Estimating Demand for Agricultural Commodities to 2050

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GLOBAL HARVEST INITIATIVE
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Background

Over the next forty years, global population is expected to reach nine billion people. This increase, combined with expected economic growth, will cause an increase in nutritional demand and inevitably strain the resources used for food production. In order to meet expected worldwide nutritional demand while maintaining sustainable agricultural practices, industries within the agricultural supply chain seek foreknowledge of future nutritional demands. Their goal is develop and deliver resources in such a way that global food needs are met efficiently and in sufficient quantity.

Many previous studies have put together projections of global food demand. These studies tend to make large commodity groupings such as cereals, oilseeds, meats, etc. and do not provide the granularity to specially identify the future demand for a specific crop. In addition, important assumptions such as feed conversion, feed efficiency, technology, etc. are often not explicitly identified in the presentation of the results. These studies often do not explicitly discuss dietary change and income growth in the context of cultural and ethnic issues which shape this change. The objective of this research was to develop a detailed forecast of global food demand to 2050 with crop specific granularity and transparent assumptions regarding macroeconomics, technology, and policy. In developing this forecast, the cultural and ethnic issues specific to each country were carefully considered.

A global forecast of food demand through 2050 was developed by IHS Global Insight (IHS-GI) using their global agricultural partial equilibrium modeling system. This modeling system includes not only food demand for crop and livestock commodities, but also feed, seed, and industrial demand for crop commodities. More details on this model are included in the appendix. Projections are developed for each year from 2010 through 2050 based on IHS-GI macroeconomic projections for variables such as income growth, population growth, inflation, exchange rates and input costs.

Other assumptions include agricultural policies and technology. Constant policy assumptions are used through the forecast period. This includes meeting current U.S. ethanol and biodiesel mandates. EU biofuel targets are not reached despite the European Commissions insistence that penalties will be assessed on countries which do not reach the 10 percent target. The experience of the EU biofuel industry, current subsidies, and barriers to higher biodiesel and ethanol blends make reaching the target extremely difficult even if generation 2 feedstock technologies were economical.

Yield growth is based on linear trends estimated over the 1990 to 2008 period. In countries adopting new technologies that recently experience rapid yield growth, downward adjustments in yield trend estimates were made.

The model recognizes saturation points in the demand for various types of food products in developing countries based on the previous experience of developed countries with similar cultural or ethnic situations meat and food based on income. The model also takes into consideration the decreasing sensitivity of food consumption demand to income growth, as

income levels increase from below subsistent levels to those associated with the developed world.

This study should be regarded as the first step in analyzing a very complex future and the results can be dramatically affected by the assumptions used in the analysis. The results reflect conservative assumptions grounded in the historical experience of dietary change. Future analysis will consider alternative assumptions which could increase agricultural commodity demand above levels presented in this study.

Critical Factors for the Analysis

This study is primarily focused on projecting demand for crop commodities resulting from food demand. The demand for specific crop commodities arising from food consumption includes not only direct human consumption of the crop, but also indirect consumption arising from the feed used to produce meat for human consumption. Other demands such as industrial and seed uses are included in the model.

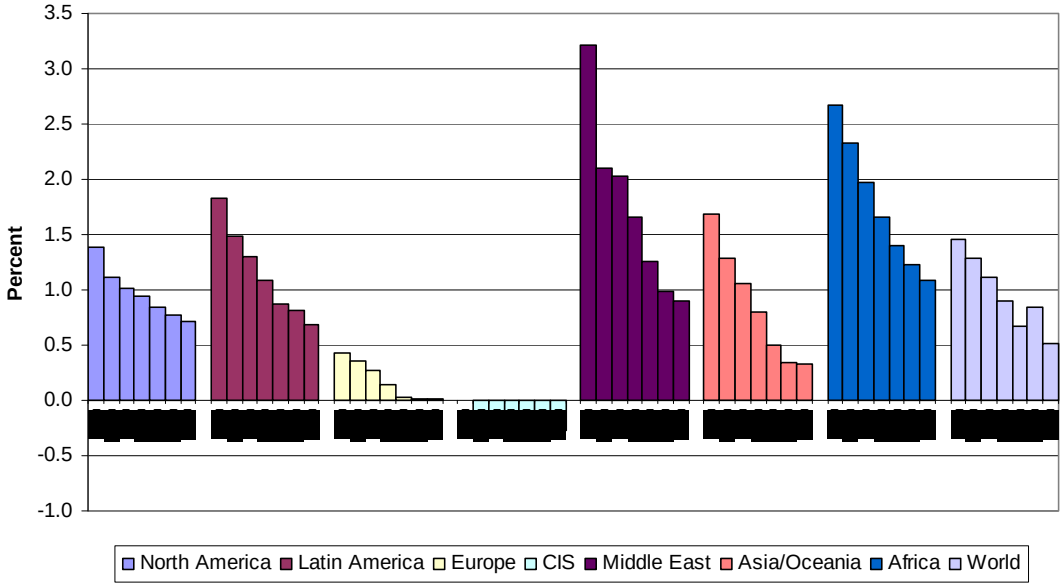
Biofuels are included in industrial demand. The policies which drove the rapid growth in corn and vegetable oil demand for biofuel feedstocks mature by 2020 in the forecast with production of some biofuels falling short of current mandates and targets. The cellulosic targets will be especially difficult to reach without some advances in current technologies. European Union biofuel targets are also aggressive especially for biodiesel even considering biodiesel imports from Brazil, Argentina and the US.

Food Demand Drivers

Population Growth

The rate of population growth is declining in all regions of the world. Within the Commonwealth of Independent States, the population growth is actually negative. Historically, developed countries have lower population growth rates than developing countries. The developing regions of the world including the Middle East, Asia and Africa have historically had some of the fastest population growth rates but as we look forward from 2010, these rates are slowing. By 2050, Africa's population is still growing at over 1 percent per year compared with an average of 0.5 percent for the world. This population growth rate limits their gains in per capita income growth. By contrast, the population growth in the Asia/Oceania region falls from 1.3% to 0.3% allowing more significant gains in per capita income growth.

Population Growth Rate by Region



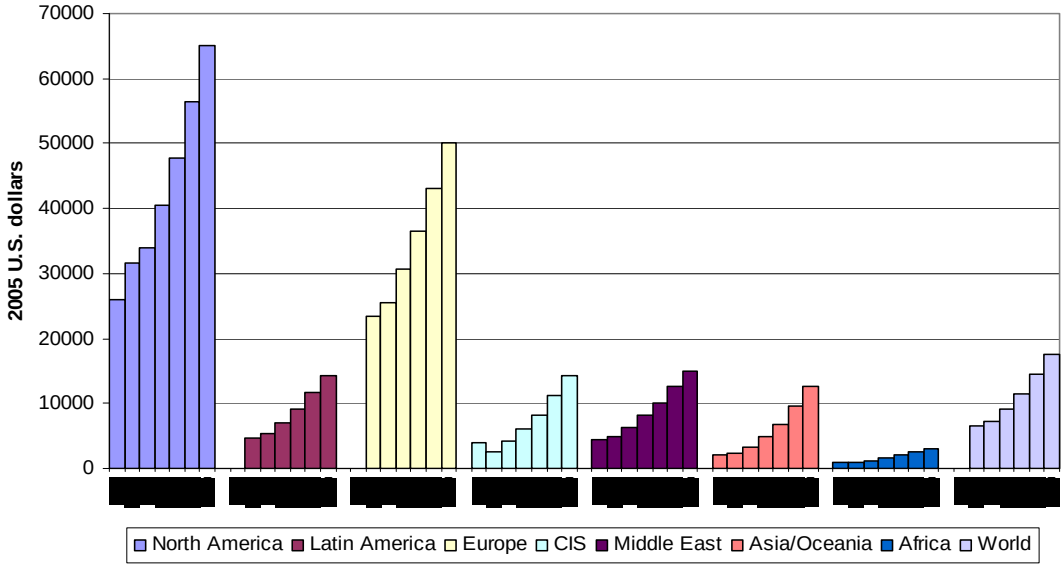
Income

Over the next 40 years an amazing transformation is projected to occur in today's developing countries driven by income growth. It is this income growth, particularly in developing countries, that enables populations to not only meet their daily calorie requirements, but also diversify their diet to include more proteins. This can be characterized by three phases. In the first phase, extremely low income countries spend nearly all of their income growth on additional food consumption. The types of foods purchased often include rice, starchy roots such as potatoes or cassava, and pulses with very little protein in the diet. Many countries in Africa are in this first phase of consumption. In the second phase, generally the total daily calories needs are being met, but consumers want to diversify their diet into more expensive protein items. India and China are clear examples of countries in this phase who are consuming more proteins as their incomes grow. In the third phase, personal preferences and health concerns dominate the choice of caloric mix. Food expenditures represent a relatively small share of the household budget and consumers can afford to be selective. Europe, Japan, South Korea, the US, Canada, etc fit easily within this category.

Over the next 40 years global real per capita income growth measured in US dollars is expected to grow by over 10,000 per capita. However, this income growth is not evenly distributed. In the poorest region, Africa, incomes only grow a dismal $1,867 per capita with much of that growth going to oil exporting countries and South Africa. Many of the countries in Africa will continue to struggle to meet their subsistence needs. Increase consumption of grains including rice and starchy roots is expected. Some small growth in vegetable oil and meat consumption is expected, but not yet at the levels experienced in Asia. By contrast, incomes in Asia/Oceania are expected to grow $9,432 per capita enabling significant diet diversification as well as movement into the third phase of consumption. Latin America, particularly Central America and the northern countries in South America, is in a similar situation as Asia/Oceania with income increasing by $8,858 per capita. In the developed world, income growth is expected to be substantial but with very little impacts on food consumption other than following health trends. Emerging trends

include less red meat consumption, saturated fats, and sweeteners in favor of more fruit and vegetable consumption.

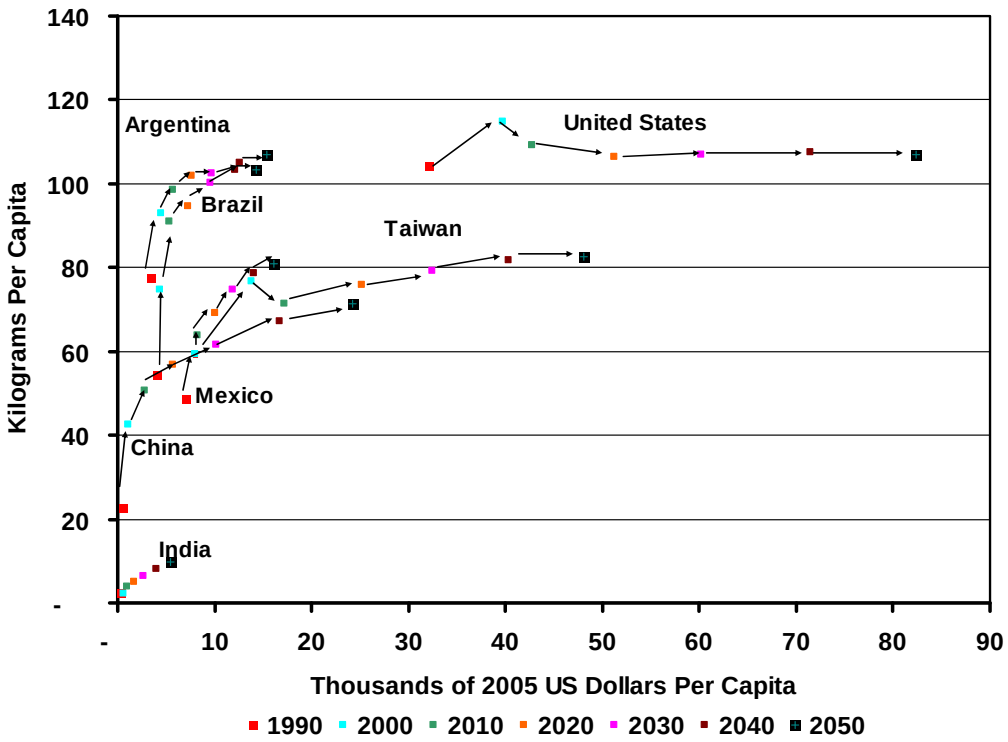
Real Per Capita GDP by Region



Inflation

Inflation is expected to remain modest in most regions of the world corresponding to the positive outlook for real income growth. However, it is important to note the overall importance of this assumption. In this projection we have relatively steady supply and demand growth with a slight increase in nominal agricultural commodity prices. With more aggressive food demand from developing regions, one could imagine a story of much stronger increases in real commodity prices. Since agriculture usually plays a significant role in income growth in developing countries, high agricultural commodity prices would substantially increase inflate reducing real income growth and thereby depleting the buying power of consumers in general. In partial equilibrium models, inflation is taken as an assumption and this effect could be missed if significant pressure on agricultural commodity prices emerged. While inflation would reduce the effective income of consumers, high commodity prices would also quickly ration demand. In this sense, this model addresses effective demand not moral demand. That is, just because someone is hungry doesn't mean they can afford to buy food.

Response of Meat Consumption to Changes in Income



Cultural Dietary Considerations

Culture and ethnic background plays a significant role in consumption patterns. Some have argued that all developing countries will simply follow western consumption patterns once they have the income to be able to afford them. However, other studies point out that there are significant differences in diets across the world regardless of income levels. One of the most obvious examples is Japan. Despite having higher per capita income than an average US citizen, their total consumption of beef, pork, and broilers is only 44 kilograms per capita compared with US per capita consumption of 111 kilograms per capita in 2009. Another example would be pork consumption in Muslim countries; essentially it is 0 kilograms per capita due to religious practices despite having higher income levels than the average Chinese consumer who consumed 36 kilograms of pork per capita. In a 2000 article in the Agribusiness Journal, Shono, Suzuki, and Kaiser published an article entitled, "Will China's Diet follow Western Diets?". In their analysis they concluded that while the Chinese would likely consume more meat, ultimately their diet would evolve more toward the dietary pattern in the developed countries of Japan, South Korea, and Hong Kong; they would not follow the pattern of U.S. diets. It is this philosophy that was used in the IHS-GI models to set the saturation points as well as declining responsiveness to income growth through time. Countries were grouped by similar ethnic and cultural practices and then developing versus developed countries were identified within each group. For example, Chinese meat saturation points were identified by comparing Chinese per capita consumption with consumption in Taiwan and South Korea. In addition, responsiveness to growth in income was tempered by experience of Taiwan and South Korea.

For many of the cultural groupings a developed country was readily apparent, but for India there really is no good match. India's population is 80 percent Hindu, of which, 20 percent are estimated to be practicing vegetarians. It appears that egg consumption is generally accepted and that poultry and buffalo consumption are becoming more socially acceptable. However, beef and pork consumption is still not socially acceptable. With the significant income growth projected for India, could their society begin consuming a great deal more meat? Cultural and religious mores tend to change slowly. We have dramatically increased India's egg, poultry, and vegetable oil consumption in their diet, but have not imposed the same responsiveness seen in countries like China for beef and pork. It is certainly an area where one could make a different assumption.

Model Results

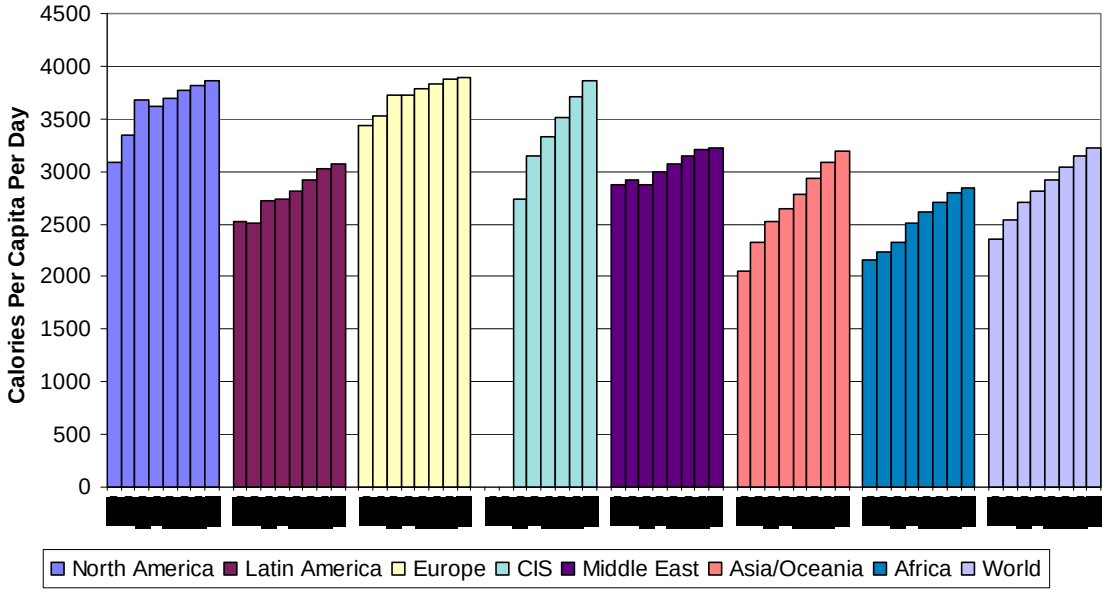
Calorie Consumption

While there are many ways to look at the results of the 2050 forecast a good starting point is calorie consumption per day. The following charts display calories delivered per capita per day for specific regions and the world by decade. The historical data is based on estimates made by the Food and Agricultural Organization of the United Nations. These data reflect calories supplied, not calories actually consumed. While the numbers are adjusted for processing, there is still food loss and waste that occurs between supplying the calories and what is actually consumed. These losses and waste vary by country depending of food storage and delivery mechanism however data on food losses in the developing world is very sparse.

The IHS-GI model explicitly captures over 70 percent of daily calorie consumption for all regions and major countries in the world. The remainder of daily calorie consumption is accounted for within the model but projections of these calories are based on trends and analyst judgment rather than econometric equations. The major food calories not econometrically modeled by IHS-GI in this forecast include fruits, vegetables, cassava, dairy products outside the US, eggs outside the US, fish, and alcoholic beverages.

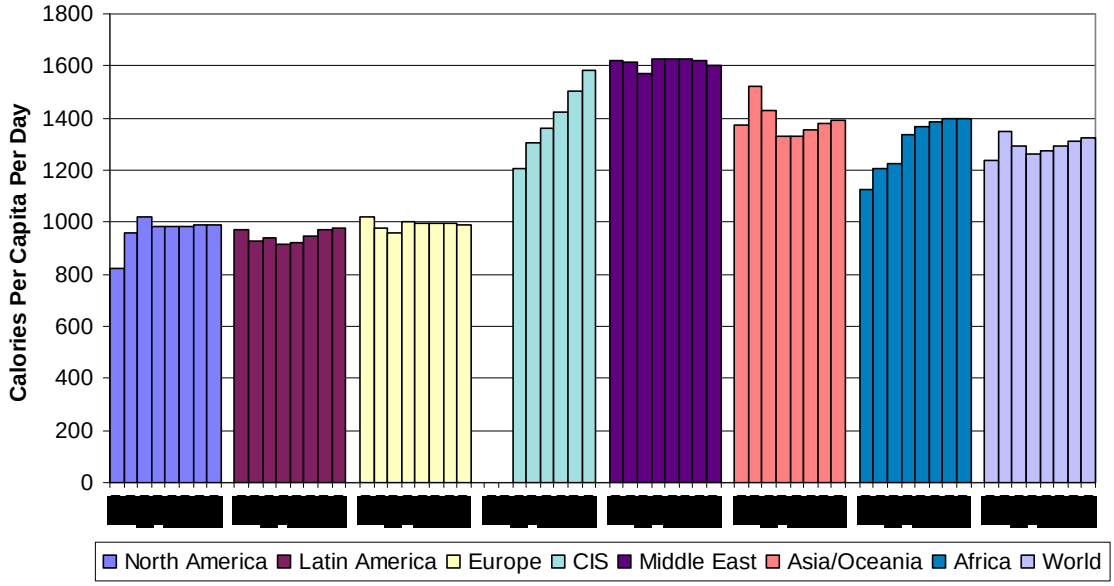
Globally calories delivered per capita are expected to continue to grow with increased consumption and diet diversification in developing countries. Globally, calories delivered per day increase from 2,712 to 3,226 from 2010 to 2050. In Asia/Oceania much of this growth occurs through increased meat and vegetable oil consumption. In Africa, grains and vegetable oils supply many of the additional calories with small gains in calories from meat consumption.

Total Calories Delivered by Region



In 2010, grains will supply nearly half of the calories delivered per capita per day. While grain calories delivered will increase by 5 percent by 2050, the share of grain calories in the diet will fall to 41 percent. Declining rice consumption in many developing countries combined with increases in meats and vegetable oils drive much of the change. Grain represents the biggest portion of daily calories delivered in developing countries in the Middle East, Asia/Oceania, CIS, and Africa, while meat and vegetable oils comprise a modestly larger share of total calories per day than grains in North America and Europe. Grain calories delivered in Africa drastically increased from 2000 to 2010, but the growth rate slows through 2050 as African consumers begin to diversify their diets to include more vegetable oils. Interestingly, North America, Latin America, and Europe show little increase in grain calorie consumption given their relatively high levels of vegetable oil and meat consumption.

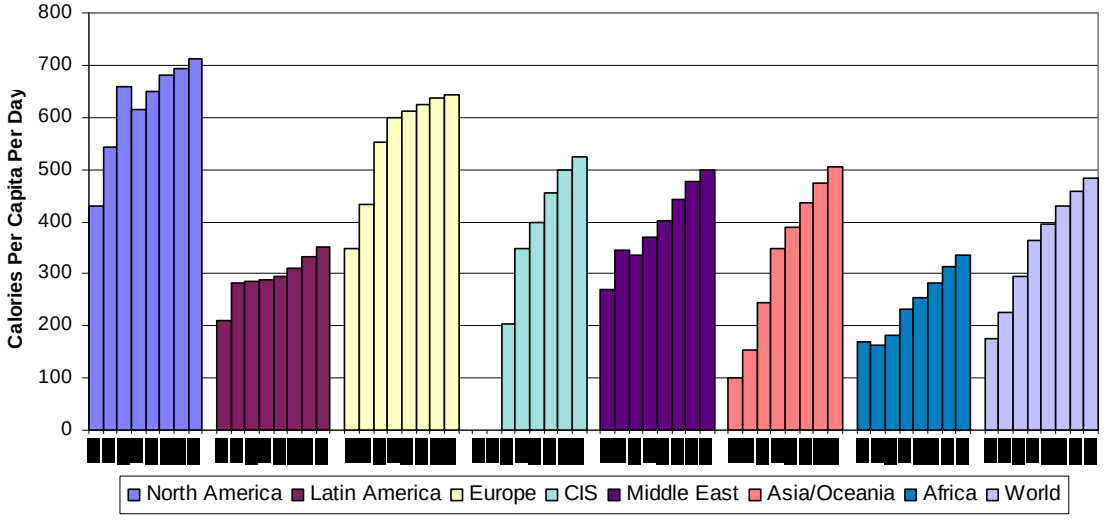
Grain Calories Delivered by Region



Grains include barley, corn, millet, oats, rice, rye, sorghum, wheat, and other minor cereals.

Vegetable oils are highly responsive to income growth in developing countries and are usually one of the cheapest protein sources available. The remarkable growth in the Asia/Oceania region over the past 30 years was driven by income growth. As incomes continue to grow in Asia, vegetable oil demand is expected to continue rising, but not as fast as the recent past as consumers spend more of their increase wealth on nonfood items. Africa is poised like the recent experience of Asia to spend more of their income on vegetable oils. Income growth in Africa is not expected to be a robust as the recent experience of Asia therefore increase in per capita vegetable oil consumption are not expected to be as large.

Vegetable Oil Calories Delivered by Region



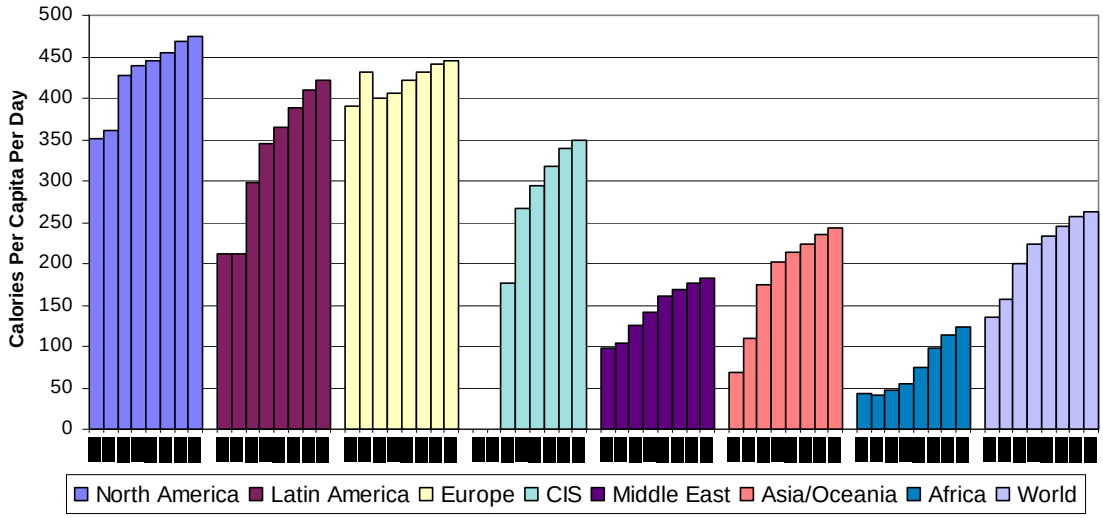
Vegetable oils include coconut, cottonseed, peanut, corn, olive, palm, palm kernel, rapeseed, ricebran, sesameseed, soybean, sunflowerseed, and other minor oils.

The rapid increase in meat consumption, particularly pork in China, has generated considerable discussion over the future of meat demand there. Some studies expect the Chinese to full adopt western diet and thus project meat consumption to continue rising. Yet culture plays an import role in shaping a particular countries diet. In the case of China, the examples of Taiwan and South Korea are particularly relevant. Pork consumption in Taiwan, a relatively wealthy province of China, appears to have reached a saturation level of around 42 kilograms of pork per capita and has diversified their meat consumption into poultry followed by beef. South Korea is still growing slightly but consumes about 30 kilograms of pork per capita. Already by 2020, we reach 40 kilograms of pork per capita in China. We expect that the Chinese will follow the pattern of Taiwan and South Korea and diversify their diet into more poultry consumption followed by an increase in beef consumption as their incomes continue to grow. It is for this reason and the fact that poultry is less calorically dense, that the Asia/Oceania meat consumption growth slows in our projections to 2050. However, India is an important wild card that could make these estimates conservative. India certainly has the income growth to afford more meat consumption, but their culture does not yet appear receptive to increases in beef and pork consumption. As mentioned earlier, Indian culture appears to be most receptive to eggs, poultry and buffalo consumption, but beef and pork are still not widely accepted. Significant increases in consumption of eggs, poultry, and vegetable oils are expected. Broiler consumption per capita is expected reach 7.5 kilograms per capita by 2050 compared with 2.1 kilograms in 2010. Egg consumption is expected to double by 2050 from current levels.

Africa meat consumption does not immediately accelerate like the recent experience of Asia in part because they are not expected to have the same level of income growth and also because of the ongoing political turmoil and infrastructure issues. By 2030, income growth accelerates to a level where the African consumer can afford to introduce more meat into their diets. But rapid population growth continues to weight on overall per capita income levels so that by 2050 they grow to slightly above Asia's 1990 meat consumption levels.

Poultry is the overall winner in consumer diets through 2050 growing 46% from 2010 in average global kilograms consumed per capita. By contrast, beef is project to grow 12% while pork consumption is flat.

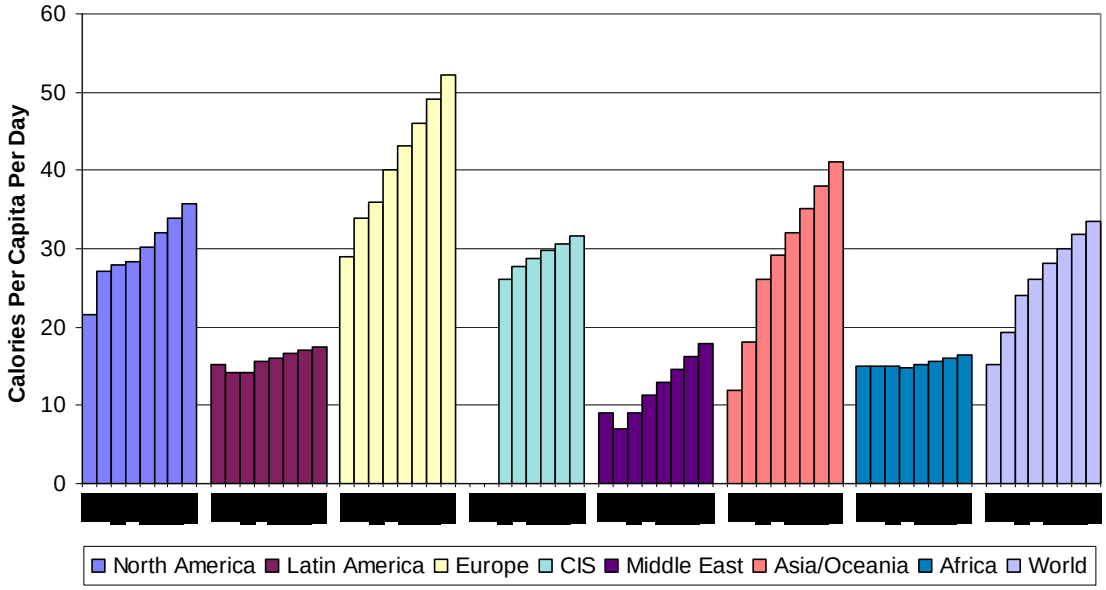
Meat Calories Delivered by Region



Meats include beef, mutton, chevron, pork, poultry, and other minor meats.

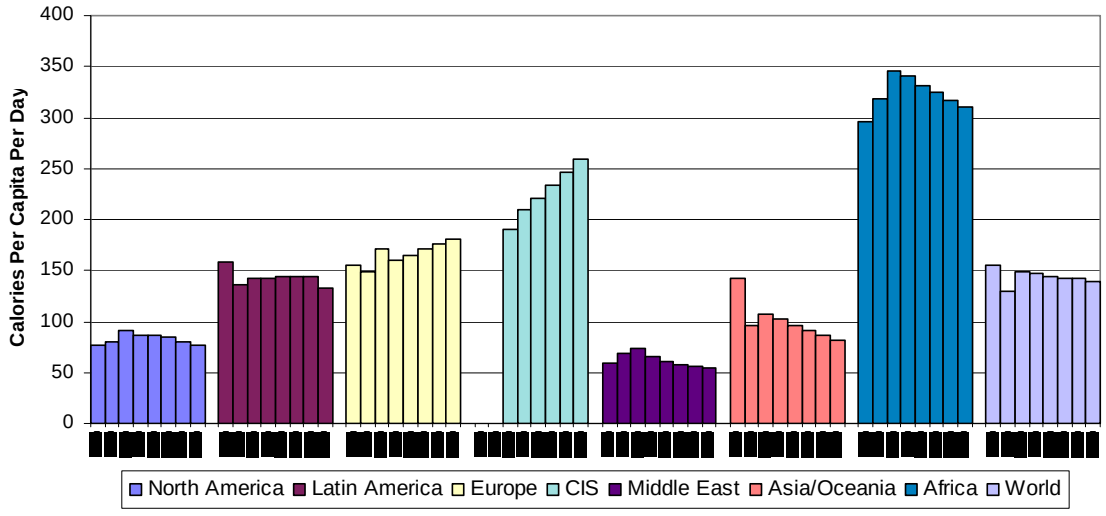
Fish and seafood calories delivered are also projected to grow over 28% through 2050. Stronger growth is possible in this area, but much of the supply must come from aquaculture as ocean catch continues to dwindle.

Fish Calories Delivered by Region



As developing countries experience income growth they diversify their diets away from starchy roots. Asia has reduced its consumption of starchy roots by nearly one third or 50 calories per capita (calories delivered). Africa is expected to follow suit as income growth allows purchases of other food stuffs.

Starchy Root Calories Delivered by Region

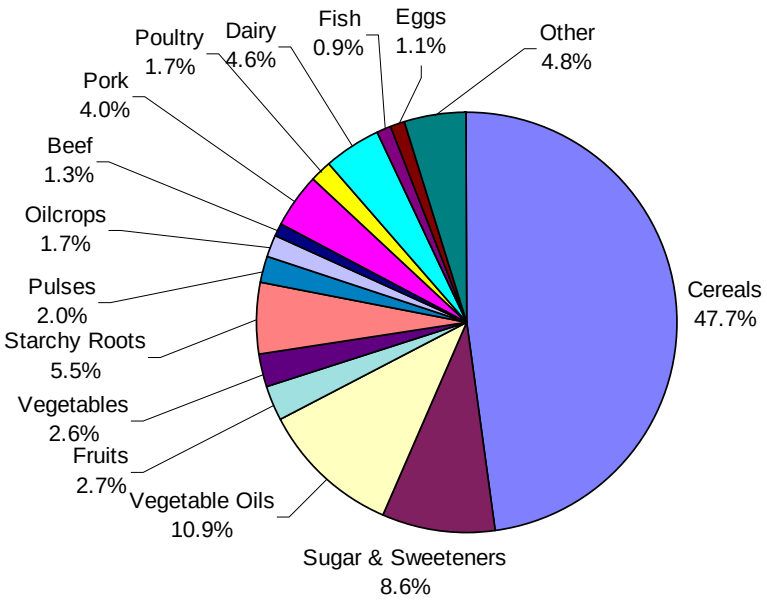


Starchy roots include potatoes, sweet potatoes, cassava and other starchy roots.

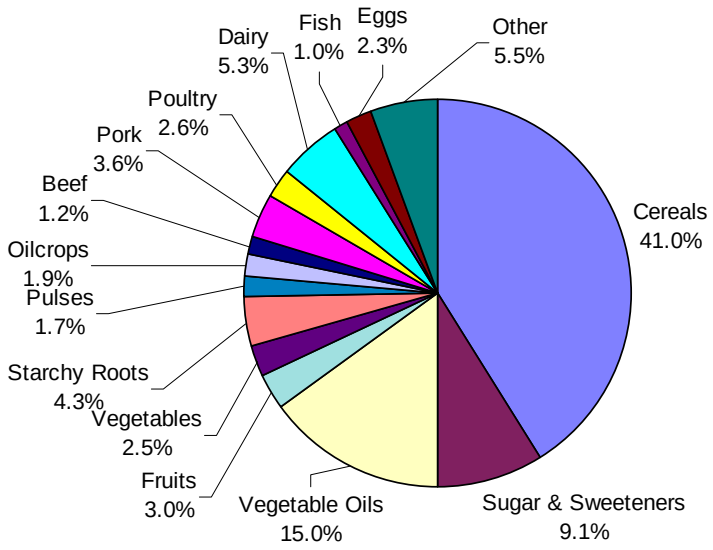
Impacts on Caloric Distribution

Cereals' share of calories delivered is projected to decline from 48% to 41% with vegetable oils, eggs, and poultry making up the difference.

Total Calories Delivered Per Capita per Day



Total Calories Delivered Per Capita Per Day in 2000
World Average 2,712



Total Calories Delivered Per Capita Per Day in 2050
World Average 3,226

Implications for Supply and Demand

Overall crop demand from all uses is expected to increase 84 percent from 2000 to 2050 driven by income growth and biofuels necessitating an 86 percent increase in crop production. Oilseeds, sugar and feed grains require significantly more area resulting in a 16 percent overall global area expansion. Crops with less demand such as wheat, rice and cotton are not expected to see significant increases in crop area. Taking into account both food and feed demand, soybeans acreage is projected to increase by 69%, while corn is projected to increase by 23%. Yield growth offsets some of the needed production increase.

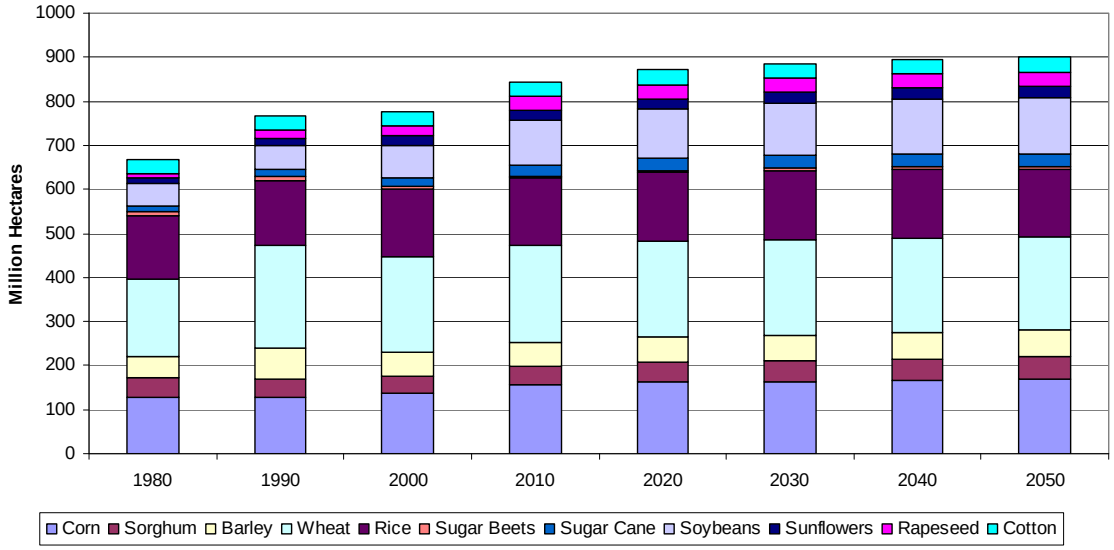
Projected Changes in World Crop Supply and Demand from 2000 to 2050

	Acreage Increase Required (2000 - 2050)	Trend Yield Increase Implied (2000-2050)	Production Increase Required (2000 - 2050)	Domestic Consumption Increase (2000-2050)	Stock Increase (2000-2050)
Corn	23%	71%	111%	105%	-14%
Sorghum	29%	61%	107%	102%	66%
Barley	12%	38%	54%	53%	19%
Wheat	-2%	60%	57%	56%	-5%
Rice	1%	46%	48%	49%	-22%
Sugar Beets	-26%	87%	93%	93%	-18%
Sugar Cane	49%	43%			
Soybeans	69%	51%	155%	153%	56%
Sunflowers	31%	67%	118%	115%	59%
Rapeseed	30%	81%	136%	125%	82%
Palm	NA	NA	265%	265%	76%
Cotton	4%	118%	127%	121%	47%
All Crops	16%	60%	86%	84%	-8%

* Palm tree area is not reported for all countries in the world. Including palm area for Indonesia and Malaysia increases the world crop area growth from 15.7 to 16.4 percent.

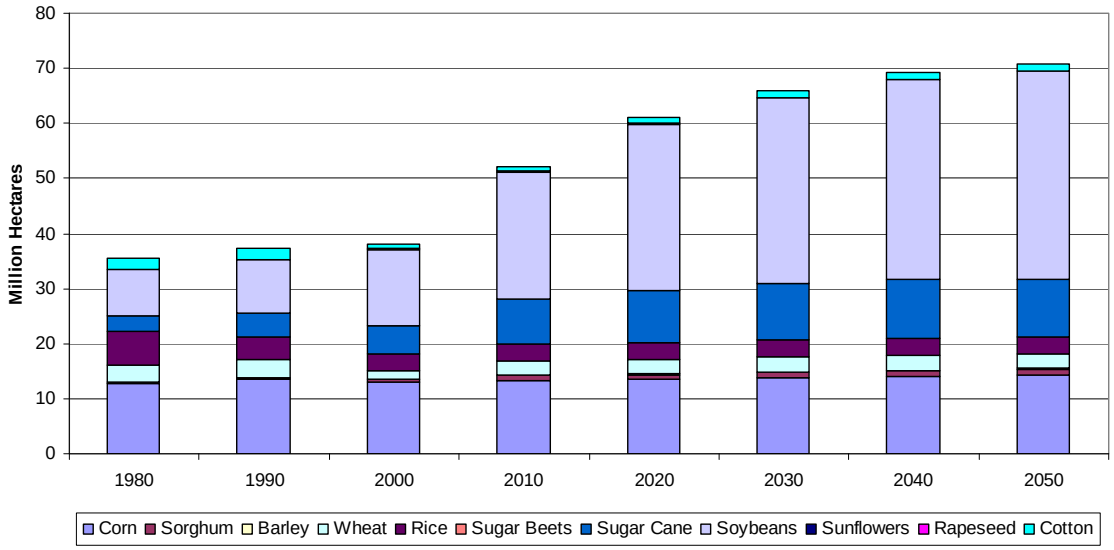
By the year 2050, world crop and meat consumption is projected to increase significantly. Corn, wheat, rice, soybeans and sugar represent the significant portions of world crop consumption via food, feed, and industrial demand. Among the major crops, wheat, corn, rice, and soybeans share the largest portion of land use with the highest growth rate on soybean acreage.

World Crop Area Needed to Meet Demand



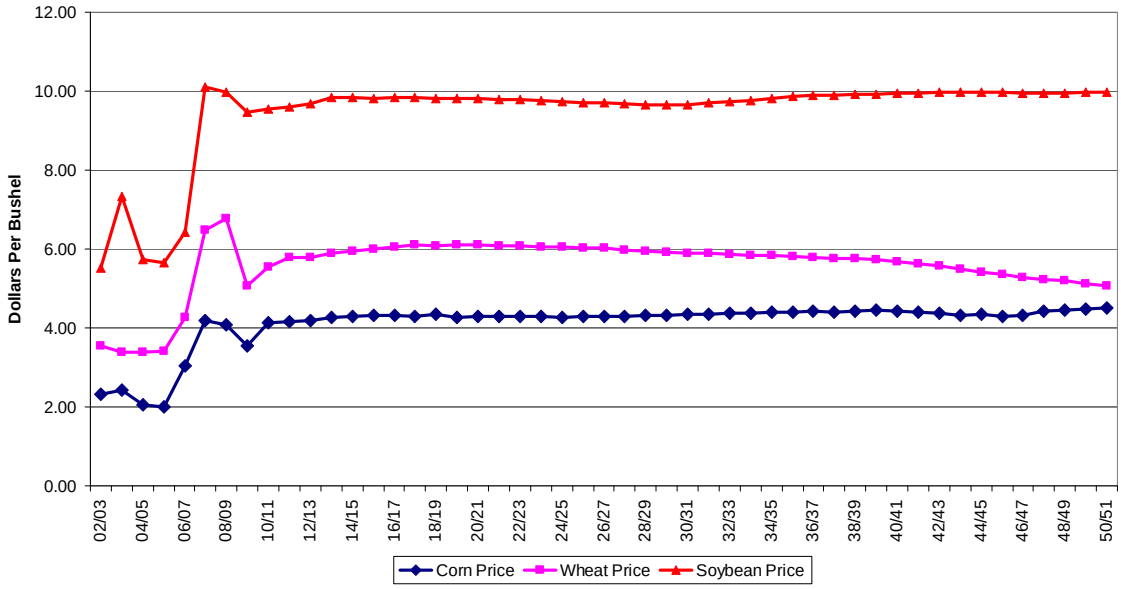
Soybean acreage is expected to significantly increase in Brazil. China's corn area is expected to increase but its rice area is expected to decline for an overall decline in area. In India, rice and soybean area drive an increase in total overall cropped area. The European Union total crop area remains flat while the US declines slightly.

Brazil Total Crop Area



Despite the upward trend in yields over the forecast period, prices of corn, soybeans, and wheat remain relatively flat through the year 2050 at fairly high equilibrium levels. This result is particularly a function of the use of linear yield growth trends in the analysis, rather than higher growth rates which reflect the current and future use of improving production technology.

Corn, Wheat, and Soybean Prices

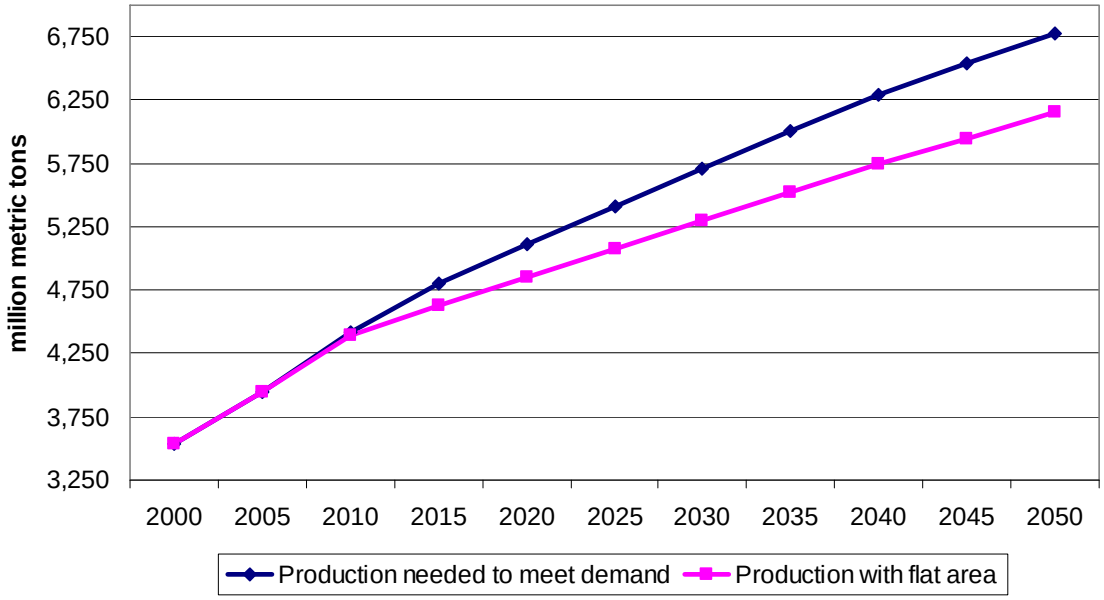


The Productivity Gap

In 2008, total world crop area for the major crops including palm area in Malaysia and Indonesia reached 850 million hectares. By 2050, this crop area will need to expand by 61 million hectares in order to meet global food demand. This area expansion will occur most significantly in Africa, Brazil, Argentina, India, Indonesia, and Malaysia. In Africa, much of the 18.2 million hectares in land expansion is driven by increased corn, sorghum, and barley use both as direct human consumption and for livestock feeds. Brazil's 20 million hectare expansion is driven by soybean and sugarcane production. Argentina's 3.6 million hectare expansion is also driven by soybeans. Indonesia's area expansion is driven by a 2.8 million hectare expansion in palm oil area. Malaysian area is also driven by palm oil area expansion increasing 0.5 million hectares. India's 12 million hectare expansion is driven by a combination of increased feed grains, oilseeds, sugarcane, and cotton area.

Clearly, this level of agricultural area expansion has environmental implications. Is it possible for global agriculture to meet the same level of demand with yield enhancements? In an alternative scenario, IHS Global Insight held total global crop area fixed and calculated the yield increases necessary to meet global demand. By holding crop area fixed and using historical yield growth over the 1990 to 2008 period, a productivity gap of 622 million metric tons (9.2 percent of total global crop demand) emerges.

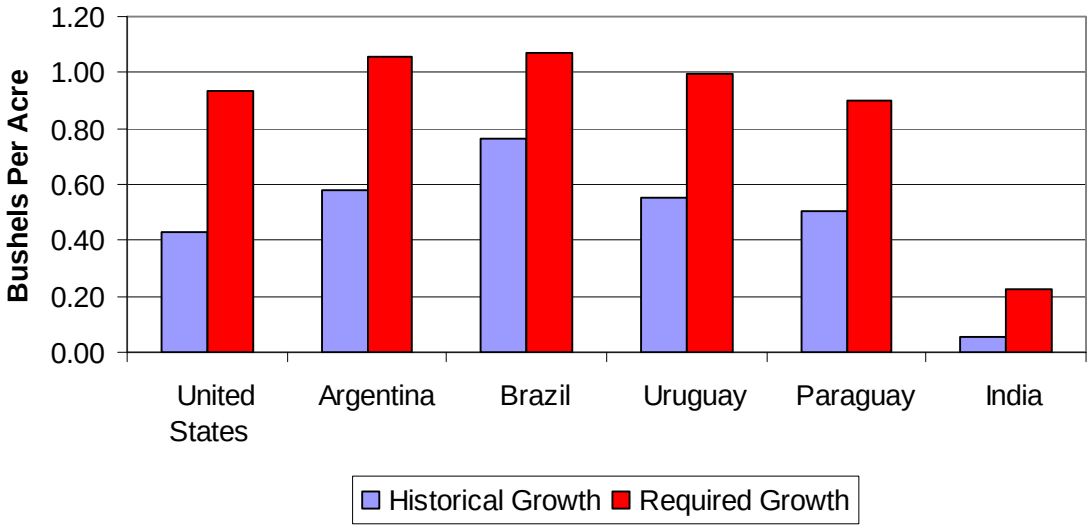
Total Global Crop Productivity Gap



In order to meet demand without increasing area acceleration in yield growth is necessary particularly in soybeans, palm oil, sunflowers, rapeseed and sugarcane. One could argue that developing countries with very low crop yields offer the greatest opportunity for accelerating global yields. But a variety of issues such as political stability, transportation, storage, input availability, crop management, etc. must be addressed in addition to providing enhanced genetics. In some developing countries such as India, these issues may be less problematic the some African countries allowing faster yield acceleration.

In the case of soybeans, the linear pace of soybean yield growth needs to double in order to fill the productivity gap. India has good potential of enhanced soybean yield growth given its low level of yield growth historically.

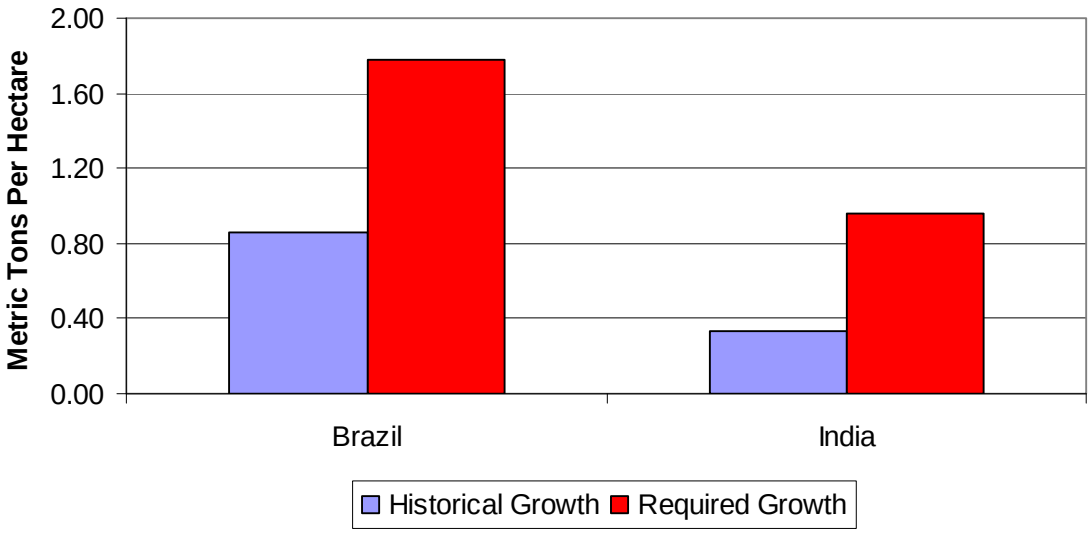
Soybean Yield Growth per Year
(Historical Yield Growth versus Required Yield Growth)



Sugarcane yield growth rates in Brazil and India must more than double from historical yield growth rates in order to meet global demands from food and energy uses. Palm oil yield growth rates in Indonesia and Malaysia must also double in order to meet global food demands without increasing crop area.

Feed grain yield growth rates in percentage terms are not under as much pressure to accelerate as oilseeds due to higher historical yield growth rates. However, corn yields need to grow about 12 percent faster than their rapid historical pace in order to keep global crop area flat. Sorghum yields must increase faster than corn but that yield growth needs to occur in Africa in order to provide feed grains at the location of the livestock. On average across all global crops, yields must grow nearly 25 percent faster than historic levels in order to keep global acreage flat.

Raw Sugarcane Yield Growth per Year
(Historical Yield Growth versus Required Yield Growth)



Conclusions

Assuming trend yield growth experience over the 1990 to 2008 period and using IHS Global Insight's macroeconomic projections, global demand for crops for all uses is projected to increase 84 percent from 2000 to 2050. Global crop production will need to increase by 86 percent. The increase in global demand is tempered by reaching saturation point for pork consumption in China, cultural and religious preferences in India and the Middle East, and modest income growth in Africa. Global stocks decrease slightly from 2000 to 2050 largely due to the big drawdown in Chinese stock levels that occurred during the last decade. The increase in demand is met through production and area increases. Using linear trend yields, crop yields are projected to increase an average of 60% from 2000 to 2050. Global crop acreage for the major crops will need to increase by 16% to meet demand growth. Corn and oilseed commodity prices strengthen slightly in the 2040-2050 period as land expansion slows.

At the regional level, while African diets improve, the bulk of their diet remains crop based with strong growth in vegetable oils. Meat consumption more than doubles in Africa over the 2000 to 2050 period, daily meat calories only reach 123 calories per capita per day, or 4 percent of total calories delivered per day. Overall Asia/Oceania meat consumption growth slows as the Chinese become saturated in pork consumption but strong growth in poultry consumption is expected. India remains a wildcard in the forecast since there is no developed country example of a Hindu culture. Rapid growth in poultry, egg, and vegetable oil consumption is expected, but dramatic increases in beef and pork consumption are unlikely given current social norms. Latin America meat consumption continues to grow approaching western levels of calories delivered by 2050. The Commonwealth of Independent States continues it journey on the path of economic recovery with gains in meat consumption as well as vegetable oils. The Middle East continues its

expansion of poultry consumption. Religious preferences are expected to keep pork consumption negligible and relatively higher price beef is expected to limit beef consumption. In North America and Europe, dietary concerns are expected to limit red meat consumption while poultry consumption grows modestly. Fruits and vegetables are expected to become an increasing share of the diet. Growth in sugar and sweetener consumption is expected to be limited by health concerns.

Meeting global crop demand in a sustainable way is critical for the future. An alternative to 61 million hectares in crop area growth to meet global demand needs is to increase global crop productivity. The increase in annual crop yield growth to accomplish this suggests that future crop yield growth for oilseeds, palm, and sugarcane must at least double. Feed grain yield growth rates which have historically been much higher than oilseeds, still must accelerate from historical growth rates particularly for sorghum in Africa. On average across all global crops, yields must grow nearly 25 percent faster than historic levels in order to keep global acreage flat.

Future Research

This study should not be viewed as the only possible outcome of an analysis of global food demand to 2050, but rather as a first step in quantifying a possible future. By design, the study results are conservative assuming that historical dietary change patterns in response to income growth and cultural traditions are representative of the future. This study does not address moral demand issues whereby every person on the planet is fed an adequate diet. Without restricting calorie consumption in developed countries, supplying adequate calories to all persons in impoverished countries would widen the productivity gap presented in this study. By relaxing these assumptions and others, this research will continue to evolve.

Appendix

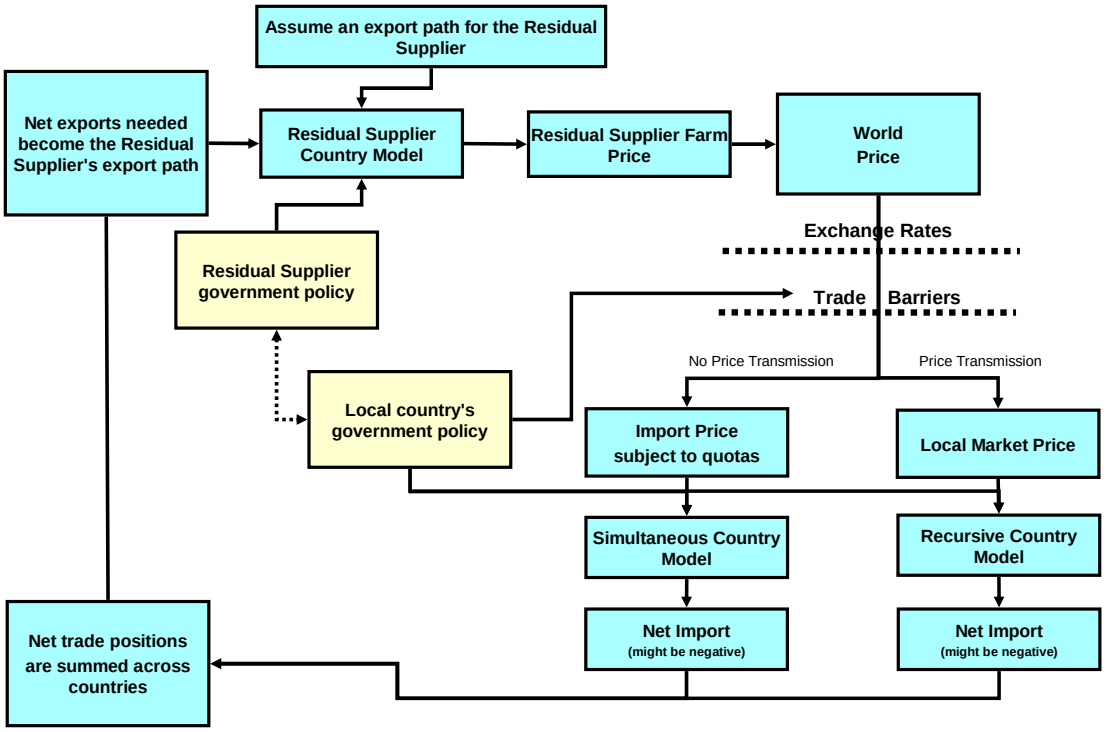
Overview of the IHS-GI Partial Equilibrium Modeling System

The core agricultural modeling system used by the Agriculture group at IHS Global Insight is a set of structural partial equilibrium econometric models. The word partial refers to the fact that these models consider only the agriculture sector and not their impacts on the whole economy. Computable general equilibrium (CGE) models capture the whole economy but are usually not detailed enough to be useful for analysis of a particular sector such as agriculture.

Partial equilibrium models require that all sources of supply and demand are included so our models use catch-all regions for the countries we do not explicitly break out. The models solve for a "global" price by equating global supply and demand. This global price is usually the price at the port in a country that exports a significant portion of world trade in the commodity and has relatively few trade barriers. This country is referred to as the residual supplier. All other prices are linked to this world price adjusting for trade policies, exchange rates and any relevant processing margins. The process of simultaneously solving for prices is initiated by initially assuming a level of exports for the residual supplying country which allows the model to solve for the "global" price. This global price is then translated through tariffs, exchange rates, processing margins, etc to determine the local price in a particular country. Based on their local price, each country can then determine its domestic supply and demand. The difference between the supply and demand becomes the net trade position for the country. This net trade position is summed across all the countries to create a new export level for the residual supplier replacing the initial assumption. Of course this generates a new "global" price and restarts the cycle which continues

until global supply and demand equilibrium is reached. The following diagram may be useful in better understanding the process:

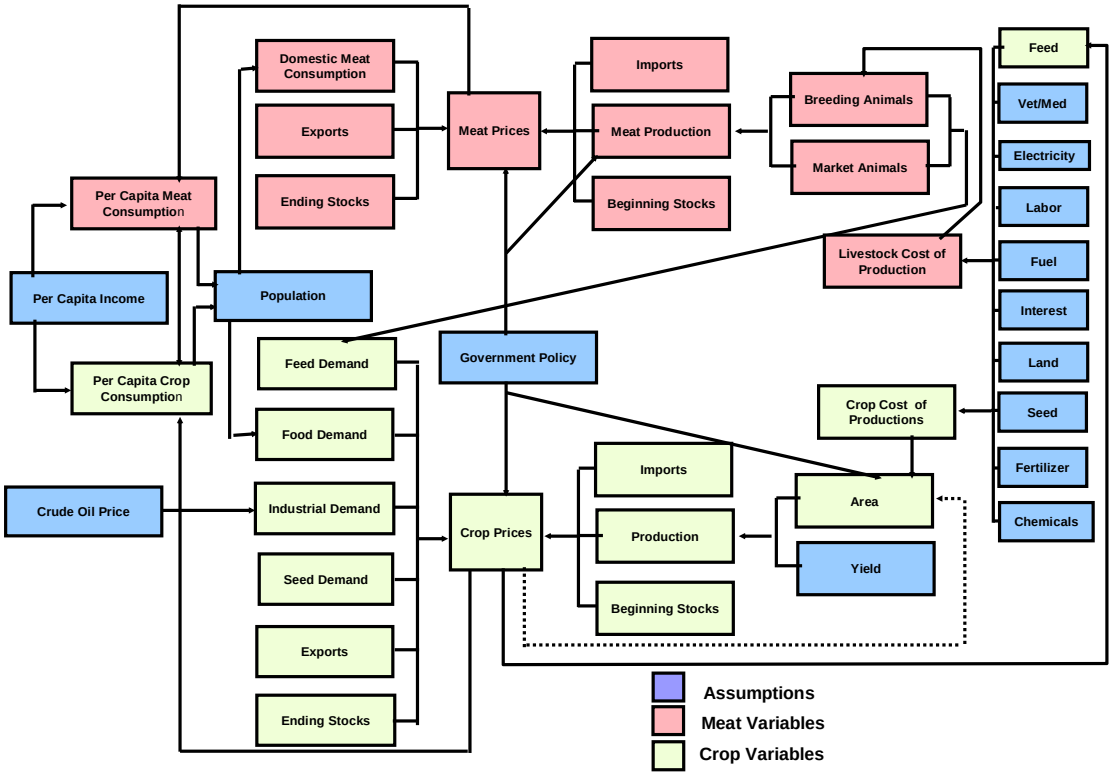
Global Price Determination



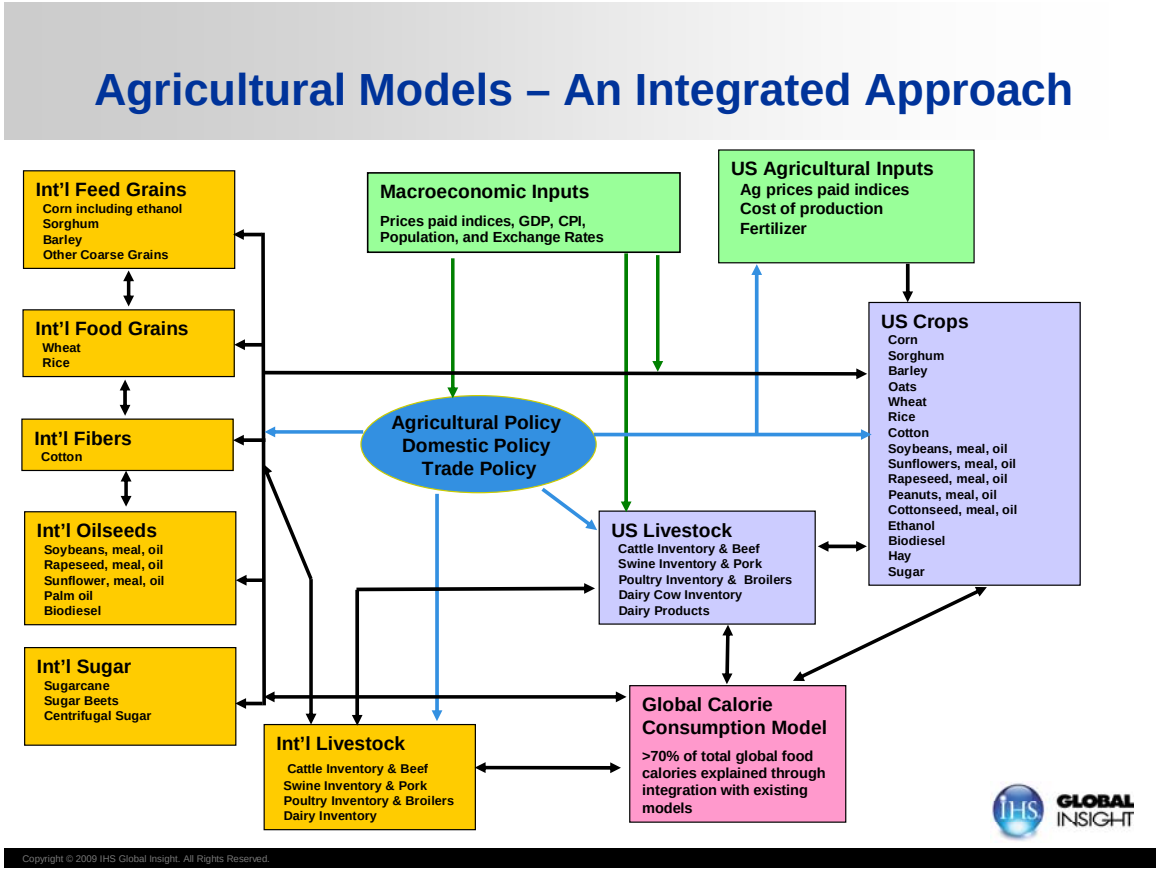
Note that the diagram also includes a provision for those countries which operate with quota systems such that their internal prices have no relationship with the prices in the residual supplying country. This can be an issue for countries with binding tariff rate quotas. If this situation occurs for a particular country, prices in that country are solved for simultaneously given the domestic supply, demand, and exogenous trade (set at the binding tariff rate quota.)

Our structural partial equilibrium models are designed to replicate the structure of the market place and the manner in which data is collected on the market. The structure mimics a supply and utilization table with explicit econometric equations for each component of supply and demand. Typically supply is broken down into acreage, yield, production, imports, and beginning stocks. Demand is broken down into mill use, feed use, food use, industrial use, and ending stocks or some combination depending on the commodity. Each commodity is interrelated with other commodities that serve as compliments, substitutes, and/or inputs. The country model flow diagram below represents a typical country showing the interrelationships among the macroeconomic variables, crops, livestock and government policy. The top half of the diagram with the light red boxes refers to the meat sector, while the bottom half of the diagram with the light green boxes refers to the crops sector. The blue boxes refer to the key assumptions that drive the model. All forecasts are conditional upon the assumptions of income growth, population growth, trade and domestic support polices, input prices, and technology (i.e. yield growth).

Country Model Flow Diagram



Due to the complexity of the agricultural modeling system, the system is broken down into major components. The current IHS Global Insight system is outlined in the diagram below. Due to the number of commodities and countries included in our system, the models are broken up into specific parts that all interact with one another but help make the process more manageable.

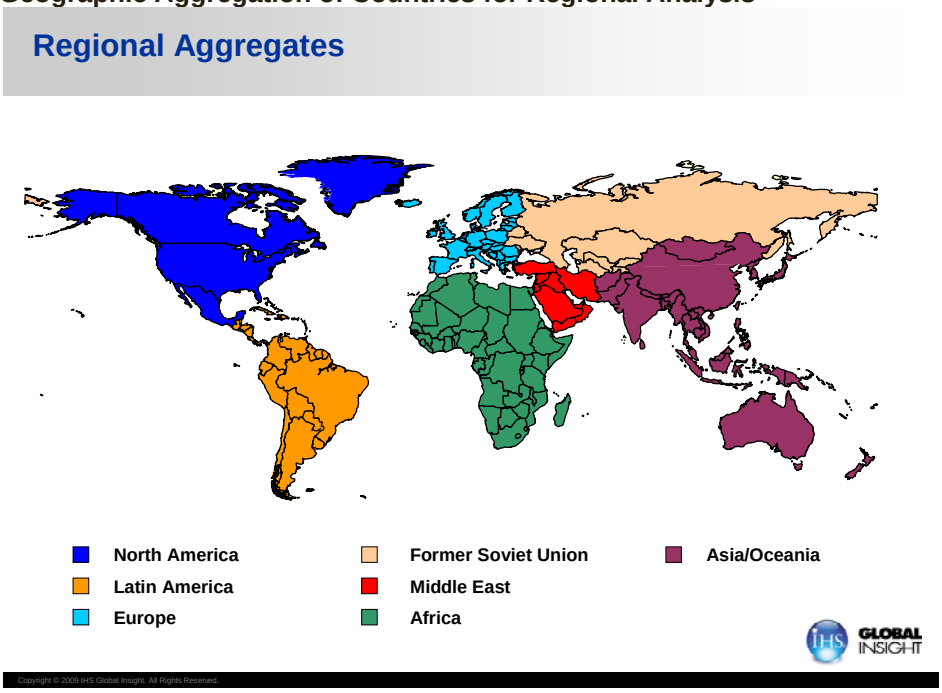


At present our models reside mostly in Microsoft Excel™ for ease of use and transparency for the model user. We also utilize SAS™ for some of the models, particularly those targeted for stochastic analysis. The estimated equations are derived using ordinary least squares for the most part. More advanced techniques such as two-stage and three-stage least squares are occasionally employed, but issues such as simultaneous equation bias are very small if the ordinary least squares equations fit well. Synthetic equations are sometimes derived based on elasticities from other studies and are often useful where there are limited observations because of structural change in a market.

Model Regions

The regional aggregates for this analysis include North America, Latin America, Europe, Former Soviet Union (CIS), Middle East, Africa, and Asia/Oceania.

Geographic Aggregation of Countries for Regional Analysis

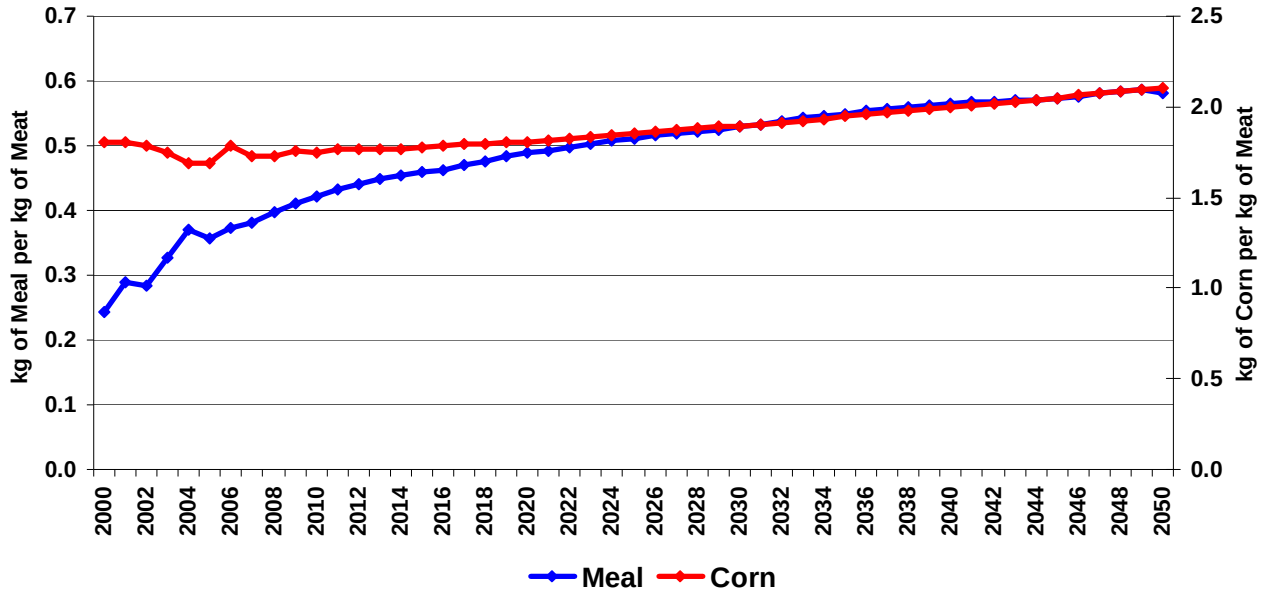


Technical Details

Livestock Feed Efficiency

Livestock feed efficiency is a critical factor in determining feed demand. Chinese livestock rations have become increasingly westernized (including more protein meal and grain) in order to meet their growing demand for meats. The inclusion of more protein has help improve overall feed efficiency. This means that protein meal required per pound of gain is actually increasing, but overall total feed per pound of gain is decreasing as other feedstuffs are reduced in the ration. There is still considerable opportunities for soybean meal consumption in livestock rations as modern swine and poultry operations replace backyard feeding operations. Corn inclusion in the livestock ration varies with the relative prices of other feed grains. Overall grain inclusion in the livestock rations is expected to increase as backyard feeding operations are replaced and overall expansion of production seek grain and protein meal rations instead of using food scraps, waste, etc. By contrast, Brazil's rations already reflect western corn and soybean meal rations and no acclimation is needed.

China Swine Feed Efficiency



Brazil Swine Feed Efficiency