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# Long-Term Forecasting of World Grain Trade and U.S. Gulf Exports

*Submitted to the Transportation Research Board For publication in Transportation Research Record*

US Army Corps of Engineers®

IWR Report 04-NETS-P-08

# Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

## Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

## Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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*The NETS program was overseen by Mr. Robert Pietrowsky, Director of the Institute for Water Resources.*

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# LONG-TERM FORECASTING OF WORLD GRAIN TRADE AND U.S. GULF EXPORTS

*Submitted to the*
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**ABSTRACT**

Important changes are occurring in the world grain trade that will impact the spatial distribution of grain flows and affect large scale transportation projects. Most important amongst these are developments in ethanol, Brazil and China. This paper develops a spatial optimization model based on longer term competitive equilibrium to make projections in the world grain trade, and shipments from individual ports to the year 2025. Results indicate that world trade should increase by about 47% with the fastest growth occurring in imports to China and Pakistan. Japan and the EU, traditionally large markets, are slowest growth. Most of the increases in terms of volume are expected in soybeans (49%), followed by corn (26%). Most of the US export growth is expected through the US Gulf barge system, with negligible growth through the Pacific Northwest and Lakes. While there are a multitude of reasons for this, one is the growth in ethanol, which is concentrated in the western states, and which will require shifting production to meet those demands. As a result, the exportable surplus from these regions will decline and through spatial competition, much of the growth in exports will be through the US Gulf and from Argentina and Brazil, particularly northern Brazil. These results reflect the impacts of growth in demand, international and intermodal competition, and hence provide insight for transport project planners about the longer term growth in exports from particular origins and routes.

## Long-Term Forecasting of World Grain Trade and US Gulf Exports

## 1. INTRODUCTION

Several important structural changes are occurring in the world grain trade that will impact the longer-term competitiveness of countries and regions and ultimately impact the spatial distribution of grain flows. These are influenced by many factors including production, consumption which is impacted by tastes, population and income growth, as well as agricultural and trade policies. The relative costs of production, interior shipping, handling and ocean shipping costs all have an impact on trade and competitiveness. Changes in any of these variables will impact the international distribution of grains and oilseeds and transportation infrastructure projects including individual port projects (e.g., Santos, US Pacific Northwest), Canal projects (including the Panama Canal) and the US inland waterway system. All of these are large scale projects and the time frame for their decisions is much longer that typical commercial projects.

The purpose of this paper is to make longer term projections of world grain trade and assess their impacts on particular transport projects, in this case grain exports through the US inland waterway system for export from the US Gulf. To do so, the longer-term competitiveness of agricultural production and trade of six major grains is analyzed using a spatial optimization model of the world grain trade using detailed data and simulate changes in production and trade to the year 2025.

## 2. BACKGROUND

While there are numerous structural changes occurring in the world grain trade, three are particularly apparent.

### Ethanol

An important change in US 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. These types of increases will impact demand for domestic consumption of corn in future.

For perspective on growth and changes in this sector, Feltes (1) indicated that the demand of corn for ethanol is projected to increase by 1 billion bushels in the next 10 years. ProExporter (2) indicated that the United States will need another 40 or 50 ethanol plants and that would divert another 1 billion bushels of corn to match the same billion bushels devoted to ethanol production today. And, USDA (3) (2003 Outlook conference) indicate that “over 1 billion bushels of corn will be used to produce ethanol in 2003/04, and this approaches 2 billion bushels by the end of the decade.”

There are two important aspects of the growth in demand for ethanol production. One is that it is concentrated in the western corn belt region. Results from two separate studies were used to form projections on future ethanol capacity and corn consumption. Guebert (4) cites industry projections for total ethanol demand for ethanol in 2012 will be 5.5 billion gallons/year. The California Energy Commission (5) surveyed current and prospective firms on plans for ethanol capacity to the year 2005 and derived expected plant capacity by region in 2005. Using these projections and some technical assumptions, the projected consumption of corn by producing/consumption regions was derived. This procedure resulted in the added corn required to meet expected ethanol production demands over that in the current year for both 2010 and 2025. These results indicate that as a result of the accelerated ethanol demand for corn, that corn consumption will increase another 13% by 2010, versus what would otherwise be natural consumption growth. Most of the growth in ethanol consumption will be concentrated in Central and Northern Plains, and the Western Corn Belt. Over time, this increase in domestic demand will result in a shift in production from soybeans and traditional small grains into corn. For each of these regions, this increase in domestic demand will reduce their exportable surplus, which otherwise would have been shipped off-shore.

**Changes in Brazil Soybean Production**

Soybean production and productivity in Brazil is changing and will impact world production and trade. Production has traditionally been concentrated in the Southern provinces of Brazil and the Central West regions. These were typically used for domestic crushing and the production of soybean oil and meals which were used locally for food and/or feeds, or were exported as products; or, the soybeans were exported directly. Typically, these soybeans and related infrastructure were exported from the Southern ports of Santos, Paraguan.

Soybean production expanded rapidly in the traditional south region, increasing from less than 2 million ha in 1970, to nearly 8 million ha in 1975. Since then, area planted in this region has remained in the 6-7 million ha level. The regions in which most of the expansion is occurring is in the Central West, and North. Area planted in these regions has increased from nil through the mid-1970s, and now has more than 7 million ha planted, exceeding that in the traditional south.

In recent years there have been 2 major changes. One is for a sharp increase in production, the other for a shift in production to more northerly regions. This has resulted in simultaneous pressures for development of transport infrastructure for exports from these regions. Schnepf, Dohlman and Bolling (6) indicated that ".... Brazil, in addition to having the world/s largest pool of undeveloped land (roughly equal to all US cropland)...." In addition to the growth in production potential, there are changes occurring in shipping economics within Brazil. In particular, there are several infrastructure projects underway, being planned, and/ or being discussed. All of these are focused on developing lower costs means of exporting soybeans, generally through the Northerly ports. These include interior truck/water shipments to Itacoatiara and Santarem (a port facility was opened in April 2003) which is fully adopted. The BR163 is a highway to Santarem which is in the process of being developed.

Taken together, these will lower shipping costs from these otherwise high-shipping cost regions, change the flows of exports within Brazil, and increase returns to producers by about \$10/mt. Specifically, analysis by ANTAQ (7) indicated that by 2015 shipments to the north would become more competitive. The results also indicated a change in the advantage in shipping north that is apparent. In most cases the Northern shipments of soybeans from Brazil would be natural tributary to Rotterdam, the traditional market, or to Asia and China via the Panama Canal.

**China Growth in Import Demand**

China is a large market with rapid growth in population and income. Both of these have the impact of rapid growth in domestic demands. Though China is also a large grain and oilseed producer, their productivity growth rate is not expected to keep pace with demand. In particular, in our base case to 2025, demand exceeds production.

Sparks (8) expects Chinese corn exports to eventually taper off to only 2 mmt by 2006. The Central planners are trying to increase soybean acres to reduce dependency on imports but have registered little success to date. Chinese soybean area has advanced only .4 million ha since 1998 despite declines in wheat/feed grain area. The 2003 USDA Agricultural Baseline Projections (3) suggested Chinese imports of wheat would increase from 1.5 mmt in 2003/04 to 9.1 mmt by 2012/13. They cite land use competition and increasing water limitations in China to increase that country's need to import wheat (9) *Milling and Baking News*, February 18, 2003, p. 39.) USDA (3) sees the sharp uptrend in Chinese imports continuing unabated for the next 10 years, eventually rising above 25 mmt by 2011. However, ProExporter (2) labeled this projection "not remotely plausible," instead seeing Chinese imports stabilizing between 16-18 mmt over the next 10 years.

## 3. PREVIOUS STUDIES

A number of studies conduct longer-term forecasts.. e.g. FAPRI, USDA, etc. However, these are for policy purposes and generally use econometric based models for projections. Most important is that they do not address issues related to transportation, spatial and intermodal competition. As a result, they are generally limited in terms of providing estimates for infrastructure planning. Other studies (10, 11) caution about the use of these types of models for infrastructure planning.

Several studies have forecast trade flows, either internal or seaborne utilizing past relationships for flows. Recent studies have focused on Mississippi river traffic (12, 13, 14, 15) and another focused on major seaborne trade flows (16). Babcock and Xiannau (12) address short term forecasting of inland waterway grain traffic. Faucett and Associates (13, 14) forecast barge traffic on the Upper Mississippi and Illinois River system where shares of barge traffic (inland) were allocated based on fixed shares of exports.

Other recent studies have focused specifically on transport infrastructure and trade flows.

Fellin and Fuller (17) developed a model to examine effects of waterway use tax on U.S. grain flows for corn and soybean sectors. A quadratic programming model of corn and soybean sectors was developed that maximizes net social payoffs or consumer plus producer surplus minus grain handling, storage and transportation costs. Barge costs were estimated by simulating movement of a barge over the complete cycle where transit times were estimated based on length of haul, number of locks encountered and prospective delay times at given locks. The authors found increases in barge fuel taxes would divert 10.6 MMT from inland waterways, of which 70% of diversions would be from the upper Mississippi/Illinois river system.

Fuller et al. (18) developed a spatial equilibrium model to examine the effect of grain transportation capacity on the upper Mississippi and Illinois rivers on trade flows. The model maximizes net social payoff of consumer plus producer surplus minus costs for grain handling, storage and transportation. The model utilized a regression equation to determine average lock delay time for shipping. Barge transportation costs for selected loading sites on the two rivers were estimated for different capacities with the tow delay equation, annual lock capacity information and a barge costing model. The authors indicate this model is only relevant for short term forecasts.

## 4. EMPIRICAL MODEL: SPATIAL GRAIN FLOWS, SIMULATIONS, PROJECTIONS AND IMPACTS

A large number of factors impact world grain trade and the spatial distribution of shipments and demands for specific routes and modes. These include supply and demand in individual countries and regions, production costs, trade and agricultural policies, interior shipping and handling costs and ocean shipping costs. To analyze these, a spatial optimization model of world trade in grains was developed. Twenty importing and exporting countries and 11 regions were identified and selected for six crops: barley, corn, rice, sorghum, soybeans, and wheat. Agronomic and consumption were estimated econometrically. Then, the spatial optimization model and data sources are described.

### Harvested Area, Yields Domestic and Import Demand

Harvested area were obtained for the 6 crops in 31 countries/regions and are specified as a function of a trend which represents gradual changes in arable land for each grain in the individual countries. The changes in arable land under cultivation may be due to changes in economic conditions, availability of water for agricultural production and trade environments in the countries/regions. Harvested area is specified as: $HA_{cit} = (_{0cit}+(_{1ci}Trend + ,_{cit}$ where c = 1 to 31, and i = 1 to 6. The model is estimated with time series data of HA from 1980 to 2001 and the estimated model is used to forecast HA for the 2002-2025 period. The estimated value was posed as a maximum available.

Yield for each crop in individual countries/regions is specified as a function of the trend which represents advancement in farming technology. Since crop yields have increased at a decreasing rate in most countries, a double log functional form was used. The yield equation is specified as: LnYLD $_{cit}$ = ($_{0cit}$ +($_{1ci}$LnTrend + ,$_{cit}$ where c = 1 to 31, i = 1 to 6, t = 1980 to 2001. Yields were estimated for each crop using time series data from 1980 to 2001 and the estimated model is used to forecast yields for the period 2002 to 2005. Annual data for harvested area (HA) and yield (YLD) for the years 1980-2001 were obtained from USDA PS&D data base (17).

Consumption functions were estimated for the 6 crops in the 20 countries and 11 regions. A double log functional form was used because of the nonlinear relationship between income and consumption. LnPCC$_{cit}$ = $B_{0cit}$ + $B_{1ci}$ LnTrend + $B_{2cit}$ LnPCI + ,$_{cit}$ where c = 1 to 31, i = 1 to 6, t = 1980 to 2001, PCC is per capita consumption, and PCI is per capita income. The estimated PPC model was used to forecast PPC for the period 2002-2005. PCI was derived from WEFA Macroeconomics (18). From these results, we derived the total domestic demand for each grain in each country or region.

Import demand (MD) for each crop in the countries/regions were defined as $MD_{cit} = DD_{cit} - DP_{cit}$ where total production (DP) and domestic consumption (DD). If MD is positive, country c is an importing country, while country c is an exporting country if MD is negative.

**Spatial Optimization Model**

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 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 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. In the long run, it is more likely that a large portion of subsidies given to producers in both exporting and importing countries under the globalizing trade environment will decrease. Under these conditions, trade flows of agricultural commodities would be determined on the basis of production costs in exporting countries and marketing costs from exporting countries to importing countries. In addition, yields in producing regions in exporting countries are included to measure efficiency in primary crops and oilseeds. Demand is projected and the least cost means of meeting demands is derived. A quadratic programming model could be used to determine the optimal flows of grain and oilseed, but it cannot compare directly production costs in regions to determine competitiveness in producing commodities. Our approach differs from econometric models that use functional relationships to project equilibrium trade levels, and, from a full blown spatial equilibrium model. Given our objective is to make longer-term forecast and the greater emphasis on spatial and modal distributions, a model based on longer-term competitive equilibrium was used.

The model is solved jointly for each of the 6 grains. Costs included in the model are production costs for each grain in each exporting country and region, interior shipping and handling cost for each grain in each exporting region and ocean shipping costs and tolls for shipments through the Panama Canal.

The model contains 13 exporting and 26 importing countries and regions with each type of grain and oilseed having different sets of exporting and importing countries. Some exporting countries are further divided into producing and consuming regions to capture the inter-dependency between the transportation system and agricultural production. Transportation modes included truck, rail and barges for inland transportation and ocean vessel for ocean transportation. The model contains 16 ports in exporting countries and 32 ports in importing countries for transit of grains and oilseeds from producing regions in exporting countries to consuming regions in importing countries.

The objective function is optimized subject to a set of linear constraints. Some of these constraints 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. The objective of the model is to minimize production costs in producing regions in exporting countries and shipping costs from producing regions in exporting countries to consuming regions in importing countries. This objective function is:

$$W = \sum_c \sum_i PC_{ci} A_{ci} + \sum_c \sum_i \sum_j t_{cij} Q_{cij}$$
$$+ \sum_c \sum_i \sum_p t_{cip} Q_{cip} + \sum_c \sum_p \sum_q t_{cpq} Q_{cpq}$$
$$+ \sum_c \sum_p \sum_q (t_{cpq} + \alpha) Q^p{}_{cpq}$$

where

| | | |
|---|---|---|
| i | = | index for producing regions in exporting countries, |
| j | = | index for consuming regions in both exporting and importing countries, |
| p | = | index for ports in exporting countries, |
| q | = | index for ports in importing countries, |
| $PC_{ci}$ | = | production cost of crop c in producing region i, |
| $A_{ci}$ | = | area used to produce crop c in producing region i, |
| t | = | transportation cost per ton, |
| Q | = | quantity of grains and oilseed shipped, |
| α | = | tariff per vessel for Panama Canal transits, |
| $Q^p$ | = | quantity of grains and oilseeds shipped through the Panama Canal. |

The first term on the right hand side represents production costs in producing regions in exporting countries; the next two terms represent transportation costs of shipping agricultural goods from producing regions to domestic consuming regions for domestic consumption and ports for exports in exporting countries. The next two terms represent ocean shipping from ports in exporting countries to ports in importing countries.

This objective function is optimized subject to the following constraints:

1) $Y_{ci} A_{ci} \geq \sum_j Q_{cij} + \sum_p Q_{cip}$

2) $\sum_{c} A_{ci} \leq TA_{i}$

3) $A_{ci} \geq MA_{ci}$

4) $\sum_{i} Q_{cij} + \sum_{q} Q_{cqj} \geq MD_{cj}$

5) $\sum_{c} \sum_{i} Q_{cip} \leq PC_{p}$

6) $\sum_{c} \sum_{p} \sum_{q} Q^{p}{}_{cpq} \leq PCC$

7) $\sum_{i} Q_{cip} = \sum_{q} Q_{cpq}$

8) $\sum_{p} Q_{cpq} = \sum_{j} Q_{cqj}$

where

| | | |
|---|---|---|
| y | = | yield per hectare in producing regions in exporting countries, |
| TA | = | total arable land in each producing regions in exporting countries, |
| MA | = | minimum land used for each crop in producing regions in exporting countries, |
| MD | = | forecasted domestic demand in consuming regions in exporting countries and import demand in consuming regions in importing countries, |
| PC | = | handling capacity in each port in both exporting and importing countries, |
| PCC | = | throughput capacity for grains and oilseeds at Panama Canal. |

Equation 1 indicates that total grains and oilseeds produced in each producing region in exporting countries should be equal or larger than the quantities of grains and oilseeds shipped to domestic consuming regions and export ports. It is assumed that a country exports quantities of grains and oilseeds after satisfying its domestic consumption. Under this assumption, exportable surplus is total domestic production of each type of grain and oilseed minus domestic consumption of the individual crops. Equation 2 represents the physical constraint of arable land in each producing region. Since total arable land is fixed in each producing region, production activities should be optimized within the physical constraint of arable land. The next constraint (Equation 3) represents characteristics of production activities in each producing region in exporting countries. In general, producers in a region tend to produce certain crops due mainly to their experience in production practices of the crops and soil types, even though producing the crops is not economically optimal. To incorporate this characteristic, Equation 3 provides the minimum production constraint for each grain or oilseed. Since demand for grains and oilseeds is estimated for 2010 and 2025 using econometric techniques, the estimated demand for grains and oilseeds in each consuming region in importing and exporting countries is introduced into the model. Equation 4 represents the import and domestic demand constraints in importing and exporting countries, respectively.

Equations 5 and 6 represent grain and oilseed handling capacities at ports in exporting and importing countries and the Panama Canal. Total quantities of grain and oilseed handled by each port and Panama Canal should be smaller than their annual handling capacities. The last two constraints are inventory clearing constraints at ports in exporting and importing countries. Ports in exporting and importing countries are considered as transhipment points in exporting or importing grains and oilseeds and are not allowed to carry inventories. Excess supply of a grain is calculated by subtracting domestic consumption from production under an assumption that carry-over stocks remain constant over time.

A base case is defined first and used for comparison to results of the impacts of prospective exogenous and endogenous changes, as well as changes in inter-regional and intermodal competitive factors. The base case should be interpreted as that reflecting the most likely (current) scenario. The base case uses values for the 2000/01 world crops marketing year for calibrating domestic consumption and production, as well as for interior and international shipping costs. In later simulations, assumptions are relaxed, and/or values of variables in the model, and evaluate them relative to the base case.

In addition to the restrictions implied above, some selected restrictions were imposed on the model to calibrate it to current trade patterns. These are summarized in Table 1. These were applied in order to capture some of the peculiarities associated with world grain shipments. Most of these restrictions affect the wheat sector and relate to costs and quality differences among suppliers and importers. The purposes of the restrictions are due in part that there are numerous suppliers that are much lower cost than North America. However, at least historically, importers have entrenched purchasing and import practices to import from these regions mostly due to quality differences, despite that they are higher cost.

**Data**

Production costs of grains and oilseeds are obtained from Wharton Econometric Forecasting Associates (19). Yields of grains and oilseeds are estimated using an econometric technique and forecasted on the basis of expected development in farming technology for 2010 and 2025. The data used for the yield estimation came from USDA/FAS and USDA/NASS (20, 21). The estimated demand equations for each category of grains and oilseeds are used to forecast consumption in each country. Income forecasts by WEFA are used to forecast consumption.

Interior shipping costs were derived from the major producing regions in the United States, to major consumption regions, and to export ports. These were done for both rail and for barges from the primary barge origin points. For shipments from Eastern and Western Corn Belts and Northern Plains to export ports, an additional shipping alternative was added for shipment via barge to the US Gulf using barge rates from USDA/AMS (22). Ocean shipping costs were derived from Nathan Associates, Inc. (23) for each movement using typical vessels sizes and characteristics serving those markets. For future years, ship sizes and associated costs were allowed to change reflecting adoption on some routes.

## 5. BASE CASE RESULTS AND PROJECTIONS

### Import Demand

World import demand for all grains is expected to increase about 47% for the 2001 - 2025 period (Table 2). Pakistan followed by China (217% from 19.8 million tons in 2001 to 62.6 million tons in 2025) would be the fastest growing markets in percentage terms. Japan and the EU will have the slowest growth in import demand (less than 1%). Among crops, import demand for wheat is expected to grow slightly faster than other crops.

Import demand for corn is expected to increase about 26 % for the 2001 - 2025 period. Japan is the largest importer of corn, followed by North Africa and S. Korea in 2001. China will be the second largest importer in 2025 with an import of 9.9 million metric tons. China is expected to produce as much meat as possible to meet rapidly increasing domestic demand for meat rather than importing the shortages from major meat producing countries. Because of this, China's imports of corn are expected to increase rapidly.

The increase in import demand for soybeans is expected to be about 49% for the 2001-2025 period. The largest soybean importer is the EU, followed by Japan. However, China will be the largest importer of soybeans at about 30 million metric tons of soybeans in 2025. Import demand for wheat is expected to increase 61% for the 2001- 2025 period. The largest importers are the Middle East, followed by North Africa. However, China's import will increase faster than other countries and will be the third largest importer of wheat in 2025, with an import volume of about 15.7 million metric tons. This is mainly due to continuous decrease in wheat production in China.

### Forecast to 2025

The model was used to generate forecasts for world trade to 2025. The sequence of changes imposed on the model are summarized in Table 3. Income and population changes both impacting demand, and yields change over time having the impact on costs and on supplies. Three models are run and compared which we refer to as the base case (most likely), and pessimistic and optimistic cases. We define optimistic and pessimistic using WEFA's definition/interpretation of changes in income projections for all importing and exporting countries. These were applied tour econometric estimates of demand and used to generate alternative projections for consumption and therefore import demand.

The results are shown in Table 4 and Figures 1-2. World trade in these grains is expected to increase from about 275 mmt in 2001 to nearly 350 mmt in 2025. The range in world trade in 2025 for these grains is 270 mmt to 360 mmt. There are a multitude of effects impacting these results. The most interesting and dramatic changes are increases in corn and soybeans to China, and wheat to China and Korea. There are a multitude of minor changes, but, the most dramatic is the reduction in corn to Japan. In addition to these generalizations, developments in China are critical. Additional area is shifted into corn production resulting in and expansion by about 9-10 mmt.

U.S. corn production is expected to increase mostly in the three dominant regions: Eastern Corn Belt (+9 mmt), Western Corn Belt (+7.5 mmt) and the Central Plains (+5 mmt). Soybeans will increase primarily in the Eastern Corn Belt (+6 mmt) and the Western Corn Belt (+5.3 mmt). Wheat will increase in each of Saskatchewan, Central Plains and the Northern Plains by about 2 mmt each. Changes in production in all other crops and regions are expected to be minimal and typically less than 1 mmt.

There are a number of interesting changes occurring in exports from specific origins. Those that are noteworthy include:

» US exports from the Gulf are expected to increase by about 26 mmt, whereas the level of exports from the US Pacific Northwest would increase only marginally. Contributing reasons to this include the growth in ethanol production, primarily in the west, shifts in cropping patterns, and the diversion of shipments through the US Gulf.

» There is also substantial growth in exports from Brazil, primarily soybeans. However, most of this is expected to be from Northern Brazil export ports (growing from 7 to 17 mmt) whereas Southern Brazil exports would grow by a lesser amount.

» Exports from Argentina are expected to grow by 23 mmt, primarily of soybeans and wheat.

» Growth in wheat exports is mostly from Argentina, Australia and the EU. Argentina and Australia are relatively lower cost producers and the EU has a transportation cost advantage shipping to Northern Africa and the Middle East.

## 6. CONCLUSIONS AND IMPLICATIONS

The international distribution of grains and oilseeds is influenced by many factors. These include agricultural production, consumption which is impacted by tastes, population and income growth; as well as agricultural and trade policies. In addition, the relative costs of production interior shipping, handling and ocean shipping costs all have an impact on trade and competitiveness.

### Summary of Major Findings

World import demand for all grains is expected to increase about 47% for the 2001 – 2025 period. Pakistan and China will have the fastest growth in import demand for all grains due to projected increases in population and income. In contrast, Japan and the EU, each being mature markets will have the slowest growth in import demand (less than 1%). Among crops, import demand for wheat is expected to grow slightly faster than other crops. China's import demand growth, which is driven by population and income, is expected to increase about 217% for all grains and oilseeds, which will be a primary factor affecting the distribution of grain shipments.

As North America is one of the major producing regions in the world, these changes have important longer-term implications. Of particular importance is the large positive changes in production in corn and soybeans are notable relative to all the other grains. Most of the positive changes in production are expected to occur in the Northern and Central Plains, and the Western Corn belt.

This analysis suggested that there are numerous changes expected to occur in world grain trade over the next 25 years. Most of these are small non-drastic changes due to the overall slow rate of consumption growth. However, there are four sources of radical change that can and will have impacts on world grain trade.

One of the more dramatic changes occurring in North American agriculture is that of ethanol. It is important that there is very rapid growth in this sector, and by 2010 there will be about 28 mmt of added demand for corn for ethanol alone. These results are drastic and have important impacts on the Pacific Northwest. Most of the proposed growth in ethanol is concentrated in the Western Corn Belt. As a result, this growth is expected to attract land into corn, away from other grains, and will reduce exportable surpluses in those regions. Taken together, this will reduce exports through the US Pacific Northwest and Asian demand will increasingly be met through Gulf shipments at ocean rates and differentials used in the base case.

Though China is a large grain and oilseed producer, their productivity growth rate is not expected to keep pace with demand. These results are critical in that China is expected to increase imports by about 40 mmt. A number of markets are expected to have growth rates exceeding two percent per year, the largest is China.

Brazil production is expected, or thought to be able to increase sharply and result in exports of up to 50 mmt by 2020. However, in our analysis, Brazil is not the low cost producer and costs in that region exceed those of the United States. In our results, Brazil exports increased from 16 mmt in the base period to 28 mmt in 2025.

The analysis uses both production and logistical costs, intercountry differences amongst the former are very important. We are using variable cost of production, which it is thought that over the very long-term will be reflective of landed costs. In this analysis, those of particular relevance and importance are wheat and soybeans. Most of the competing regions are lower cost than the major exporting regions in North America. While this is true of Australia and Argentina, traditional exporters, the differences are greater amongst the emerging exporters of India, Former Soviet Union, and Eastern Europe. More than any of the other grains, there are differences in production costs in wheat among competing exporters. Most important is that the US is a higher cost producer, followed by Canada. Other traditional suppliers are lower cost and still other emerging exporters are even lower cost. This is compounded by the growth in production in Eastern Europe and the Former Soviet Union countries, as well as other non-traditional exporters (e.g. India). (Using Wharburton Econometric Forecasting Associates cost comparisons (19))

**Implications for infrastructure investments**

The changes noted above are notable and have important implications for larger scale transport projects in grain. The overall logic of the analysis is that demand in individual countries is driven by income and population growth and these vary substantially across countries. In addition, there are major differences in production and logistical costs, all of which will impact the future spatial distribution of grain trade. Admittedly, there is lots of uncertainty in evaluating the future of many of these variables. Most important are yields, consumption and intermodal shipping cost relationships.

The combination of these determines the longer-run demand for expansion of individual projects. Certainly, the results suggest there will be an escalation in demand for shipping through the US Gulf port areas, and those from Argentina and Northern Brazil. Lesser growth is expected from the North America west coast ports for numerous reasons, due to growth in ethanol which is concentrated in the Western Corn Belt, the effect of which is to attract land into corn production and reduces exportable surpluses of other grains.

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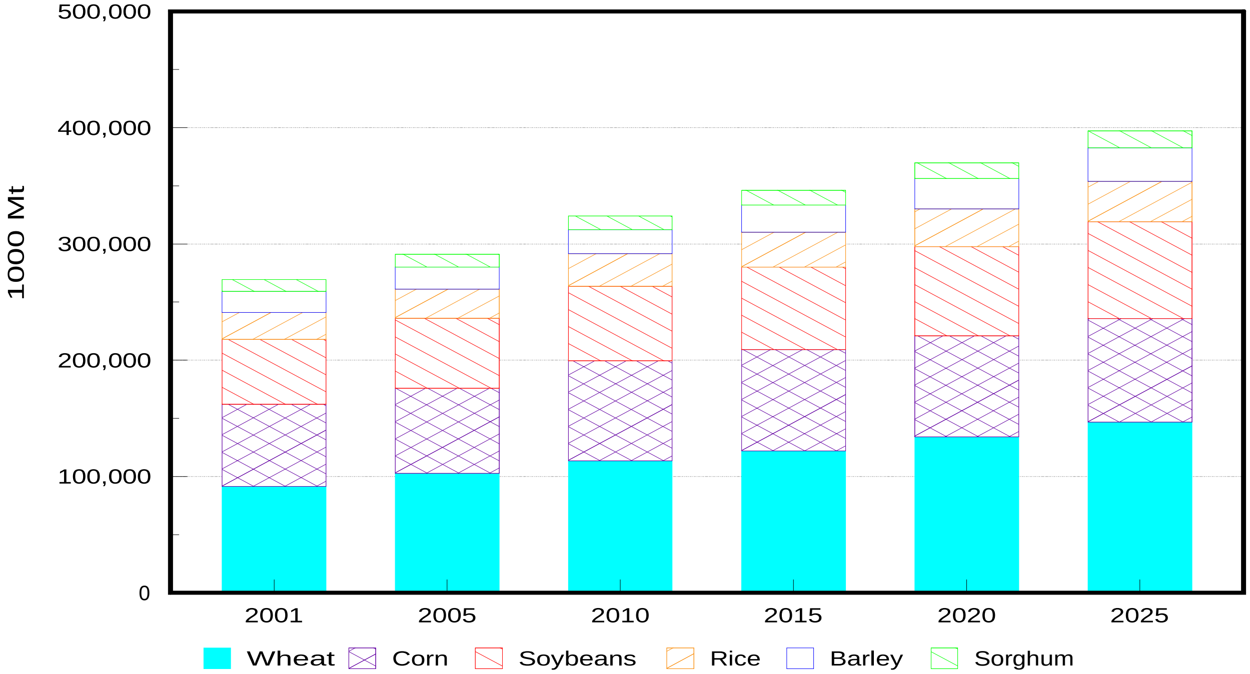


**Figure 1. Total Import Demand, 2001-2025, All Grains.**

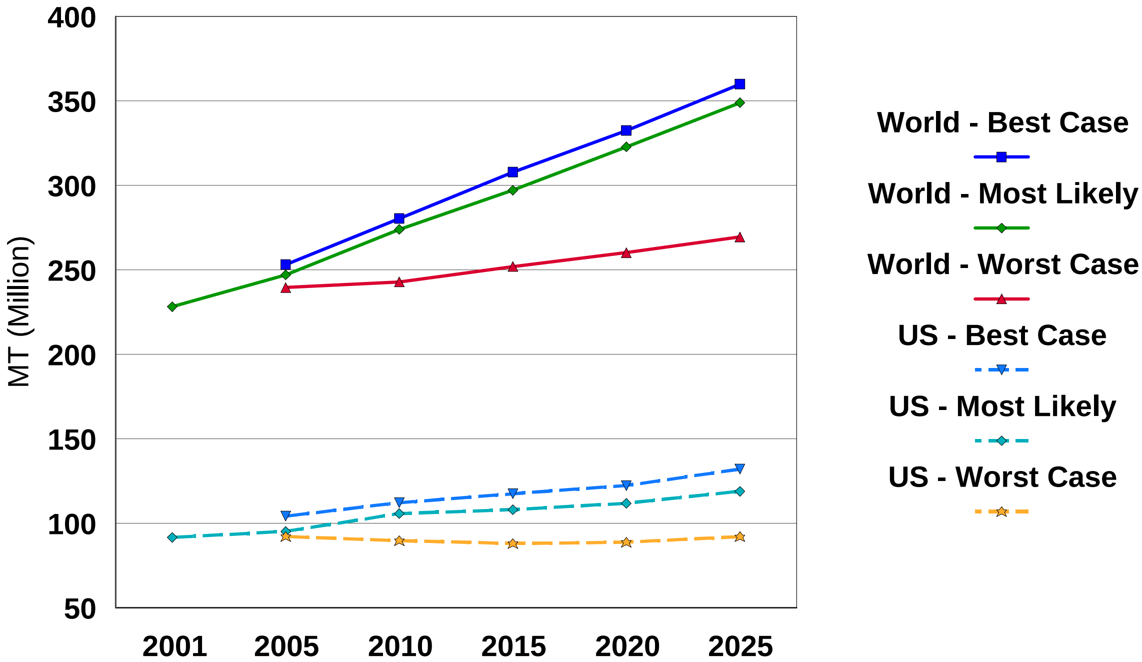


**Figure 2. U.S. and World Trade for Worst, Most Likely and Best Case Scenarios, 2001-2025.**

**Table 1 Constraints Imposed on Model: Market and Trade Policy Restrictions**

| Exporter | Importer | Grain | Restriction | Reason | Impact | Duration |
|---|---|---|---|---|---|---|
| US | Cuba | All grains (rice) | No trade | Trade policy restriction | Maintained assumption. Rice is imported from China | Relaxed in 2005 forward |
| US Ethanol | none | corn | none | Accelerated expansion. Reduced exportable supplies concentrated in western regions | Exports favored from eastern regions through US Gulf to Asia, versus US PNW | Commencing in base case with existing production; expanding in 2010 |
| US West Coast | China | Wheat | Not allowed | TCK Smut | Forces China wheat to US Gulf–relax in 2005 | Relaxed in 2005 forward |
| US/Canada West Coast | Japan ,Korea, Philippines, Singapore, Thailand | Wheat | Only allowed from West Coast N. America despite higher cost | Quality requirements | Disallows Gulf to these Asian markets at lower cost | Maintained |
| Australia | Japan ,Korea, Philippines, Singapore, Thailand | Wheat | Max shipments only allowed at recent values | Quality requirements | Forces hard wheats from N. America. No direct impact on Canal | Maintained |
| Argentina, India | Japan ,Korea, Philippines, Singapore, Thailand | Wheat | No shipments allowed | Quality requirements | Forces hard wheats from N. America. No direct impact on Canal | Maintained |
| E. Europe | Japan | Wheat | No shipments allowed | Quality requirements | Forces hard wheats from N. America. No direct impact on Canal | Maintained |
| China | Korea | Corn | Imports of 3 mmt | Reflect recent trade | Reduce exports from US Gulf/Canal | Maintained |
| US and Arg | EU | Soy beans | Minimizes US/Arg to EU, thus, making Brazil dominant supplier to EU | Reduces exportable supplies for Canal shipments to Asia | GM-free soybeans are required in EU and produced only in Brazil. | Relaxed in 2005 forward |

**Table 2 Estimated Import Demand for All Grains, 2001-2025 , 1,000 Mt**

| | 2001 | 2005 | 2010 | 2015 | 2020 | 2025 | % change |
|---|---|---|---|---|---|---|---|
| Africa East | 4,770 | 5,306 | 5,843 | 6,970 | 8,097 | 9,224 | 0.93 |
| Africa North | 26,664 | 28,370 | 30,077 | 33,391 | 36,705 | 40,019 | 0.50 |
| Africa South | 2,263 | 2,423 | 2,583 | 2,832 | 3,081 | 3,330 | 0.47 |
| Africa West | 7,054 | 7,780 | 8,507 | 9,607 | 10,707 | 11,807 | 0.67 |
| Brazil | 9,196 | 11,058 | 12,358 | 13,367 | 11,626 | 13,702 | 0.49 |
| Canada | 4,055 | 4,294 | 4,532 | 4,977 | 5,422 | 5,868 | 0.45 |
| Caribbean | 4,505 | 4,681 | 4,857 | 5,120 | 5,383 | 5,645 | 0.25 |
| Chile | 2,046 | 2,158 | 2,271 | 2,466 | 2,661 | 2,856 | 0.40 |
| China | 19,793 | 26,638 | 44,213 | 50,098 | 56,457 | 62,648 | 2.17 |
| East Europe | 567 | 1,052 | 1,570 | 2,433 | 3,138 | 4,012 | 6.08 |
| European U | 20,907 | 19,157 | 19,516 | 19,908 | 20,202 | 20,701 | -0.01 |
| FSU | 667 | 780 | 821 | 903 | 986 | 1,069 | 0.60 |
| India | 0 | 2,655 | 4,287 | 203 | 171 | 134 | |
| Indonesia | 9,924 | 10,309 | 10,694 | 11,324 | 11,954 | 12,584 | 0.27 |
| Japan | 31,381 | 31,546 | 31,711 | 31,869 | 32,027 | 32,186 | 0.03 |
| Korea | 13,609 | 13,870 | 14,132 | 14,266 | 14,400 | 14,534 | 0.07 |
| Malaysia | 4,644 | 4,918 | 5,192 | 5,633 | 6,073 | 6,513 | 0.40 |
| Mexico | 17,725 | 19,301 | 20,877 | 22,614 | 24,352 | 26,089 | 0.47 |
| Middle East | 37,722 | 40,788 | 43,854 | 48,530 | 53,206 | 57,883 | 0.53 |
| Other South Am | 14,850 | 15,153 | 15,455 | 16,222 | 16,989 | 17,756 | 0.20 |
| Pakistan | 662 | 1,197 | 1,733 | 2,087 | 2,441 | 2,795 | 3.22 |
| Philippines | 4,865 | 5,433 | 6,001 | 6,953 | 7,905 | 8,857 | 0.82 |
| Singapore | 660 | 688 | 715 | 752 | 789 | 826 | 0.25 |
| Taiwan | 8,572 | 8,800 | 9,028 | 9,410 | 9,792 | 10,174 | 0.19 |
| Thailand | 7,134 | 7,285 | 7,617 | 8,099 | 8,573 | 9,065 | 0.27 |
| Venezuela | 2,445 | 2,550 | 2,655 | 2,843 | 3,030 | 3,218 | 0.32 |
| Viet Nam | 680 | 768 | 991 | 1,153 | 1,336 | 1,490 | 1.19 |
| Total | 269,364 | 290,988 | 324,147 | 346,119 | 369,621 | 397,131 | 0.47 |

**Table 3. Sequence of Changes in Factors Impacting Canal Grain Shipments**

| Grain/Factor | Timing | Effect | Most Likely-Base Case |
|---|---|---|---|
| Demand growth due to population and income growth | Continual | Greater expansion for Canal shipments due to China | Projections and scenarios based on WEFA projections for income and population |
| Soybeans/GM in Brazil | 2005 | Shift soybeans from Brazil to EU to China, and replaced by US Gulf going to EU. | Maintained assumption in all cases |
| Rice to Cuba | 2005 | Liberalized trade will shift Cuba rice to US, thereby reducing Canal shipments from Asia | Maintained assumption in all cases |
| Corn/ethanol | Continual, but accelerating in 2010 | Reduced supplies for US PNW exports, shifting exports to Asia via the US Gulf and Asia | Maintained assumption in all cases |
| Brazil transport projects adopted | 2010 | Reduced shipping costs for northerly shipments | Adopted |

**Table 4 Results Summary: All Grain Shipments by Exporter.**

| | 2001 | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|---|
| Argentina | 34,430 | 39,109 | 44,968 | 49,781 | 55,098 | 57,850 |
| Australia | 23,056 | 25,927 | 27,495 | 30,839 | 32,762 | 35,030 |
| Brazil North | 6,858 | 8,975 | 11,299 | 11,844 | 14,325 | 17,615 |
| Brazil South | 8,157 | 8,847 | 9,600 | 10,634 | 10,917 | 11,429 |
| Canada East | 1,326 | 1,366 | 1,469 | 1,653 | 1,718 | 1,966 |
| Canada West | 4,976 | 4,801 | 5,029 | 5,479 | 5,574 | 5,587 |
| China | 808 | - | - | - | - | 374 |
| E. Europe | 2,463 | 2,308 | 2,797 | 2,797 | 2,797 | 2,797 |
| EU | 29,458 | 33,323 | 37,124 | 42,812 | 49,509 | 55,331 |
| FSU | 10,583 | 9,150 | 8,774 | 11,041 | 13,496 | 15,221 |
| India | 3,603 | 4,008 | 4,008 | 4,008 | 4,008 | 3,910 |
| Thailand | 6,982 | 8,844 | 9,518 | 10,497 | 11,722 | 13,385 |
| US East | 17,435 | 18,397 | 18,842 | 18,388 | 18,601 | 19,501 |
| US Gulf | 63,392 | 67,090 | 77,209 | 79,903 | 83,318 | 89,330 |
| US West | 9,793 | 9,768 | 9,746 | 9,869 | 9,981 | 10,180 |
| Vietnam | 4,948 | 5,172 | 6,095 | 7,670 | 9,015 | 9,494 |
| ***Corn Shipments by Exporter.*** | | | | | | |
| Argentina | 9,847 | 9,587 | 11,969 | 12,055 | 12,055 | 12,055 |
| Australia | 112 | 112 | 112 | 112 | 112 | 112 |
| Former Soviet Union | 1,515 | 1,515 | 1,515 | 1,515 | 1,515 | 1,515 |
| US Gulf | 39,351 | 42,816 | 51,353 | 51,285 | 53,847 | 56,339 |
| US West | 8,100 | 8,100 | 8,100 | 8,100 | 8,100 | 8,100 |
| ***Soybean Shipments by Exporter.*** | | | | | | |
| Argentina | 10,076 | 13,240 | 14,354 | 16,911 | 20,041 | 20,400 |
| Brazil North | 6,858 | 8,959 | 11,204 | 11,644 | 14,010 | 17,178 |
| Brazil South | 8,157 | 8,828 | 9,481 | 10,382 | 10,521 | 10,875 |
| Canada East | 519 | 539 | 623 | 798 | 853 | 900 |
| India | 24 | 97 | 97 | 97 | 97 | - |
| US East | 7,000 | 7,000 | 7,000 | 7,000 | 7,000 | 7,000 |
| US Gulf | 16,046 | 14,332 | 14,150 | 16,709 | 17,243 | 19,877 |
| ***Wheat Shipments by Exporter.*** | | | | | | |
| Argentina | 13,578 | 15,041 | 16,568 | 18,393 | 20,297 | 22,280 |
| Australia | 17,020 | 18,115 | 19,202 | 22,059 | 23,324 | 25,835 |
| Canada East | 777 | 795 | 814 | 828 | 843 | 1,049 |
| Canada West | 3,596 | 4,801 | 5,029 | 5,040 | 5,081 | 5,093 |
| East Europe | 2,463 | 2,308 | 2,797 | 2,797 | 2,797 | 2,797 |
| Europe Union | 25,096 | 28,006 | 30,882 | 35,841 | 41,848 | 47,015 |
| Former Soviet | 4,122 | 3,954 | 3,786 | 4,822 | 6,280 | 7,313 |
| US East | 10,215 | 10,451 | 10,689 | 11,034 | 11,306 | 11,657 |
| US Gulf | 4,340 | 5,959 | 8,015 | 8,205 | 8,463 | 8,734 |
| US West | 679 | 608 | 539 | 638 | 723 | 830 |

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