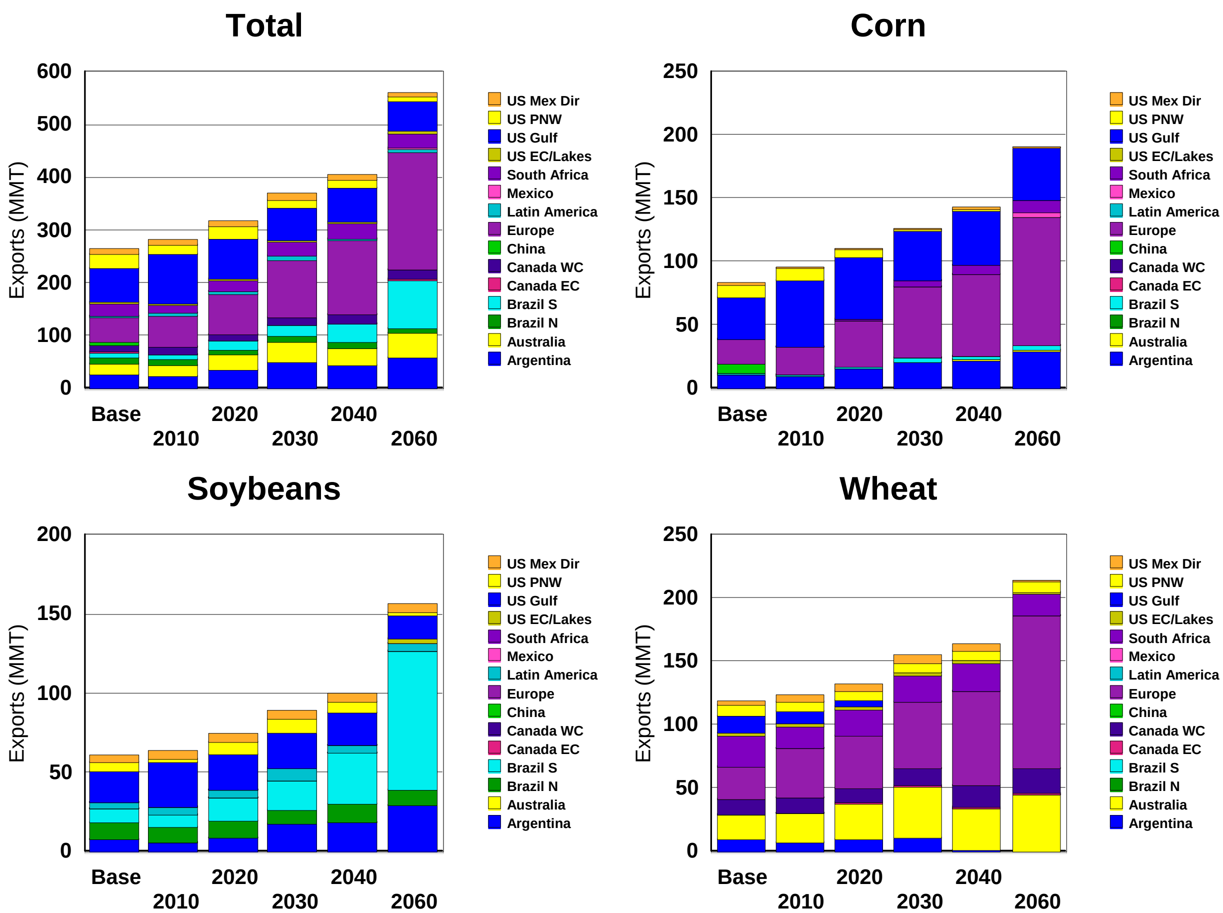


Figure 10. Base Case Projections: Exports

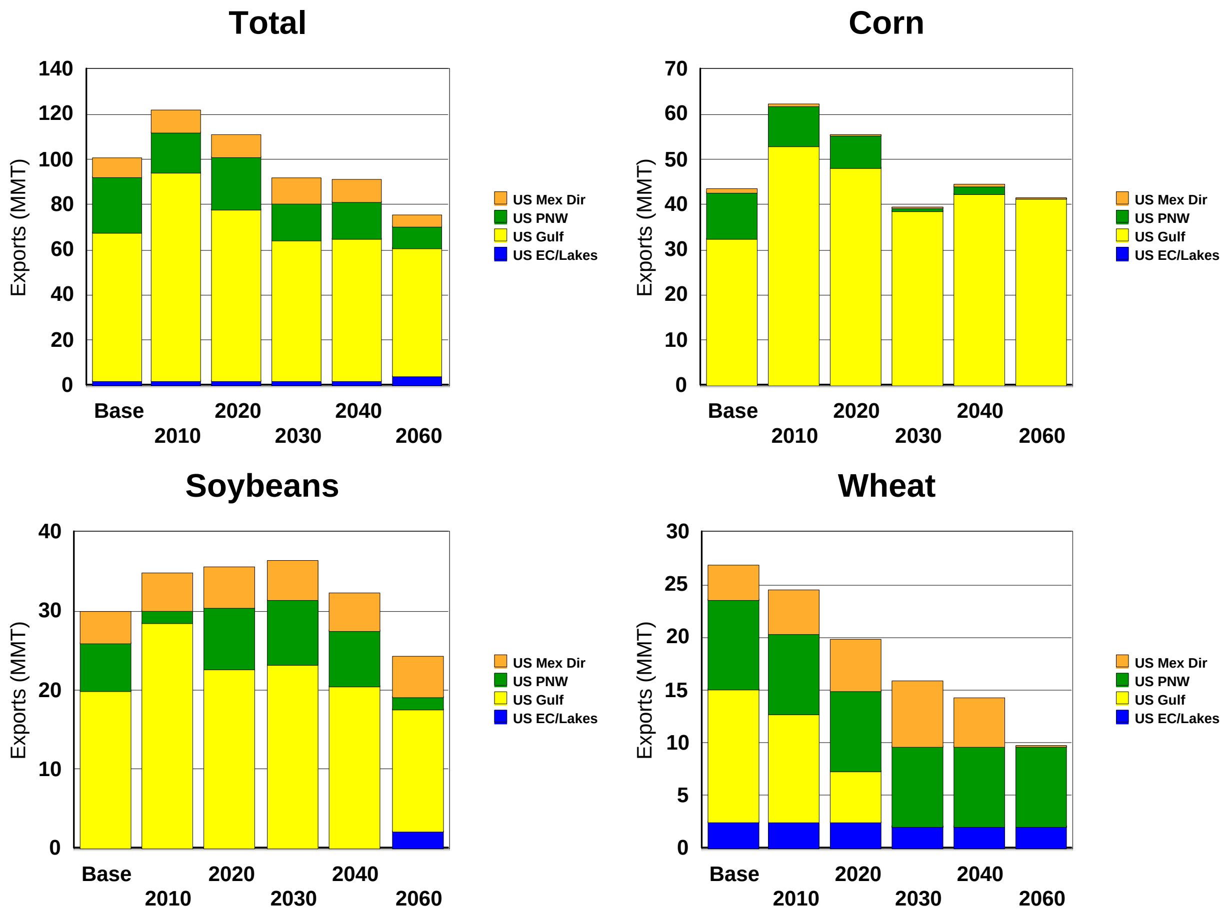


Figure 11. Base Case Projections: U.S. Exports by Port Area

Exports by country/region: Results indicate that total world trade increases from base values at 264 mmt to nearly 406 mmt in 2040 and 561 mmt in 2060. That for the US increases from 101 mmt to a peak at 122 mmt in 2010 and then declines. Countries and grains that have notable increases are Argentina (corn and soybeans, but wheat declines substantially), Australia wheat, Europe corn and wheat exports which includes Eastern Europe, Brazil soybeans which increase from about 20 to 97 mmt. Thus, the shift is for increased corn from Argentina and Eastern Europe, soybeans from Brazil and Argentina, increased wheat from Australia and Canada; and reduced wheat from Argentina and the United States. It should be noted that part of the increase, particularly in off-shore countries in the latter years is due to the need to expand area available in those countries to increase supplies to get a model solution.

Exports from the United States increase from the base period to 2010 in part due to the assumption that the maximum area for plantings would increase to 107% and in part due to that China's corn exports are reduced from eight mmt to nil in 2010. Thereafter China exports stay at nil. This implies a relaxed CRP (as represented by the 7% increase) and/or taking area from other crops (i.e., other than corn, soybeans and wheat). The decline that occurs after 2010 is in part due to increasing competitiveness of other exporting countries, increased domestic use of these crops (notably ethanol) which requires a shift in area planted amongst these crops. US corn exports decline the most, from a peak of 62 mmt to 42 mmt. Wheat exports decline substantially but soybeans increase, falling only in 2060.

Exports from the United States are concentrated in the US Gulf (including Texas Gulf) and decline from 101 to 76 mmt after reaching a peak in 2010. Exports from the PNW decline slightly from 25 mmt to 9 mmt in 2060. Again the reason for this is the increased domestic use and shifting amongst crops.

There are important area shifts amongst US crops. Most important is for an increase in corn area planted (recall, this was restricted to shift a maximum of 7%), and soybeans. These are offset by reductions in wheat area.

Finally, the results illustrate that the United States remains an important exporter of soybeans and this conclusion persists in other scenarios. There are reasons for this result. First, the United States is a lower cost producer of soybeans, compared to other countries and to Brazil North. Second, most of the growth for soybeans is international. Finally, Brazil has a higher amount of land to bring into production than the other soybean producers.[8] The cumulation of these means the United States retains its soybean production to the extent it is technically feasible (including substituting acres for corn, etc.), and exports the remainder. As the world needs more soybeans due to demand growth, it attracts that by increasing area devoted to soybeans, primarily in Brazil North, even though these are a higher cost.

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[8]The model allows the following maximum restrictions on Brazil area (in mil ha):

	2010	**2030**	**Possible Increase in Maximum Area %**
Brazil North	12.5	16.3	30
Brazil South	10.4	10.8	4

For comparison and to illustrate the importance of US area restrictions, we ran the model for 2010 assuming the maximum area was 100%, as opposed to 107% shown here. The impacts of this are to shift area and exports to other countries as expected. From a port perspective, the PNW shipments decline from 18 mmt to 9 mmt; and those through the US gulf decline from 92 to 72 mmt.

Reach Shipments: See Figure 12. Reach volume increases from the base period at 51 mmt to 65 mmt in 2020. Thereafter, shipments decline to a longer term level at about 57 mmt. The reduced volume comes from both reduced wheat shipments which declines drastically (from three mmt to nil) and soybeans which occurs in 2060.

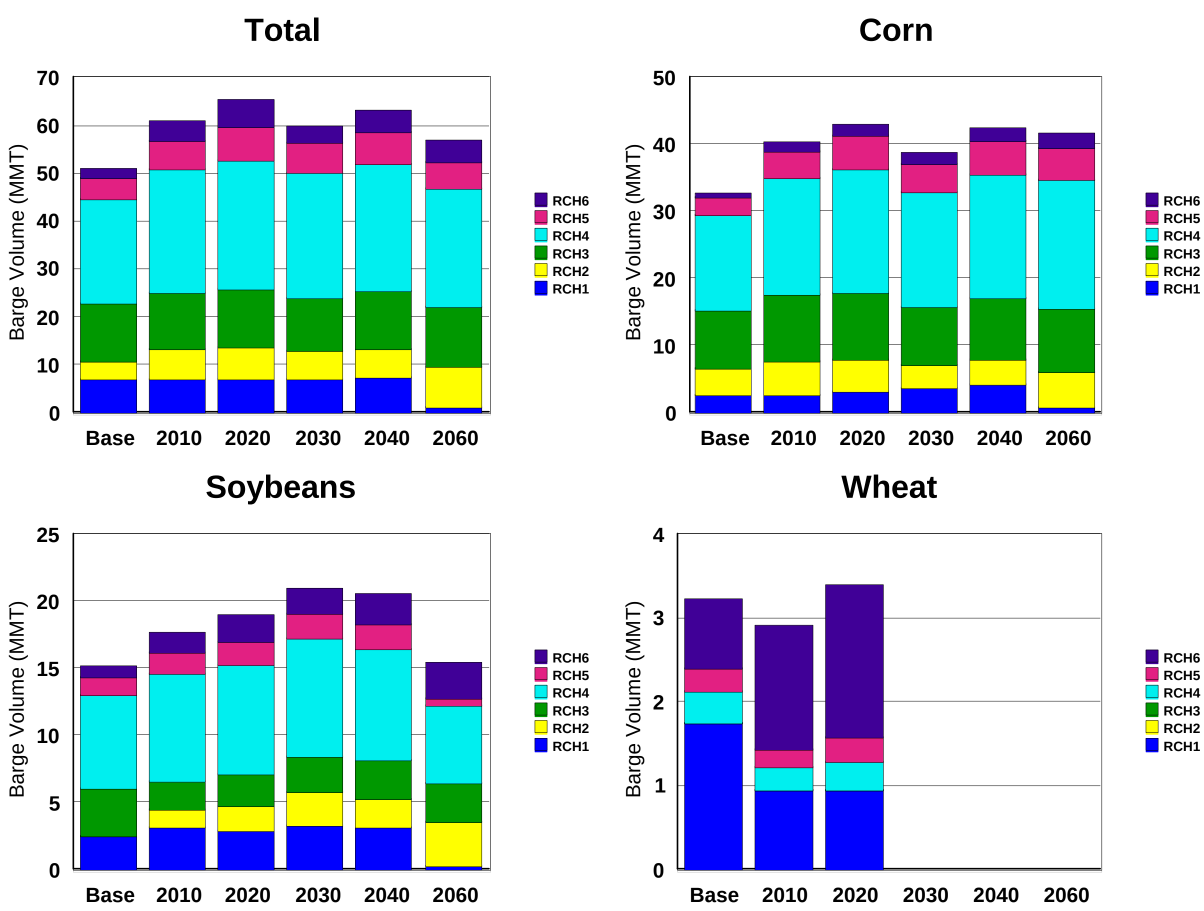

Figure 12. Base Case Projections: Barge Reach Volumes

Projections with Expanded Capacity: The model was run assuming the capacities at each of Reaches 1, 2, and 4 were expanded and reflected in changes in delay costs. The upward-sloping delay functions were changed to reflect that of an expanded lock capacity. The changes would occur and in these estimates would be completed by 2020. Results are shown in Figure 13 and changes are summarized in Table 12.

The results indicate a change in barge shipments by about +4 mmt by 2020, nearly all of which would be for corn and soybean in equal amounts. Thereafter, the change in barge shipments would be about +1 mmt to +2.5 mmt, with most of it being soybeans. Changes would also occur in Reach shipments. In 2020, there would be increases in shipments on Reach 1, 2 and 4, but decreases in Reach 5 and 6. These suggest that inter-Reach competition is important. As delay costs decrease in the Upper Reaches, shipments from the lower Reaches decline.

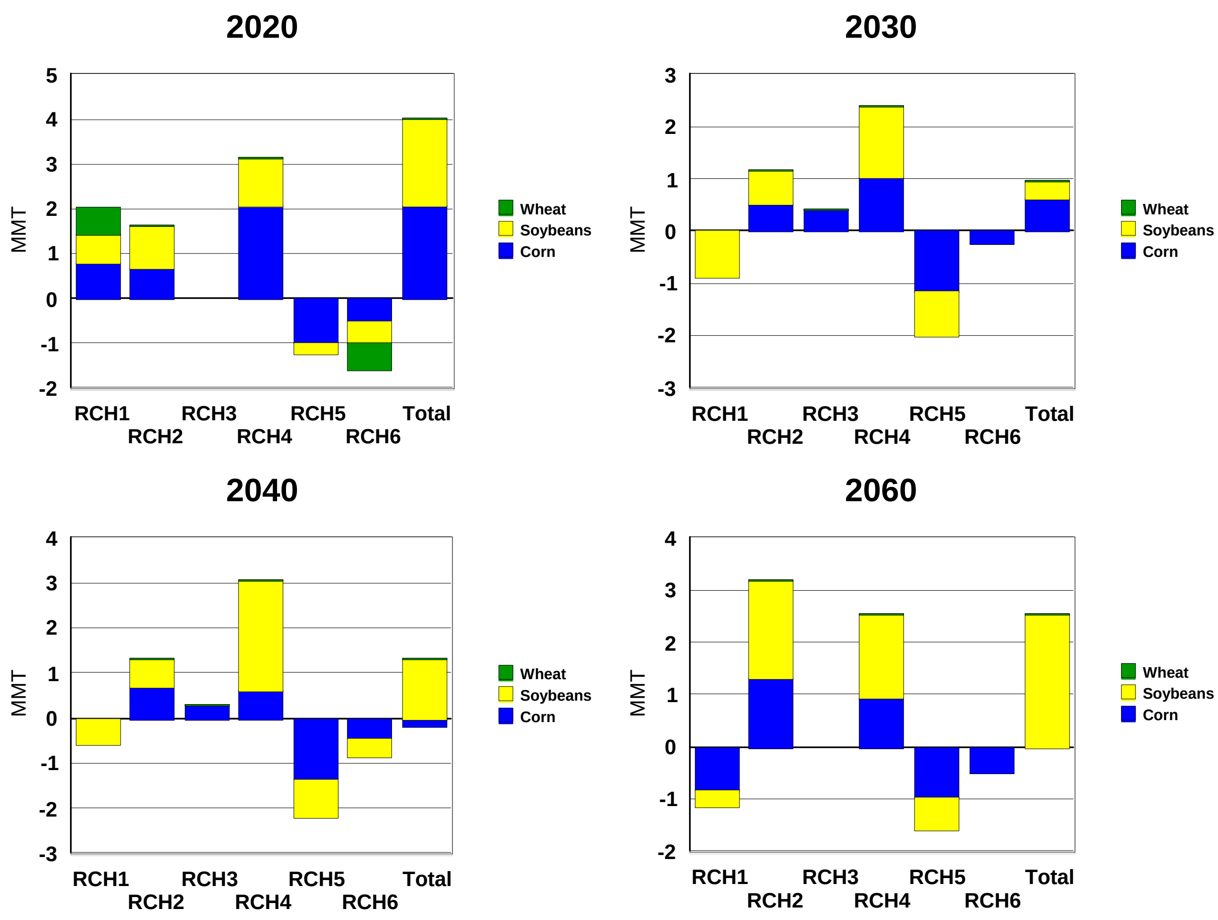

Figure 13. Changes in Barge Reach Volume Due to Expansion of Barge Reach Capacity Measured as Expanded - Current Capacity for 2020-2060, by Crop and Reach.

For later periods (2030-2060), changes in barge volumes reflect increases in total soybean barge movements which occur in reaches 2 and 4. Changes in corn barge volumes after 2030, largely become shifts among reaches with little overall change in total barge volumes. Barge volume for corn increases in reaches 2 and 4 and decreases in reaches 1, 5 and 6.

Table 12. Change in Barge Volume (Expanded Capacity-Current Capacity), Total and by Grain, by Reach, 2020-2060.

Change in Barge Volume 2020				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	2,018	799	653	566
RCH2	1,644	688	956	0
RCH3	0	0	0	0
RCH4	3,147	2,086	1,061	0
RCH5	-1,216	-980	-236	0
RCH6	-1,566	-500	-500	-566
Total	4,027	2,092	1,935	0
Change in Barge Volume 2030				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-860	0	-860	0
RCH2	1,161	526	635	0
RCH3	427	427	0	0
RCH4	2,418	1,037	1,381	0
RCH5	-1,983	-1,136	-846	0
RCH6	-207	-208	0	0
Total	956	646	311	0
Change in Barge Volume 2040				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-563	0	-563	0
RCH2	1,340	689	651	0
RCH3	304	304	0	0
RCH4	3,086	627	2,459	0
RCH5	-2,204	-1,378	-827	0
RCH6	-831	-434	-397	0
Total	1,132	-192	1,323	0
Change in Barge Volume 2060				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-1,143	-830	-312	0
RCH2	3,187	1,324	1,863	0
RCH3	0	0	0	0
RCH4	2,561	953	1,608	0
RCH5	-1,577	-953	-624	0
RCH6	-493	-493	0	0
Total	2,535	0	2,535	0

Delay costs were quantified for each simulation on each Reach. These are the delay costs accrued in the model solution. Technically, the delay costs are the “lock-processing time” including the added queuing time for going through the locks. As barge volumes increase, there is an increase in barge rates. As barge rates increase, there are slight shifts to other modes, routes, or potentially crops. This traffic diversion is not quantified. As barge shipping costs increase further due to delay costs, some barge shipments may continue despite the higher costs.

It is these additional delay costs that are quantified. These are shown in Table 13 for the base case without any expansions, and then for the expanded barge capacity. The implicit assumption here is that there is nil-growth in non-grain traffic (relaxed below).

Table 13. Comparison of Delay Costs ($/MT) by Reach for Current Barge Capacity, Expanded Barge Capacity and Change.

Delay Costs: Current Barge Capacity ($/MT Barge Volume (Grain + Non-Grain))						
	Base Year	2010	2020	2030	2040	2060
Reach 1	-0.12	-0.04	-0.02	-0.09	-0.04	-0.14
Reach 2	-0.19	0.08	0.14	-0.08	0.03	0.55
Reach 3	0.10	0.10	0.10	0.08	0.09	0.10
Reach 4	0.45	0.86	1.08	0.94	1.04	0.80
Delay Costs: Expanded Barge Capacity ($/MT Barge Volume (Grain + Non-Grain))						
	Exp Base	Exp 2010	Exp 2020	Exp 2030	Exp 2040	Exp 2060
Reach 1	-0.12	-0.04	-0.46	-0.47	-0.47	-0.47
Reach 2	-0.19	0.08	-0.90	-0.94	-0.92	-0.79
Reach 3	0.10	0.10	0.10	0.09	0.10	0.10
Reach 4	0.45	0.86	0.06	0.00	0.53	-0.03
Delay Costs: Change from Current Capacity to Expanded Barge Capacity						
	Base Year	2010	2020	2030	2040	2060
Reach 1	0.00	0.00	-0.44	-0.39	-0.42	-0.34
Reach 2	0.00	0.00	-1.04	-0.86	-0.95	-1.34
Reach 3	0.00	0.00	0.00	0.01	0.01	0.00
Reach 4	0.00	0.00	-1.01	-0.93	-0.52	-0.83

In the base case, without expansion, negative delay costs are accrued for shipments on Reach 1 and 2, and positive delay costs occur on Reach 3 and 4. The negative delay costs are slight and are reflective that shipments are slightly less than normal during the base period, resulting in a cost savings. These values are relatively small. The delay costs that occur on Reach 4 are more substantive at $0.45/mt. As barge shipments increase on Reach 4, barge rates increase, and when shipments begin to approach about 32 mmt, delay costs are accrued without any traffic diversion. The amount of this added cost due to delay is the delay cost reported in Table 13. Through time, without an expansion, the delay cost on Reach 4 increases to $1.08/mt in 2020.

Expanding lock capacity has the effect of reducing delay costs, and increasing capacity. The delay costs associated with these scenarios are shown in the middle-panel of Table 13 and changes versus the base case are shown in the lower panel. An expanded lock system would result in lower delay costs at each Reach. Those at Reach 4 decline by about $1.01/mt. Similar declines occur at Reach 2 ($1.04/mt) and those at Reach 1 are about $0.44/mt.

Evaluation of the change in delay costs include both a price effect and a substitution effect, as illustrated in Figure 14. The price effect is the impact of switching to the lower delay cost function which results in lower total barge shipping costs due to the lower delay costs for any given volume. The price effect is calculated as the reduction in barge shipping costs[9] at Q_1 and the reduction in costs is equivalent to the shift in delay costs from D_1 to D_2. In addition to this, there is a substitution effect which is the cumulative result of substituting increased barge shipments, due to the now lower barge shipping costs, for alternative modes and routes. This is shown by the movement from Q_1 to Q_3 along the new expanded capacity delay cost function which also reflects a movement along the total barge cost function. Due to the reduced delay costs (and subsequent lowering of total barge shipping cost), there is a shift from other modes to barge which we refer to as the substitution effect.

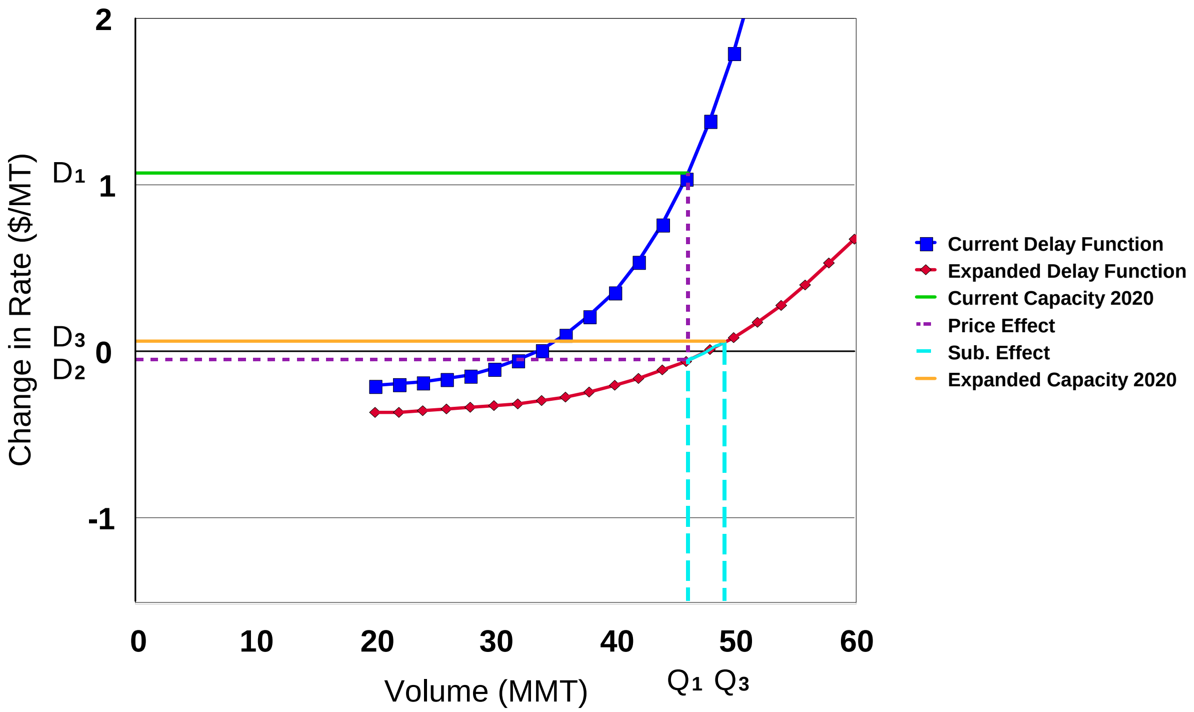

Figure 14. Price, Substitution and Total Effects on Barge Reach Volume of Shift from Current to Expanded Barge Capacity, Reach 4, 2020

In addition to the price and substitution effects on barge volumes, there is an impact on other modes, routes and production and shipping of other commodities. This can be evaluated by comparing the equilibrium solution from the model without the expansion, to a model including the expansion. In this case the impact of the expanded barge capacity is for increased barge shipments (as described above), which has the impact of reducing rail shipments, potentially changing the composition of port area shipments (e.g., from the PNW to the US Gulf), and potentially causing a slight shift in the composition of production and shipments amongst commodities.

These impacts were each evaluated and summarized below. The direct impacts on barge volumes are explained first and shown in Table 14. The first panel shows the delay costs accrued by reach with current barge capacity. These are largest for Reach 4, and, slightly negative in Reach 1. Panel 2 reflects the delay costs estimated with the expanded barge capacity

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[9] Since total barge costs are the barge rate plus delay costs at any given volume and barge rates for a given volume are unchanged, the change in total barge shipping costs is the change in delay costs.

delay function at Q1. Here, the delay costs are about $-29.9 million and are largely a result of reduced delay costs at Reaches 1,2 and 4. The total effect on delay costs is shown in Panel 3. The lower portion of Table 13 shows the effects on barge delay costs for the price effect, Panel 4, the substitution effect in Panel 5, and the total effect in Panel 6. As shown in Panel 6, the impact of expansions on delay costs are in the area of $61 million, inclusive of both the price and substitution effects. Most of this accrues on Reach 4, followed by Reach 2 and 1.

The effect of the expansion on the change in equilibrium between the base case without expansion in 2020 and that with an expansion was also evaluated (Table 15). The expansion results in reduced delay costs of $61 million (about $1.02/mt), which includes the effect of a shift to a delay curve with slightly greater negative costs. As a result, there is an increase in quantity shipped by barge, which results in a slightly higher barge rate i.e., a movement along the barge rate function. This is an increase in cost of about $50 million, or, $0.84/mt. In total, barge shipping costs including delay costs are reduced by $11 million, or, $0.18/mt. Other impacts are for reduced shipping costs by rail to ports and reaches of about $59 million, increased rail shipments to domestic, and slightly greater ocean shipping costs, $10.4 million, due to an increase in shipping from the US Gulf. Taken together, the effect of the expansion is to reduce these costs by $52 million.

The model was also simulated assuming increases in non-grain traffic on the river. Recall that the base case was for nil-growth in non-grain traffic. If non-grain traffic increases, this shifts delay costs upward along the curve for total barge volume and reduces the volumes of grain that can be shipped at a given delay cost. It is not clear the extent of potential increase in non-grain traffic. Consequently, to give a range we simulated different percentage changes in non-grain traffic.[10] These results are shown in Figure 15-16 and summarized in Table 16.

The results show that if the non-grain traffic grows by 50%, (i.e., cumulatively over the base period to 2020), then delay costs increase and grain traffic would decrease by about 7 mmt. At this growth rate, and without any expansion, the delay costs in 2020 would increase on each Reach. Those on Reach 4 would increase from $1.08 to $2.15/mt. With an expanded barge capacity, these delay costs would increase to $0.54/mt. Expansion would result in reduced delay costs on each Reach. Delay costs would decrease by $61 to $76 million depending on the percentage increase in non-grain traffic with most of the delay costs reductions occurring in Reach 4, followed by Reach 2 and 1.

[10] A 50% increase over a 15 year period reflects a 2.7% compound annual growth rate.

Table 14. Total Delay Costs by Reach, Current Capacity, Expanded Costs for Current Capacity Volumes, Expanded Costs for Expanded Volumes, and Differences, by Reach and Year

	Base	2010	2020	2030	2040	2060
1) Delay Costs: Current Capacity ($ 000)						
Reach 1	-2672	-1133	-394	-2072	-1125	-3015
Reach 2	-2983	1488	2631	-1338	619	11519
Reach 3	1222	1176	1222	937	1126	1222
Reach 4	9795	21967	28989	24298	27904	19841
Total	5361	23498	32448	21825	28524	29567
2) Delay Costs: Expanded Capacity at Current Volumes ($ 000)						
Reach 1	-2672	-1133	-12243	-11492	-11974	-10588
Reach 2	-2983	1488	-17533	-16457	-17077	-18597
Reach 3	1222	1176	1222	937	1126	1222
Reach 4	9795	21967	-1313	-2013	-1476	-2659
Total	5361	23498	-29868	-29026	-29401	-30622
3) Delay Costs: Expanded Capacity at Expanded Capacity Volumes ($ 000)						
Reach 1	-2672	-1133	-13642	-11798	-12413	-11471
Reach 2	-2983	1488	-18355	-17474	-18007	-19112
Reach 3	1222	1176	1222	1060	1222	1222
Reach 4	9795	21967	1896	10	1564	-826
Total	5361	23498	-28879	-28201	-27633	-30187
4) Change in Delay Costs: Expansion Effect (2-1)						
Reach 1	0	0	-11849	-9420	-10849	-7573
Reach 2	0	0	-20164	-15119	-17696	-30116
Reach 3	0	0	0	0	0	0
Reach 4	0	0	-30302	-26311	-29380	-22500
Total	0	0	-62316	-50851	-57925	-60189
5) Change in Delay Costs: Change in Volume Effect (3-2)						
Reach 1	0	0	-1399	-306	-439	-883
Reach 2	0	0	-822	-1017	-930	-515
Reach 3	0	0	0	123	96	0
Reach 4	0	0	3209	2023	3040	1833
Total	0	0	989	825	1768	435
6) Change in Delay Costs: Total Effect (3-1)						
Reach 1	0	0	-13248	-9726	-11288	-8456
Reach 2	0	0	-20986	-16136	-18626	-30631
Reach 3	0	0	0	123	96	0
Reach 4	0	0	-27093	-24288	-26340	-20667
Total	0	0	-61327	-50026	-56157	-59754

Table 15. Summary: Delay Cost Impacts and Expansion

Impact	$million	$/mt
Reduced delay costs	61	1.02
Increase barge shipments (higher barge rates)	50	.84
Total	-11	-.18
Reduced shipping costs by rail to ports and reaches	59	
Slightly greater ocean shipping costs (more U.S. Gulf Shipments	10	
Total cost reduction	-52	

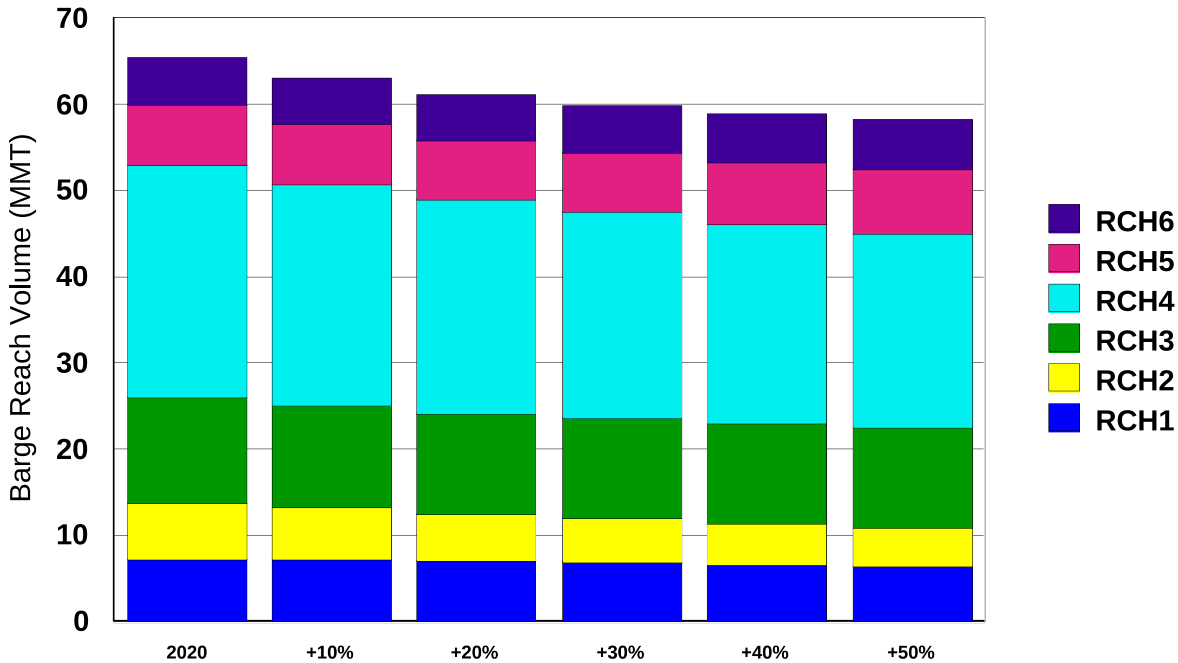

Figure 15 Sensitivity of Barge Reach Volumes in 2020 to Non-Grain Traffic Increases (for Non-Grain in Reaches 1-4), Current Barge Capacity

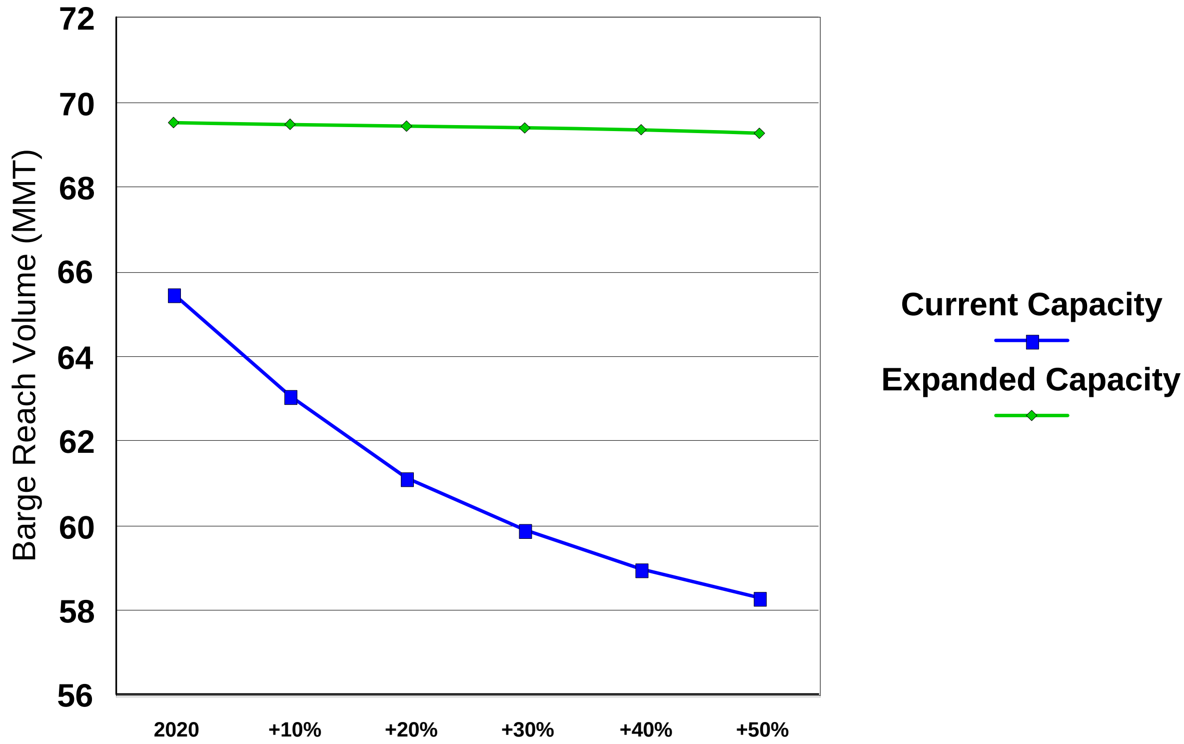

Figure 16. Sensitivity of Total Barge Reach Volumes for Current and Expanded Capacity in 2020 to Non-Grain Traffic Increases

Table 16. Sensitivity of Delay Costs to Changes in Non-Grain Barge Traffic, 2020

Delay Costs: Current Barge Capacity 2020 ($/MT Barge Volume (Grain + Non-Grain))						
	2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-394	-15	676	1,752	2,932	4,560
Reach 2	2,631	2,804	3,970	6,027	8,618	11,651
Reach 3	1,222	1,251	1,363	1,529	1,700	1,876
Reach 4	28,989	31,148	33,737	37,544	42,725	48,561
Total 1-4	32,448	35,188	39,746	46,852	55,976	66,648
Delay Costs: Expanded Barge Capacity 2020 ($/MT Barge Volume (Grain + Non-Grain))						
	Exp 2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-13,642	-13,486	-13,313	-13,122	-12,911	-12,678
Reach 2	-18,355	-17,784	-17,134	-16,397	-15,567	-14,636
Reach 3	1,222	1,394	1,571	1,753	1,940	2,132
Reach 4	1,896	4,148	6,658	9,433	12,490	15,807
Total 1-4	-28,880	-25,728	-22,218	-18,334	-14,048	-9,375
Delay Costs: Change 2020 (Expanded - Current Capacity)						
	2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-13,248	-13,471	-13,990	-14,875	-15,843	-17,238
Reach 2	-20,987	-20,588	-21,103	-22,424	-24,185	-26,287
Reach 3	0	143	208	224	240	256
Reach 4	-27,093	-27,000	-27,079	-28,111	-30,235	-32,754
Total 1-4	-61,327	-60,916	-61,964	-65,186	-70,024	-76,022

Finally, in assessing these estimates of delay costs, it is important to note they are derived assuming a very conservative number for ethanol production. The effect of this is for more exportable supply which impacts the aggregate delay costs. If ethanol production expands further, the exportable supplies will decline (as shown in the next section), and though the unit cost savings associated with delay would likely not change, the aggregate costs would differ.

Ethanol Scenarios

One of the major changes in US grain agriculture is emergence of ethanol. Base case projections allowed expanded ethanol demand for corn based on current projections for ethanol demand for corn in United States using the EIA estimates in 2005. Since then, the Energy Bill was signed and would result in prospectively a greater amount of ethanol to be produced. The base case assumed EIA 2005 projections of corn use in ethanol demand, 107% of US base area and longer-term yield growth rates by region.

To explore the prospective impacts of further changes in ethanol, the model was revised assuming the EIA 2006 estimates of ethanol produced from corn.[11] In this case, corn used in ethanol production increases from four billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons for 2020 forward. In the period after 2015 a minor portion of this will be met by ethanol from cellulose (EIA 2005). All other assumptions from above are retained. Area assumptions necessary to reach a feasible solution are:

Maximum Area Limit Relative to Projected Base Area to Achieve a Solution (%)						
	Base	*2010*	*2020*	*2030*	*2040*	*2060*
US	100	107	107	107	107	107
ROW	107	109	118	132	129	134

In addition, we solved the model assuming an ethanol production of 7.5 billion gallons, for comparison.

Exports by Country/Region: Results indicate substantial changes in production and exports amongst exporting countries and regions, as well as the Reaches. World exports from these countries decrease slightly, suggesting there is increased domestic production in some countries. In particular, world trade in 2020 declines from 318 mmt in our base case to 296 mmt.

Exports from the following countries increase sharply, with the change from the base to 2020 in ( ):

» Argentine corn (16 to 18.5 mmt);
» Europe and Eastern European corn (36 to 46 mmt);
» Brazil soybeans declined (25 to 23 mmt), in part due to a shift to corn in Brazil South;

[11] For comparison, ProExporter's (ProExporter 2006e) "Blue Sky" model has ethanol growing to 18.7 billion gallons by 2015-16.

» Wheat exports from Australia increase (29 mmt to 32 mmt), Europe decreases (41 to 31 mmt), US decreases from 20 to 19; and Canada increases marginally.

Exports from the United States with high ethanol demand decline from 101 mmt in the base year to 78 mmt by 2020, vs. the base case which increased over the same period from 101 to 111 mmt. Gulf and PNW exports in 2020 with high ethanol demand decrease to 51 mmt and 15 mmt, respectively vs. base case exports of 76 mmt and 23 mmt, respectively. Most of the decline in 2020 exports is due to decreases in corn and wheat shipments. Soybeans decline to 28 mmt for the same reasons described above. Wheat exports from the United States decrease substantially.

Reach Shipments: Reach shipments change as well (Figures 17-18 and Table 17) and summarized versus the base case. There is a slight increase through 2010. Thereafter, shipments decline to 48 mmt in 2020 and lesser values in years beyond. This contrasts with values of about 65 mmt in 2020 in the base case. The decline is greatest for corn, and then wheat.

Compared to the base case, the decline to 2010 is about -9.4 mmt, which grows to 18 mmt in 2020 and about 39 mmt in years thereafter. In 2010, the largest decline is from Reach 3, followed by Reach 2 and Reach 4. Interestingly, shipments from Reach 1 increase. In latter years, the magnitude of the decline increases and the decline from Reach 4 increases sharply.

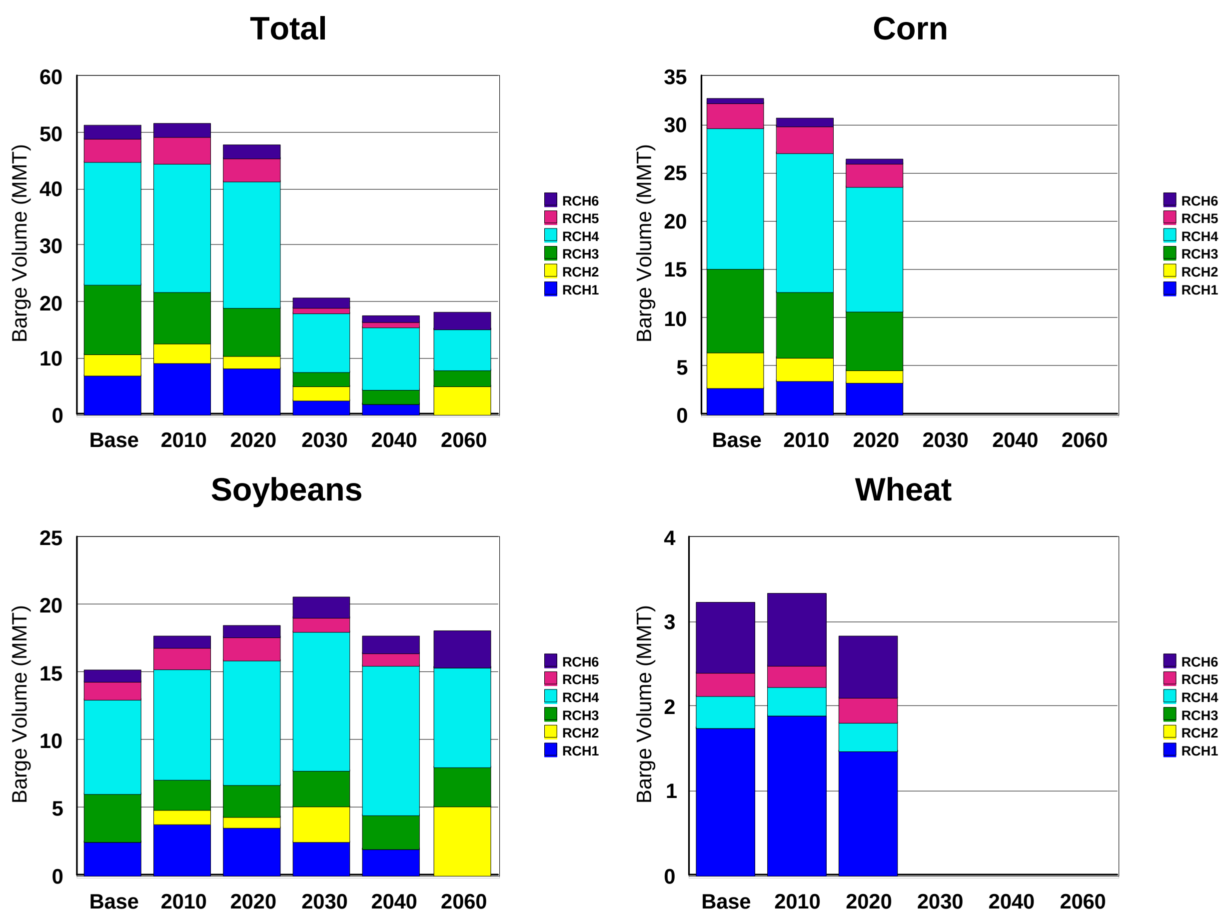

Figure 17. High Ethanol Demand Scenario: Barge Reach Volumes

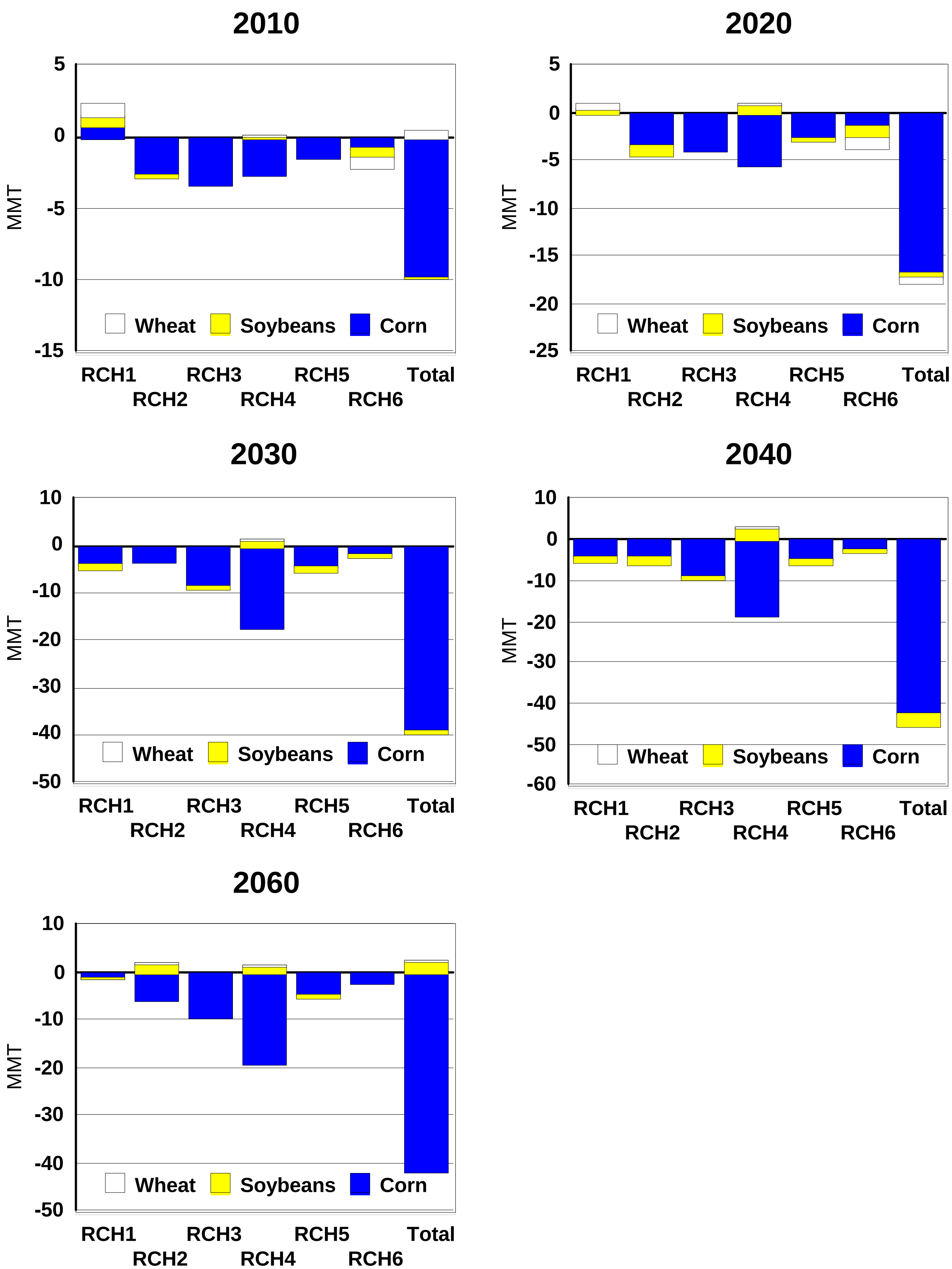

Figure 18. Changes in Barge Reach Volumes Due to High Ethanol Demand (High Ethanol Demand - Current Capacity) for 2010-2060, by Crop and Reach

Virtually all of the decrease is in corn shipments. However, in later years, there are decreases in soybeans and wheat as land is shifted from those crops to produce corn.

Major Changes in Flows: In the high-ethanol scenario, there are changes in flows. These are shown in Tables 18-19 and 20-21 for 2010 and 2020 respectively.

Within the United States, grain flows in 2020 change substantially. Most interesting are the drastic increase in shipment to the Eastern and Western corn belts reflecting the increase in domestic demand for ethanol use. Also of interest are changes in flows from the Northern Plains which had previously exported most of its corn through the PNW. A substantial portion of these is now shifted to domestic shipments.

There are substantial changes in flows from US production regions to the Reaches and port areas. Most important are reductions in shipments from Iowa River to Reach 2, Minnesota River to Reach 3, and Illinois North to Reach 4. There are reductions from most regions to New Orleans, but, an increase from Illinois South to New Orleans. There are also substantial reductions from Northern Plains to the PNW, declining from 14 mmt to 6 mmt.

Table 17. Change in Barge Volume (High Ethanol Demand - Current Capacity), Total and By Crop, 2010-2060.

Change in Barge Volume, 2010				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	2,363	790	623	950
RCH2	-2,753	-2,650	-103	0
RCH3	-3,225	-3,266	41	0
RCH4	-2,490	-2,688	141	57
RCH5	-1,308	-1,349	0	41
RCH6	-2,032	-704	-702	-625
Total	-9,445	-9,867	-1	423
Change in Barge Volume, 2020				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	1,086	9	551	526
RCH2	-4,308	-3,367	-941	0
RCH3	-3,814	-3,820	6	0
RCH4	-4,404	-5,489	1,084	1
RCH5	-2,820	-2,667	-154	1
RCH6	-3,529	-1,358	-1,082	-1,089
Total	-17,788	-16,691	-535	-561
Change in Barge Volume, 2030				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-4,566	-3,814	-752	0
RCH2	-3,233	-3,368	135	0
RCH3	-8,624	-8,618	-6	0
RCH4	-15,792	-17,150	1,359	0
RCH5	-5,010	-4,307	-703	0
RCH6	-2,081	-1,606	-476	0
Total	-39,305	-38,863	-442	0
Change in Barge Volume, 2040				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-5,324	-4,254	-1,070	0
RCH2	-6,087	-3,890	-2,196	0
RCH3	-9,538	-9,035	-503	0
RCH4	-15,548	-18,484	2,936	0
RCH5	-5,905	-4,912	-992	0
RCH6	-3,100	-2,024	-1,076	0
Total	-45,501	-42,600	-2,901	0
Change in Barge Volume, 2060				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-1,143	-830	-312	0
RCH2	-3,579	-5,442	1,863	0
RCH3	-9,419	-9,419	0	0
RCH4	-17,553	-19,183	1,630	0
RCH5	-5,285	-4,661	-624	0
RCH6	-2,072	-2,071	0	0
Total	-39,049	-41,606	2,556	0

Table 18. Change in Shipments from U.S. Production Regions to U.S. Export Reaches in 2010 due to High Ethanol, (High Ethanol Demand 2010 - Current Capacity 2010) for All Crops, Rail and Truck Movements, (000 MT).

U.S. Production Regions	U.S. Export Reaches										
	RCH1	RCH2	RCH3	RCH4	RCH5	RCH6	Toledo	Duluth	New Orleans	PNW	TX Gulf
USCP	0	0	0	0	0	0	0	0	0	0	59
USCPR	0	0	0	0	0	0	0	0	2,333	0	0
USD	0	0	0	0	0	0	0	0	76	0	0
USIAR	0	-5,121	0	0	0	0	0	0	0	0	0
USILN	0	0	0	-2,490	0	0	0	0	81	0	0
USILS	941	0	0	0	0	0	0	0	-6,863	0	0
USINR	0	0	0	0	-1,308	0	0	0	0	0	0
USMN	0	0	0	0	0	0	0	0	0	0	0
USMNR	0	0	-3,225	0	0	0	0	0	0	0	0
USMOR	-1	0	0	0	0	0	0	0	0	0	0
USMOW	624	0	0	0	0	0	0	0	0	0	0
USNP	0	0	0	0	0	0	0	0	0	-5,899	0
USOH	799	0	0	0	0	-2,032	0	0	944	0	0
USPNW	0	0	0	0	0	0	0	0	0	0	17
USSP	0	0	0	0	0	0	0	0	0	0	0
USWIS	0	2,368	0	0	0	0	0	0	0	0	0
USWNP	0	0	0	0	0	0	0	0	0	0	0

Table 19. Change in Shipments from U.S. Production Regions to U.S. Consumption Regions in 2010 due to High Ethanol, (High Ethanol Demand 2010 - Current Capacity 2010) for All Crops, Rail and Truck Movements, (000 MT).

U.S. Production Regions	U.S. Consumption Regions									
	USCPC	USDC	USECBC	USNEC	USNPC	USPNWC	USSEC	USSPC	USWC	USWCBC
USCP	-8	0	0	0	0	0	1	0	0	-189
USCPR	3,509	-56	0	0	0	-3,312	0	0	-144	-272
USD	0	-1	0	0	0	0	0	0	0	0
USIAR	0	0	0	0	0	0	0	0	0	5,203
USIAW	0	0	0	0	0	0	0	0	0	208
USILN	0	0	2,596	0	0	0	0	0	0	0
USILS	0	0	6,494	0	0	0	-430	0	0	0
USINN	0	0	148	0	0	0	0	0	0	0
USINR	0	0	1,347	0	0	0	0	0	0	0
USMI	0	0	48	0	0	0	0	0	0	0
USMN	0	0	0	0	0	3,288	0	0	-5,222	69
USMNR	0	0	0	0	0	0	0	0	0	3,275
USMOR	0	0	205	0	0	0	0	0	0	-174
USMOW	0	0	-625	0	0	0	0	-3	0	103
USNE	0	0	45	-2	0	0	0	0	0	0
USNP	10	0	-2,225	0	2,599	0	0	-97	5,313	0
USOH	0	0	0	-60	0	0	517	0	0	0
USPNW	0	0	0	0	0	0	0	0	-17	0
USSE	0	0	0	0	0	0	103	0	0	0
USSP	0	0	0	0	0	0	0	-2	0	0
USW	0	0	0	0	0	0	0	0	17	0
USWIS	0	0	-2,867	0	0	0	0	0	0	534
USWIW	0	0	6	0	0	0	0	0	0	3
USWNP	0	0	0	0	0	0	0	0	0	0

Table 20. Change in Shipments from U.S. Production Regions to U.S. Export Reaches in 2020 due to High Ethanol, (High Ethanol Demand 2020 - Current Capacity 2020) for All Crops, Rail and Truck Movements, (000 MT).

U.S. Production Regions	U.S. Export Reaches										
	RCH1	RCH2	RCH3	RCH4	RCH5	RCH6	Toledo	Duluth	New Orleans	PNW	TX Gulf
USCP	0	0	0	0	0	0	0	0	0	0	0
USCPR	0	0	0	0	0	0	0	0	0	0	0
USD	0	0	0	0	0	0	0	0	0	0	-384
USIAR	0	-5,685	0	0	0	0	0	0	0	0	0
USILN	0	1,306	0	-4,404	0	0	0	0	-362	0	0
USILS	-172	0	0	0	0	0	0	0	-6,540	0	0
USINR	0	0	0	0	-2,820	0	0	0	0	0	0
USMN	0	0	0	0	0	0	0	0	0	568	0
USMNR	0	0	-3,814	0	0	0	0	0	0	0	0
USMOR	13	0	0	0	0	0	0	0	0	0	0
USMOW	547	0	0	0	0	0	0	0	0	0	0
USNP	0	0	0	0	0	0	0	0	0	-8,647	0
USOH	698	0	0	0	0	-3,529	0	0	305	0	0
USPNW	0	0	0	0	0	0	0	0	0	0	-165
USSP	0	0	0	0	0	0	0	0	0	0	0
USWIS	0	70	0	0	0	0	0	0	0	0	0
USWNP	0	0	0	0	0	0	0	0	0	0	0

Table 21. Change in Shipments from U.S. Production Regions to U.S. Consumption Regions in 2020 due to High Ethanol, (High Ethanol Demand 2020 - Current Capacity 2020) for All Crops, Rail and Truck Movements, (000 MT).

U.S. Production Regions	U.S. Consumption Regions									
	USCPC	USDC	USECBC	USNEC	USNPC	USPNWC	USSEC	USSPC	USWC	USWCBC
USCP	74	0	0	0	0	0	486	0	0	0
USCPR	2,291	-2,024	0	0	0	-226	0	0	0	-980
USD	0	14	0	0	0	0	0	0	0	387
USIAR	0	0	0	0	0	0	0	0	0	5,746
USIAW	0	0	0	0	0	0	0	0	0	154
USILN	0	0	3,786	0	0	0	0	-195	0	0
USILS	0	1,928	6,721	0	0	0	-2,034	0	0	0
USINN	0	0	81	0	0	0	0	0	0	0
USINR	0	0	2,839	0	0	0	0	0	0	0
USMI	0	0	31	0	0	0	0	0	0	0
USMN	0	0	0	0	0	189	0	0	-163	5
USMNR	0	0	0	0	0	0	0	0	0	3,856
USMOR	0	0	178	0	0	0	0	0	0	-216
USMOW	0	0	-628	0	0	0	0	29	0	-181
USNE	0	0	5	23	0	0	0	0	0	0
USNP	3,070	0	-486	0	4,012	0	0	0	84	0
USOH	0	0	0	288	0	0	2,298	0	0	0
USPNW	0	0	-95	0	0	3	0	0	259	0
USSE	0	0	0	0	0	0	-1,698	0	0	0
USSP	0	0	0	0	0	0	0	22	0	0
USW	0	0	0	0	0	0	0	0	-257	0
USWIS	0	0	-6,012	0	0	0	0	0	0	5,960
USWIW	0	0	1,191	0	0	0	0	0	0	-1,184
USWNP	0	0	0	0	1	0	0	0	0	0

Summary of Ethanol Impacts: Impacts of these scenarios are summarized in Figure 19. These include the base case, the high ethanol case which implies ethanol production of 12 billion gallons. In addition, we illustrate impacts of a 7.5 billion gallon ethanol scenario. For each, we show the total barge shipments, as well as for the individual commodities. As illustrated, in the high ethanol case, barge shipments decline sharply, eventually to the 18 mmt rage. Corn shipments by barge decrease and fall to nil by 2030. Soybean shipments by barge increase through to about 2030 and then the combination of competition from corn in the United States and off-shore increases in production results in reduced barge exports. Finally, wheat shipments by barge decline from the 3 mmt range in all cases to nil by 2030.

It is important that these are only exports by barge. As shown above in the detailed results, exports from other ports do not fall to zero, but, do suffer from similar pressures.

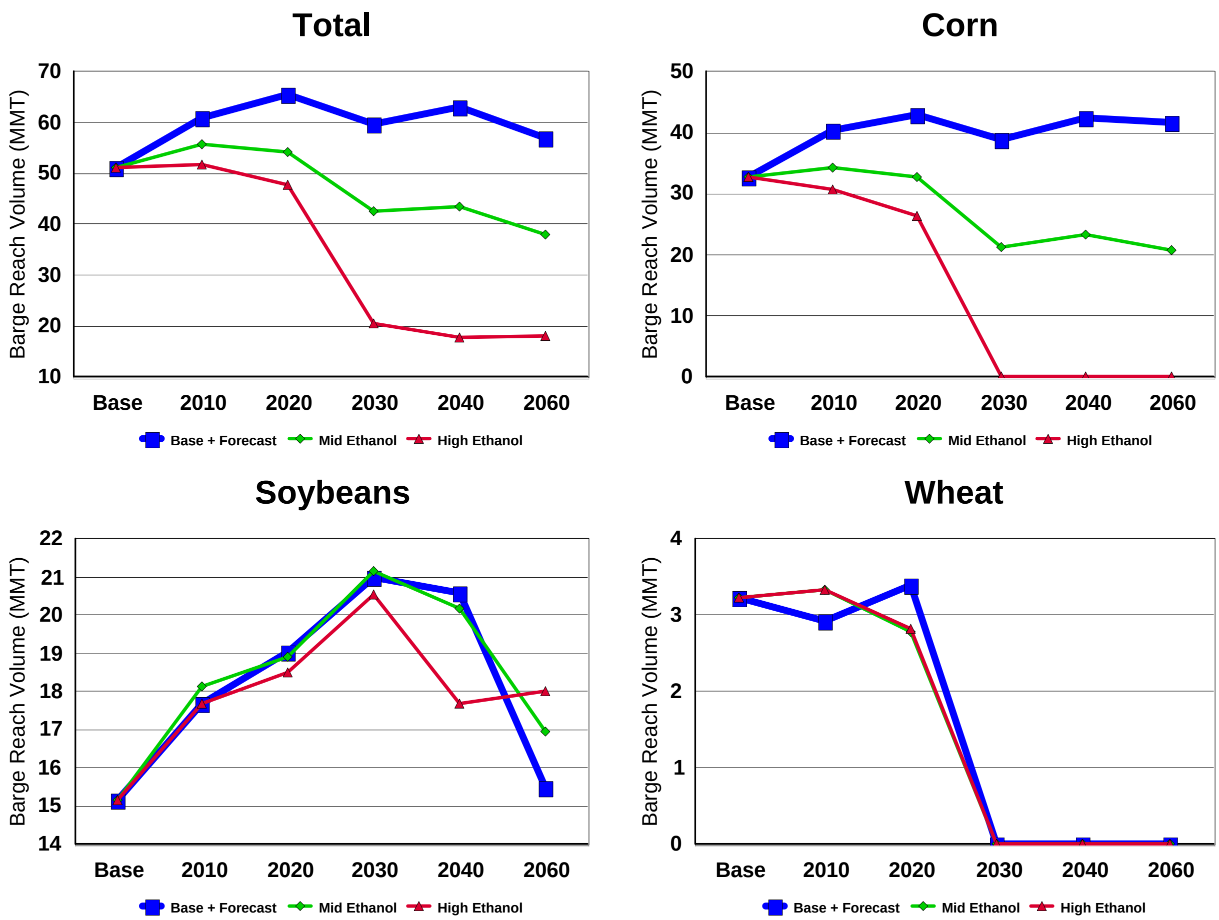

Figure 19. Comparison of Barge Reach Volumes for Ethanol Scenarios, Base Case, Mid Ethanol and High Ethanol Demand Scenarios, by Crop and Total

Qualifications and Stylized Assumptions on the High-ethanol Scenario: The scenario above was posed for illustration purposes, in part because of the overriding importance of ethanol in the United States grain economy and how important these developments are on the barge system. Of particular importance is that if EIA 2006 demand were to be realized, and corresponding with the spatial distribution of current ethanol plants, the model needs to make some extreme assumptions in order to get a solution. In particular, it requires expanding U.S. acres by 7% reflecting approximately land available in CRP, and other small grains, and, in addition, increasing area available elsewhere in the world. These regions of the world have some capacity for expanded area, but not as much as would be projected here.

All these topics are debatable. Most important are those related to yield increases, the ability to expand area in the United States, and demand for non-ethanol corn. If corn prices increase, demands in some segments within the United States and/or off-shore would be impacted. Impacts of course, would change the potential Reach flows as generated from this scenario.

In order to evaluate the robustness of the model and the assumptions about these critical variables, we simulated the model with alternative assumptions with respect to two variables for the year 2020. These are: yields in 2020 were increased 5%; area harvested at 88 million acres versus 67 million acres in our base case. This implies 92 million acres planted to corn, or 32% increase from the base. The land area for soybeans and wheat were reduced so that the maximum land for these three commodities was unchanged. However, ultimately the model chooses which crops are grown and where, so these changes reflect maximums allowed and may not be fully utilized. These are representative of some of the analysis that have been posed to assess the impacts of ethanol.[12]

These values are at the national level and were implemented in the model as proportionate changes by region. These assumptions have the impact of increasing U.S. supplies of corn. Note, these are by assumption as opposed to model solutions. Most important is that the model requires reconciling shifts in acres relative to the competing crops (corn, soybeans and wheat), in the United States as well as competitor countries.

The results of the model are compared in Figures 20 to 22 to the results from the unrestricted high-ethanol solution for 2010 and 2020. Results from the revised assumptions are labeled as "Revised 2020." Most striking in making these comparisons are:

» Total exports from the United States, increase as opposed to decreasing in our base case by 2020. Total exports are 129 mmt in 2020 and 86 mmt and 29 mmt from the US Gulf and PNW respectively;

» Corn exports from the United States increase to nearly 83 mmt, as opposed to decline to 26 mmt for the base high ethanol demand 2020. In the revised 2020 solution, corn exports also decrease from Argentina.

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[12] Technically, this results in area harvested as follows, and all values are in million acres: corn 88, soybeans 77 and wheat 44. Production is as follows with values in ( ) the base case value, and each are in million mt.: corn 367 (340), soybeans 93 (82), and wheat 53 (33).

» Soybean exports from the United States decline to 28 mmt vs 36 mmt for the 2010.

» Wheat exports would increase from each of the competitors. Those from the United States decline, but, by not as much as in our unrestricted high-ethanol case.

» Barge shipments increase from 48 mmt in the unrevised 2020 case to 70 mmt in the revised 2020 case. Most of the increases would be from Reaches 2 and 4. However, volume in Reach 1 would drop from 8.4 mmt in the unrevised 2020 case to 5.9 mmt in the revised case.

These illustrate that minor tweaking of assumptions result in fairly important changes. These are not inconsequential. In making these comparisons, there are a number of important differences:

1) The base case model also has important underlying growth in world demands for corn and soybeans that must be satisfied;

2) The ability to expand area is important. Our results suggest it would come mostly from wheat CRP and/or from other minor crops not included in the model. Some could come from soybeans, but there is substantial international competitive pressures and demand for the United States to retain its soybean area;

3) These results differ from other studies. These may appear more drastic because as we kept ethanol demand at EIA 2006 projections, and forced corn yields up and allowed for increased corn area. Hence, we had greater exports. Other studies assume an expansion of ethanol beyond the EIA 2006 projections, and then, see how many acres are necessary to support that growth.

4) Yield increases and ethanol conversion improvements are based upon assumed anticipated genetic and technological improvements, whereas those from the base solution are based on a continuation of past trends.

5) Finally, soybean competition is critical and a source of fundamental difference versus other studies. In our case, the US exports more soybeans for two reasons. One is that it is a lower cost producer than the new-areas in South America. Second, is due to the logistical costs that favor shipments from the United States to some key destinations. The impact of this is to constrain the ability to expand area planted to corn for higher-ethanol demands.

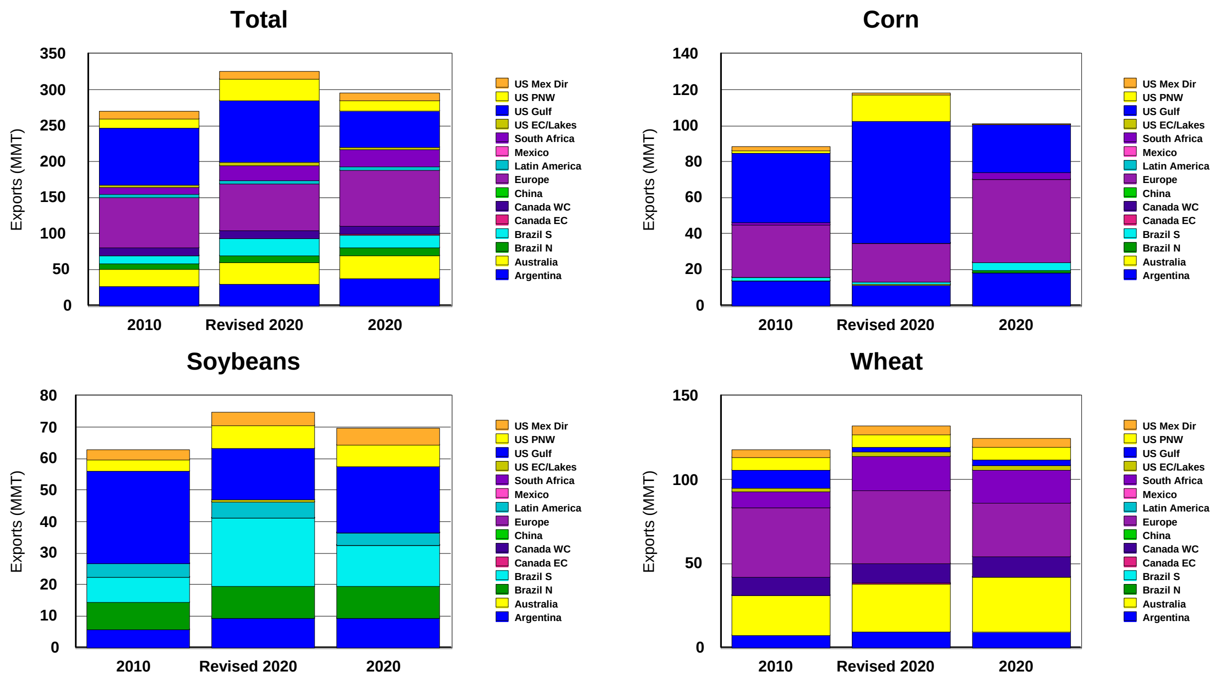

Figure 20. Comparison of Exports by Port Area for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total

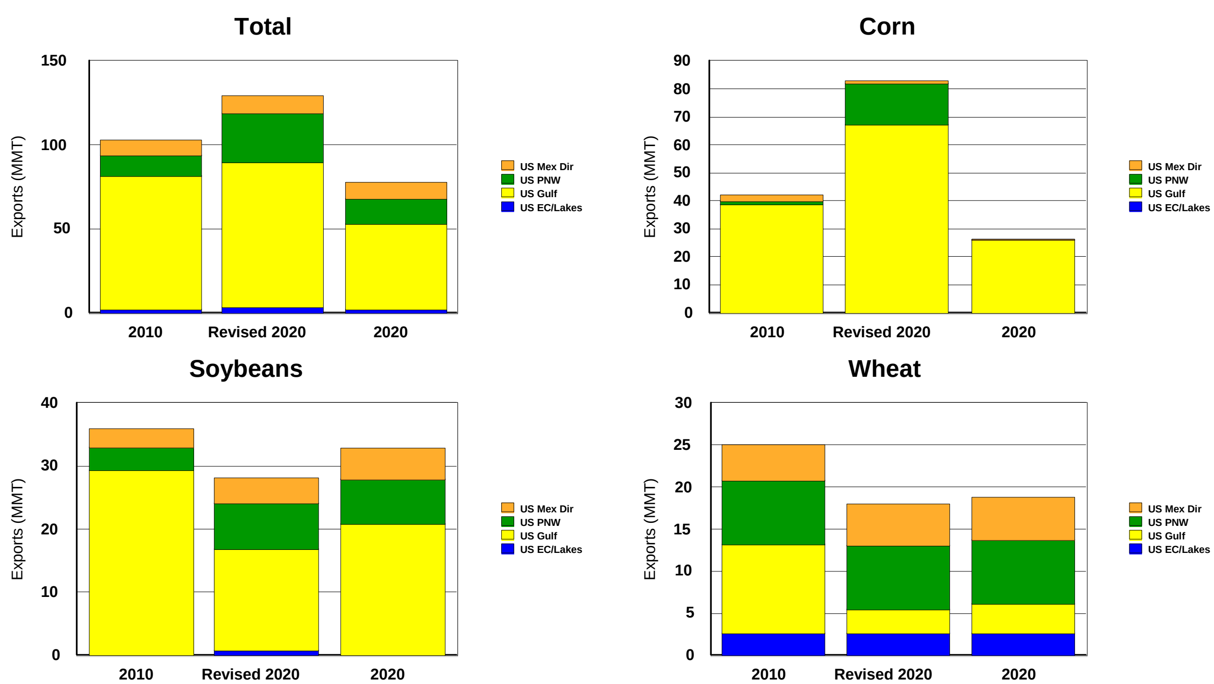

Figure 21. Comparison of U.S. Exports by Port Area for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total

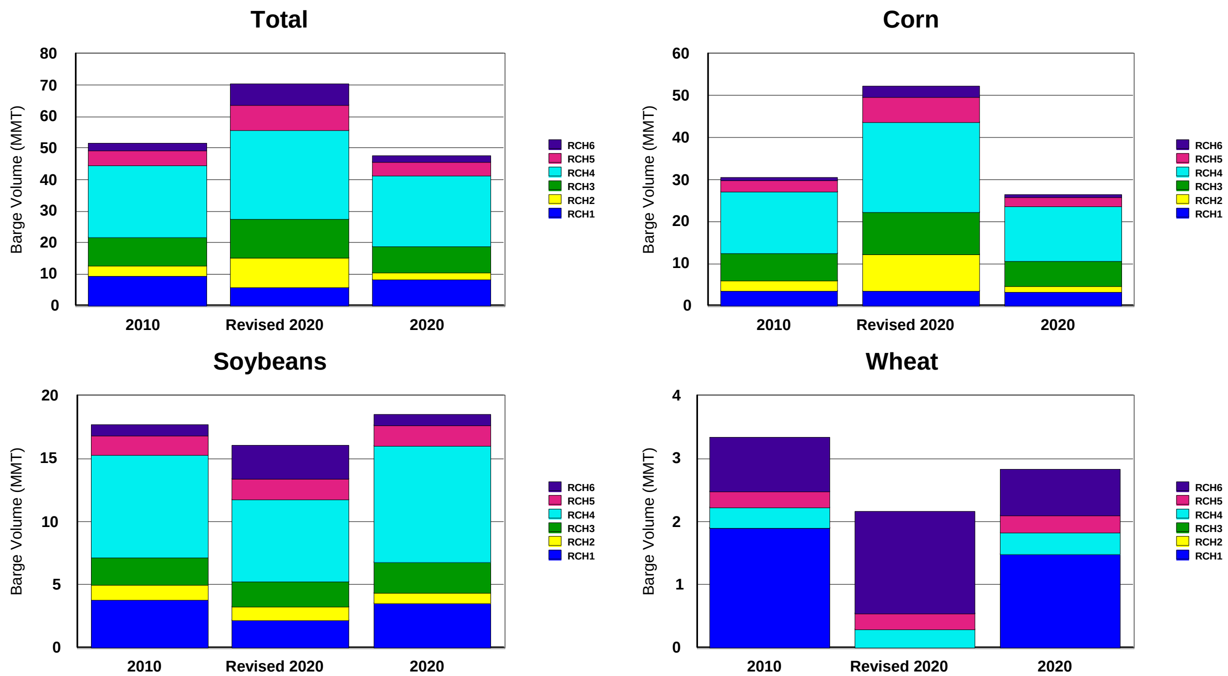

Figure 22. Comparison of Barge Reach Volumes for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total

China Trade Policies

One of the most dynamic countries in the world grain market is China. This country is experiencing rapid increases in income and a large and growing population. In addition, there are changes in consumer patterns and trade policies with respect to corn export subsidies. But China is also a large producer and has potential to improve productivity substantially. In this section sensitivities were conducted to illustrate China's role in some critical policies. Two policies are simulated, each with respect to corn.

China Imports Corn: In this sensitivity, we ran the 2010 model assuming China imports 5 mmt of corn. Results are shown in Figure 23. These indicate that the results depend on the ethanol assumption. Under base case ethanol scenario, shipments on the barge system increase slightly (61.1 mmt to 61.2 mmt). Under a high-ethanol assumption, barge shipments decrease to 51.6 mmt.

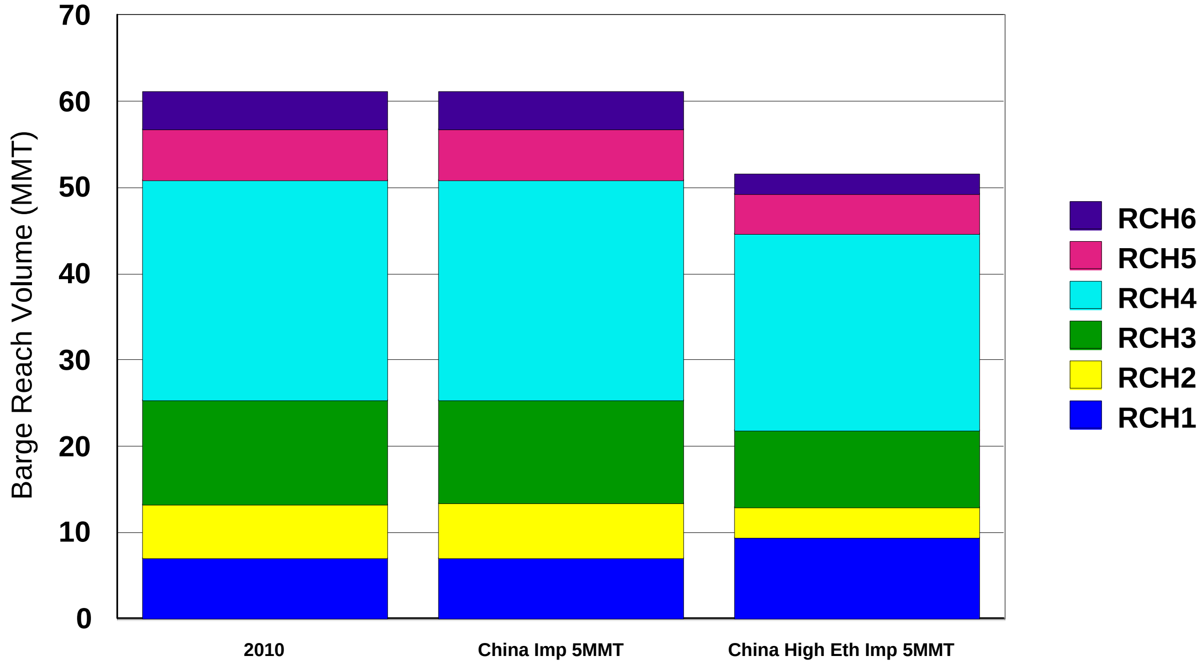

Figure 23. Sensitivity of Barge Reach Volumes in 2010 to China Corn Imports

Summary of Major Projections and Policies

The above are the major projections and policy issues affecting barge shipments. Figures 24 and 25 show projections for barge shipments and area devoted to each crop in the United States.

These results show how barge shipments would vary under different scenarios. Overall the trends are the same: increase to 2010 and decline thereafter. Differences amongst these are one of magnitude. The most optimistic scenarios from a barge shipment perspective are if ethanol remains at base case values.

Figure 25 shows the shift in area devoted to these crops in the United States for each scenario. In all cases, there are shifts from wheat to corn and soybeans, and slightly from soybeans to corn. Differences are also a matter of magnitude. It is important that this is really constrained by competitive factors and that the model imposed a maximum switch amongst crops of 7% of the area devoted to that crop in the base period, as well as the necessary change in maximum area restrictions identified above.

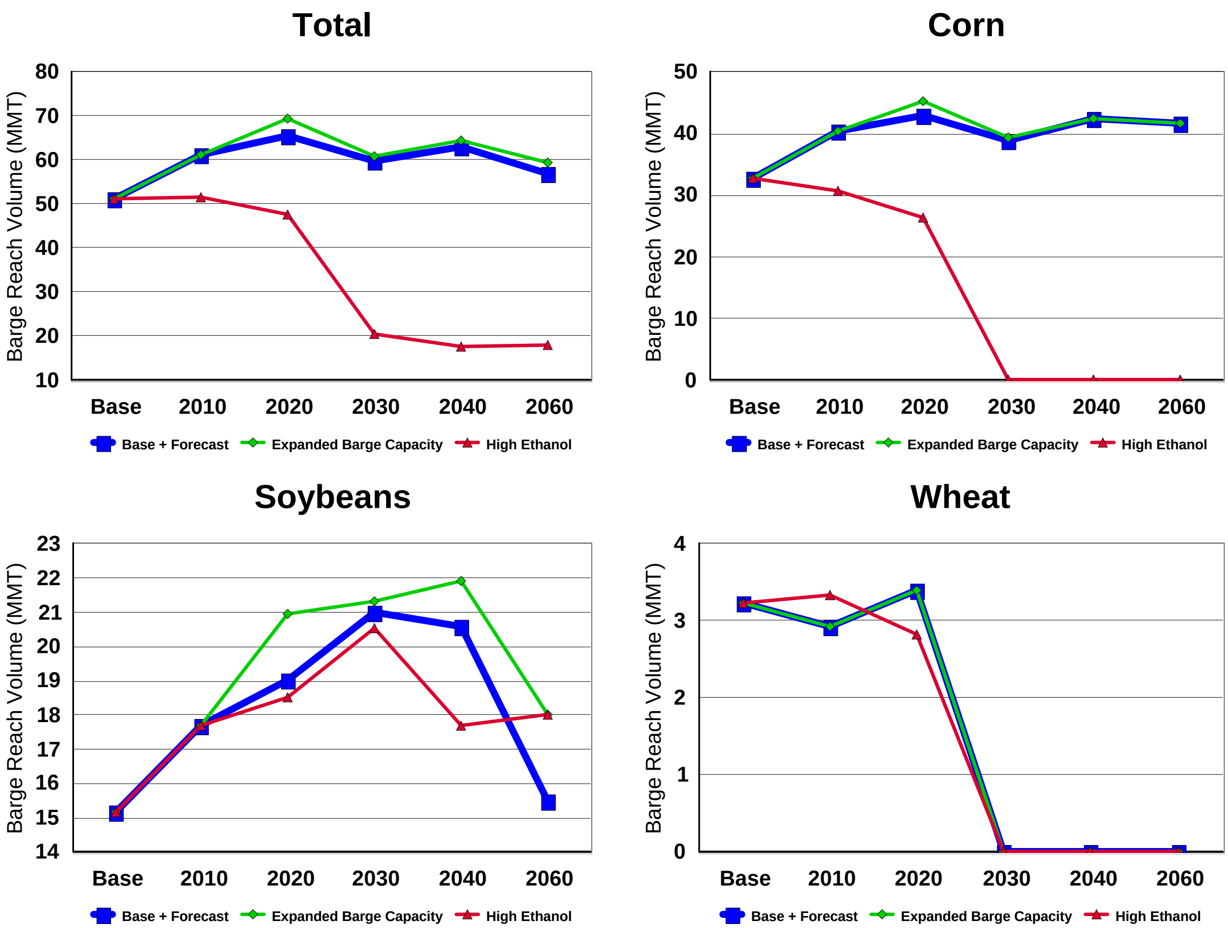

Figure 24. Barge Reach Volume, Total and by Crop for Base Case, Expanded Barge Capacity and High Ethanol Demand Scenarios

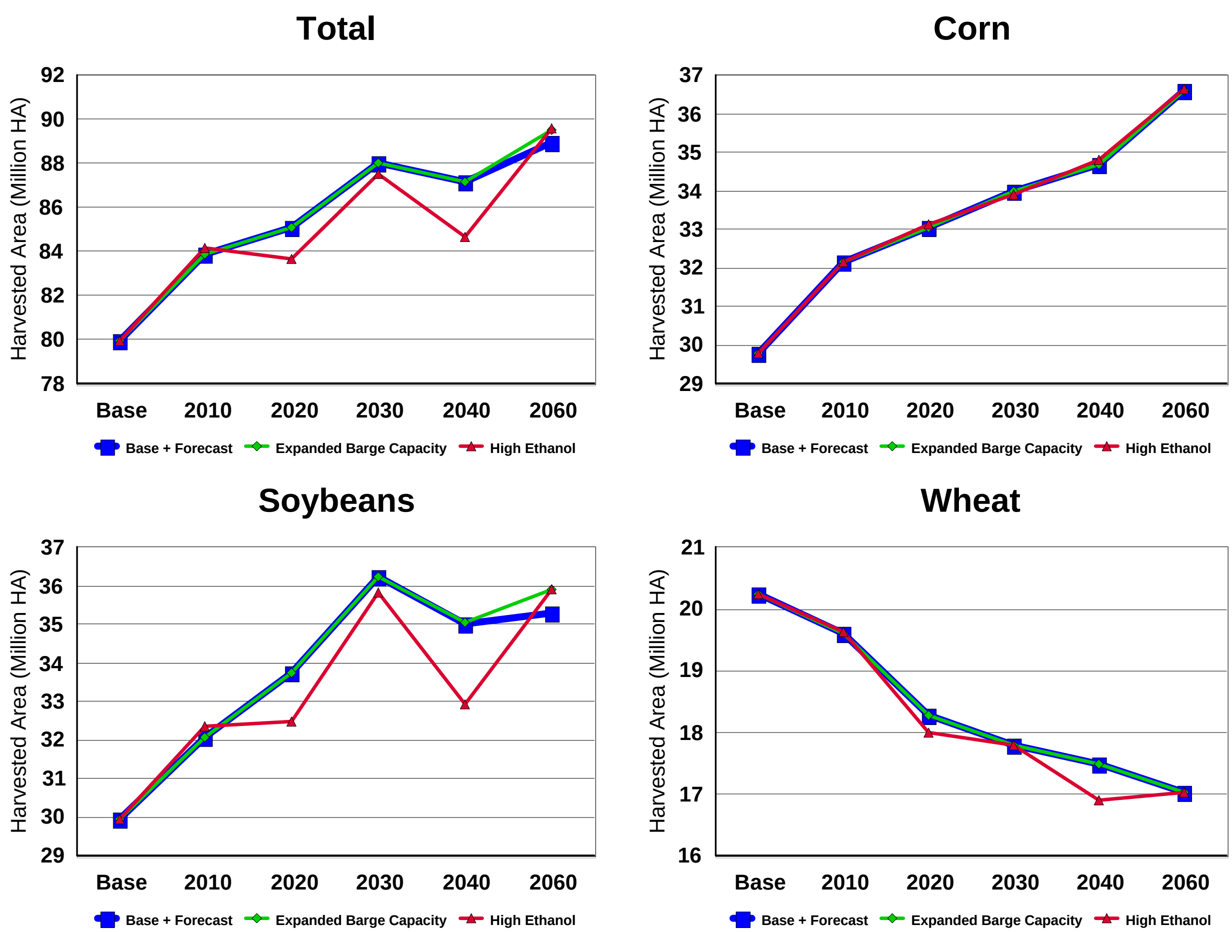

Figure 25. Comparison of U.S. Harvested Area, Total and by Crop for Base Case, Expanded Barge Capacity and High Ethanol Demand Scenarios

Conservation Reserve Program (CRP): One of the more important US policies in the near term that could impact these results is the administration of the CRP program. This is particularly true in light of the recent expansion in ethanol.

The CRP is a voluntary program to protect environmentally sensitive lands. In 1998, 18.5 million acres were put under the program. Many of these acres could be brought back into the program commencing in 2007 as illustrated in Table 22.

Currently, there are 37 million acres in the CRP program. These acres are mostly concentrated in the dry sections of the Great Plains. There are 13.7 million acres in Texas, Montana, North Dakota, Kansas and Colorado. There is some in the corn belt states, including 2 million in Iowa and 1.1 million in Illinois. Most of these acres are not up for renewal anytime soon. Of the 16 million acres coming up for renewal in 2007, 3 million acres are currently slated to expire and not re-enter the program. The bulk of these are in the plains, with expiring Iowa acreage of 114,000 and Illinois at just 70,000 acres.

Table 22. 2007 Expiring CRP Acres for Specific Crops and Model Base Area

	2007 CRP	%
Corn	1.9	0.03
Soybeans	2.6	0.04
Wheat	9.3	0.19
Total	13.8	0.07

* CRP area adopted from Hart (2006a).

These values represent 7% of the land in the model's base period. If prices are strong during the expiration period, it may result in a portion of these being returned to production. Hart (2006a) indicated that USDA has been notifying producers on their eligibility to extend current CRP acres or to re-enroll under a 10-15 year contract; and, that USDA opened a general CRP sign up for the spring of 2006. This implies that there are 13.8 mill acres in corn, wheat, soybeans that expire in 2007. In early June 2006 USDA announced it had re-enrolled or extended all 2007 expiring CRP contracts except those involving voluntarily withdrawals. These contracts covered 13 million acres that were previously scheduled to expire on Sept 2007 (NGFA 2006). USDA indicated there were 12 million acres scheduled to expire between 2008-2010.

During late 2006 there was discussion that USDA would announce a more meaningful shift in the CRP system this winter that will have a big impact over the coming decade (as reported by Mann Global Research, 2006a, amongst others). There was an idea that USDA would enact policies to substantially increase US corn planting, beginning in 2007, and then expanding dramatically over the coming decade. While this will presumably be a several point plan, the crux will center around a racheting back in CRP acreage, and a corresponding shift into grain and oilseeds crops. This was subsequently suggested by Secretary of Agriculture Johanns as baseless, but, it remains hotly debated (Tomson).

To assess the importance of this, the model was used to evaluate these impacts. Results are not repeated here since a maintained assumption was that the maximum area would increase by 7% the acres commencing with the 2010 projection. The result of our base case projections implies a return of these acres to production. As noted above, if these were not, the implication would result in competitor countries expanding their area.

To explore this further, the model was run for 2020 assuming an additional 7% increase in area available for planting where this 7% was allocated based on the distribution of CRP acres by production region. The results are show in Figure 26 and illustrate that if this were to occur, the amount shipped by barge would increase by about 5 mmt. Most of the increase would be in Reaches 2, 4, 5 and 6.

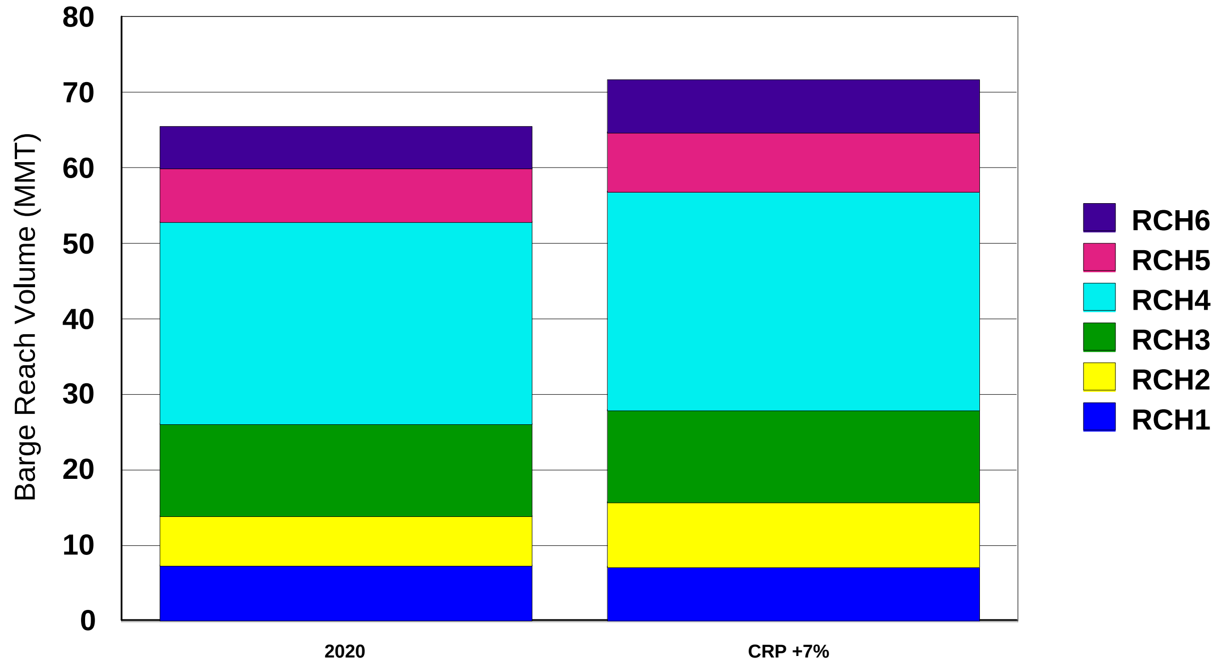

Figure 26. Effect on Barge Loadings of Increased Production Area in U.S. from CRP (7%), based on Regional Adoption of CRP

SUMMARY

The purpose of this study was to develop a methodology and analytical model to forecast grain and oilseed shipments through the Mississippi River system. The focus is on the world grain trade and expected changes in response to a multitude of evolving competitive pressures and structural changes. Emphasis is on the competitiveness of the US agriculture sector that is tributary to the Mississippi River system, to assess impacts of critical variables on its competitiveness, and to project changes in flows.

The model is a spatial optimization model of the world grain trade. Important parameters are forecasted and used to evaluate changes in flows through specific logistical channels. Projected import demands are based on consumption functions estimated using income and population and accounting for intercountry differences in consumption dependent on economic development. Each of the competing supply regions and countries were represented by yields, area potential that could be used in production of each grain, costs of production and interior shipping costs where relevant. Crucial in this model is the interior spatial competition between the US Pacific Northwest and shipments through the US Gulf as well as inter-Reach competition. This differs from other analysis based on econometric projections which do not address inter-port and inter-Reach competition.

This model differs from others. It is a longer run model. Consequently, the model allows for numerous longer-run adjustments. For example, changes in barge rates or capacities have the impact of simultaneously affecting barge shipping costs including delay costs, as well as barge movements on particular Reaches, rail rates, as well as marginal changes in production and exports from the United States and other countries. Thus, the comparative statics captures the impact of longer-run adjustments. Second, the model has very extensive intermodal competition which affects inter-port, inter-Reach and intermodal as well as interregional competition.

Summary of Underlying Data

The results identified a number of important factors that will be impacting barge shipments. These include:

Growth Markets: The most important and fastest growth markets, for consumption of corn and soybeans are China, North Africa, South Africa and the FSU and Middle East. Growth in wheat is lesser and is dominated by South Asia, Southern Africa, China and Latin America. The larger traditional wheat markets of Japan and the EU has near nil growth rates.

Corn Used in Ethanol: An important change that is occurring and will have an important impact on the amount of corn available for export is the explosion of the ethanol industry. In concept, the US energy policy will result in increased domestic demand for corn, increased planting of corn to the extent technically possible, reduced plantings of wheat and soybeans in the United States. The latter will result in increased plantings in other countries and reduce exportable supplies from the United States. Corn used in ethanol production is expected to increase from four billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons in 2020 forward. More recent studies have suggested this could be greater and all point toward severely reduced exports.

Grain Production Costs and International Competition: These results indicate there are substantial differences in production costs. In particular: 1) the US is the lowest cost producer of corn and soybeans; 2) most US regions' production costs for soybeans are less than those in Brazil, and those in Brazil South are less than those in Brazil North; and 3) other countries have lower costs for producing wheat than those in the United States. However, the United States, and Canada have quality advantages not shared by other wheat producing countries. The cost advantage of the United States diminishes over time and in some of the latter years costs of competing countries decline relative to the United States. These notwithstanding, as illustrated the world supply/demand balance is relatively tight for most grains and as such production from most regions is necessary to satisfy demand requirements.

Intermodal Competitiveness: Most important is the close relationship between rail and barge shipments, particularly from the Upper Mississippi River. During the base period, it is critical that rail rates are less than barge shipping costs for some larger origin areas and movements. In some cases the direct rail cost to the US Gulf is less than barge shipping costs.

Delay Costs on the Barge System: Delay costs are the additional costs associated with shipping on the barge system and result from queuing and the added costs for shipments that are delayed. These are an important feature of barge shipping, particularly when shipment volumes are greater. In several of the Reaches grain flows are near the point at which positive delay costs are accrued. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic.

The delay curves would change if the locks were expanded, as proposed. In each case the proposed improvements would have the impact of shifting the delay function rightwards meaning that near-nil delay costs exist for a broader range of shipments. In addition, the value of the negative delay costs for lower volumes are slightly greater than in the previous case.

Results From the Empirical Analysis

Below is a summary of the projections and sensitivities:

Base Case Projections: The results suggest exports from the United States increase from the base period to 2010 in part due to the assumption that the maximum area for plantings would increase and in part due to that China's corn exports are assumed nil in 2010 and beyond. US corn exports decline the most, with a potential peak of 62 mmt to around 42 mmt. Wheat exports decline substantially, but soybeans increase through 2030. Exports from the United States are concentrated in the US Gulf, which declines to 57 mmt after reaching a peak of 92 mmt in 2010. Exports from the PNW are 25 mmt in the base year and declines in later years. The results illustrate that the United States remains an important exporter of soybeans and this conclusion persists in other scenarios.

Total barge volume increases from the base period at 51 mmt to 65 mmt in 2020. Thereafter, shipments decline to a longer term level at about 57 mmt. The reduced volume comes from limited reductions in corn and soybeans with drastic declines in wheat shipments.

Projections with Expanded Capacity and Delay Costs: There are currently delay costs, particularly on Reaches 1 and 4. As volumes increase, costs of shipping by barge increase, some shipments are diverted to different modes and/or routes, and delay costs accrue to shippers. Without the expansion in barge capacity, the delay costs in 2020 would increase on each Reach. Those on Reach 4 would increase to $1.08/mt.

Expansion would result in reduced delay costs on each or Reaches 1, 2 and 4 by about $0.44/mt, 1.04/mt and $1.01/mt respectively. Expanding lock capacity reduces delay costs, increases capacity and shipments by barge. Barge shipments increase by about +4 mmt by 2020. Thereafter, the change in barge shipments would be about +0.9 mmt to +2.5 mmt. There is substantive inter-reach competition and by 2020 shipments on Reach 1, 2 and 4 increase, but shipments on Reach 5 and 6 would decrease.

Delay costs, in aggregate are comprised of the lower delay costs that would occur at current capacity, plus the volume effect. The impact of expansions on delay costs are in the area of $61 million, inclusive of both direct effects. Most of this is accrued on Reach 4, followed by Reach 2 and 1. Expansion results in an increase in barge costs due to the increase in volume, a decrease in rail shipping cost, and a slight increase in ocean shipping costs. In total, the impact of expanding locks is a decrease in costs by about $52 million.

High-Ethanol Impacts: The base case assumed EIA 2005 projections of corn use in ethanol demand. The model was revised assuming the EIA 2006 estimates of ethanol produced from corn. Results are drastic. Exports from Argentina, Europe and Eastern Europe, increase and wheat exports from Australia Increase.

Exports from the United States decline from 101 to 78 mmt by 2020, vs. the base case which increased from 101 to 111 mmt. Gulf exports decrease (65 to 51 mmt) and PNW changes only slightly to 14 mmt. Most of the decline is in corn and wheat shipments. Soybeans remain at about 30 mmt. Reach shipments change as well. There is a slight increase through 2010 and thereafter shipments decline to 48 mmt in 2020 and lesser values in years beyond. The decline is greatest for corn, and then wheat. The largest declines for 2030 and beyond are for shipments from Reaches 1, 3, 4, and 5, each declining in the area of 5 to 10 mmt vs. the base case.

In addition, there are major changes in flows within the United States. Most interesting are the increase in shipment to the Eastern and Western corn belts reflecting the increase in domestic demand for ethanol use. Also are the changes in flows from the Northern Plains which had previously exported most of its corn through the PNW. These are now shifted with a significant portion destined for domestic movements. There are also substantial changes in flows from US domestic regions to the Reaches and port areas. Most important are reductions in shipments from Iowa River to Reach 2, Minnesota River to Reach 3, and Illinois North to Reach 4. There are reductions from most regions to New Orleans, but, an increase from Illinois South to New Orleans.

The model was also run assuming more stylized assumptions for some critical variables, mostly impacting the ability of corn production to expand to meet these competing demands. The results suggest the model is fairly robust in capturing these different assumptions. Most striking in making these comparisons are: 1) Corn exports from the United States increase to nearly 83 mmt, as opposed to decline to less than 26 mmt in 2020; 2) Soybean exports from the United States decline to 28 mmt vs. 36 mmt for the 2010 case and those from Brazil and Argentina each increase sharply vs. our base case solution; 3) Wheat exports increase from each of the competitors and those from the United States decline, but, by not as much as in our unrestricted high-ethanol case; and 4) Reach shipments increase.

There are important reasons for these differences. Most important are assumptions about the yield growth, the ability to expand corn acres, and differing assumptions on soybean production and exports from the United States vs. competitor countries.

China Policies: One of the most dynamic countries in the world grain market is China and whether China becomes an importer is highly uncertain. If China becomes an importer, the results depend on the ethanol assumption. Under base case ethanol scenario, shipments on the barge system increase slightly. Under a high-ethanol assumption, barge shipments decline.

Conservation Reserve Program (CRP): One of the more important US policies in the near term that could impact these results is the administration of the CRP program, particularly true in light of the recent expansion in ethanol. There are 13.8 mill acres in corn, wheat, soybeans that would expire in 2007. USDA indicated there were 12 million acres scheduled to expire between 2008-2010.

The model was used to evaluate these impacts. Results are reflected in the base case projections since returning 7% of the base area was a maintained assumption. If these CRP acres are not returned, competitor countries would expand production and barge demand would decline by 10 mmt. In either case, this is a critical policy that impacts barge demand.

Major Factors Impacting Results

These results are very clear in terms of the direction and size of future barge shipments. Those of greatest importance are ethanol, longer term competitiveness of competitor countries, and competitiveness of rail/road versus barges.

Ethanol: The ethanol impact is drastic and has a very important negative impact on barge demand. Simply, increases in ethanol demand results in a shift toward domestic use of corn, reduced exports of corn, shifts from wheat (primarily) into corn which reduces exportable supplies. These are offset by expanded production in competitor countries. Notable amongst these are Brazil and Argentina, Australia, Eastern Europe and China.

The results are very sensitive to underlying assumptions regarding area planted to corn and yields.

Competitor Countries: The United States has the advantage of being a low cost producer of corn and soybeans. However, other countries costs per mt are declining relative to those in the United States. This is a subtle conclusion but impacts the results when extrapolated forward. In addition, while some other countries have the ability to expand area, the ability to expand in the Untied States is restricted in part due to the CRP, and in part due to the technical ability to substitute into other crops.

Even though Brazil and Argentina are not lower cost in corn and soybeans, they play a critical role. Though there is strong demand for soybeans internationally and the United States is lower cost, the ability to expand in the United States and simultaneously serve other demands is limited. This is what provides opportunity for these countries.

Rail Competition: Rail competition is critical and has a direct impact on barge shipments. There are two aspects of rail competition. One is the level of rail rates relative to barge rates on some specific barge competitive movements. These results show that 1) on some movements, rail rates to US gulf and/or other transit points are lower than by barge; and 2) rail rates have benefitted from productivity increases and lower rates over time. The second is rail capacity which has increased over time due to investment in cars and productivity. These increases in capacity have the impact of reducing demand for barges.

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