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Global Food Security: Key Drivers—A Conference Report

NATIONAL INTELLIGENCE COUNCIL REPORT

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Scope Note
Global Food Security: Key Drivers—A Conference Report

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In June 2008, the National Intelligence Council (NIC) produced the National Intelligence Assessment, *National Security Implications of Global Climate Change to 2030*. The key findings were that climate change would have wide ranging implications for US national security interests in the next 20 years. The most significant impacts to US national security interests would be indirect and would result from climate-driven effects on other countries. Climate change alone is unlikely to trigger state failure through 2030, but the effects of climate change—reduced water availability, degraded agriculture production, damage to infrastructure, and changes in disease patterns—would worsen existing problems such as poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions.

Based in part on the anticipated impact of climate change on water and food, the NIC asked CENTRA Technology, Inc., to organize a conference on the drivers of global food security to 2040. CENTRA contacted ten subject matter experts (SMEs) who provided papers and presentations for a one-day conference held on 6 May 2011 in Arlington, VA to discuss future trends in global food security. This conference report is derived from the papers provided for and discussions held at that event.

2040 was selected as the target end point for this research to consider longer-term impacts from climate change, growing populations, and continued economic development. However, the data SMEs referenced covered a wide variety of dates (e.g., 2030 and 2050).

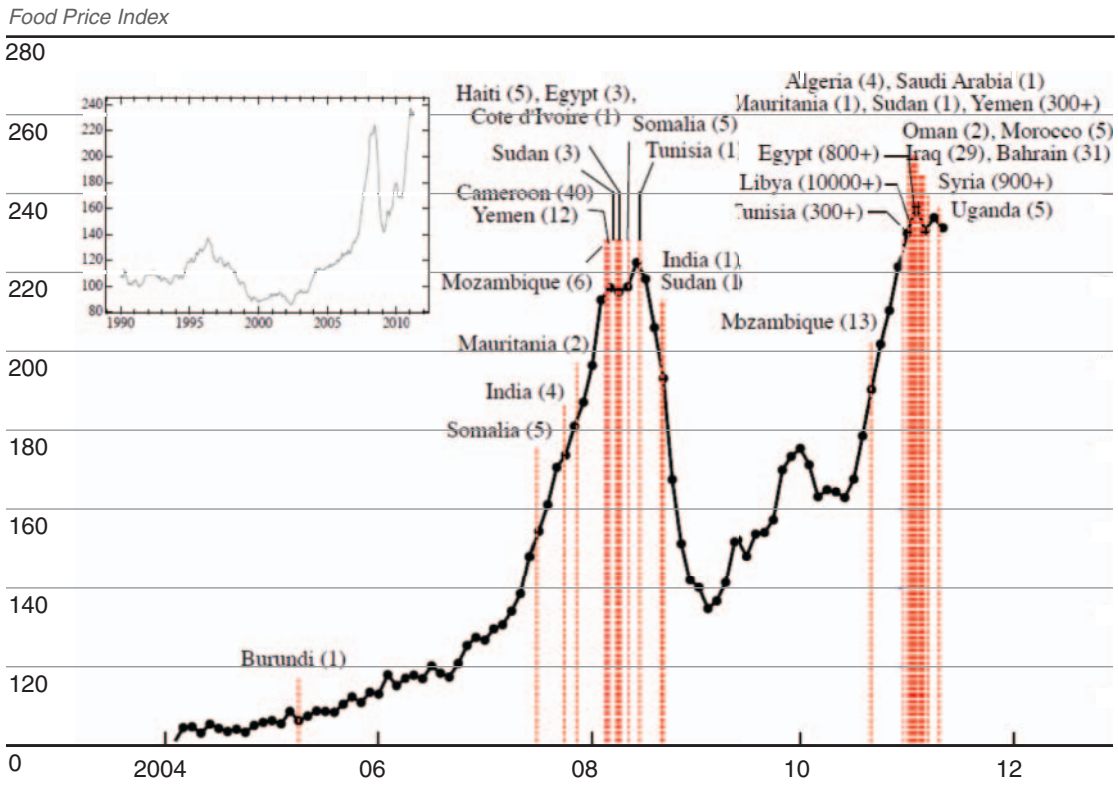
This introductory conference is the first of four external efforts the NIC will publish over the next four months to explore global food security. Also in the series are a case study report that looks at selected countries with an emphasis on the agricultural markets, an investigation exploring agriculture technology trends, and finally a large 20-plus nation study that examines global food security and the potential impacts on US national security. Following the publication of these external studies, the NIC will lead an Intelligence Community (IC) analytic effort to report on global food security and potential impacts to US national security.

Food Security Definition

The World Food Summit of 1996 defined food security as a condition “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life.” Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences.

Civil Unrest and Food Prices

Time dependence of FAO Food Price Index from January 2004 to May 2011. Red dashed vertical lines correspond to beginning dates of "food riots" and protests associated with the major recent unrest in North Africa and the Middle East. The overall death toll is reported in parentheses. Inset shows FAO Food Price Index from 1990 to 2011.



Source: M. Lagi, K.Z. Bertrand, Y. Bar-Yam, "The Food Crises and Political Instability in North Africa and the Middle East." arXiv:1108.2455, 10 August 2011, page 3, extracted from: http://necsi.edu/research/social/food_crises.pdf, 25 August 2011, respected research organization.

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Executive Summary

Fast rising food demand, slow rising food supply, ineffective government policies, and the uncertain impact of climate change will almost certainly lead to higher and more volatile global food prices over the next ten years, according to a conference of experts convened by the National Intelligence Council (NIC). Participants observed that wars over food are not likely, but higher and more volatile food prices will increase the potential for political and social instability in developing countries and regions of strategic interest to the United States.

- During the 2008 food-price spike, at least 61 countries experienced unrest because of price inflation; in 38 of these countries, protests were often violent.

The application of new technology and more investment in agriculture will almost certainly reduce the risk of higher and more volatile food prices. However, some experts believe that the world may soon hit an irreversible food security "tipping point"—where the impact of technology application and agriculture infrastructure development cannot be accomplished fast enough to meet rising demand and avoid a significant humanitarian crisis. The global food system is increasingly fragile as demand is increasing and the resilience of the supply system is inadequate to accommodate shocks caused by adverse weather or policy decisions. There is little political consensus on the appropriate path to build resilience in the system. Governments also lack a marked sense of urgency and coordination to address the drivers of food insecurity.

Population growth, increased purchasing power, and changing dietary preferences will almost certainly put upward pressure on demand.

- According to US Census projections, global population will increase by 27 percent to over 8.9 billion people by 2040. Much of the projected growth will almost certainly be in low income countries that are both politically fragile and/or strategically significant. These include Pakistan, Nigeria, Bangladesh, the Democratic Republic of the Congo, Ethiopia and Kenya. In fast growing economies, such as China, Brazil and India, increasingly affluent consumers push up the demand for meat and dairy products as incomes rise. As a result, demand for grains to use as animal feed increases.

- Global meat production must rise by 70 percent from 200 million to 470 million tons to accommodate increasing demand by 2040. Likewise, cereal production must rise from 2.1 billion to 2.9 billion tons.

The supply of food grain is unlikely to meet demand because of increasing land and water constraints and the inadequate application of new technologies to increase agriculture productivity.

- The adoption of "Green Revolution"[1] seed technologies enabled global average annual grain yield growth rates to reach two percent between 1970 and 1990. Since then (1990-2007), these grain yield growth rates have fallen by nearly one half.

[1] Green Revolution refers to a series of research, development, and technology transfer initiatives, occurring between the 1940s and the late 1970s, which increased agriculture production around the world, beginning most markedly in the late 1960s.

- Conference participants estimated that 12 percent more arable land will be available globally by 2050. However competition among different land uses—for farming, livestock grazing, biofuel production, and urban development—will almost certainly intensify, reducing land available for food production.

- By 2025 up to two-thirds of the world's population will live in water-stressed conditions, while current agriculture will almost certainly increase water demand 45 percent by 2030.

Unless entrenched institutional and economic barriers are reduced, they will almost certainly continue to hamper food production. National subsidies and price controls can magnify the impact of food scarcity by reducing incentives to farm. Trade-restrictive policies—often in reaction to high global prices or perceived local shortages—lead to sharp price spikes. In addition, poor infrastructure leads to high food waste in developing countries. Finally, use of land for biofuels production reduces its availability for food.

- Ailing infrastructure and inefficiency push up transport costs for food. Such costs, for example in Sub-Saharan Africa, can be as high as 77 percent of the value of exports, whereas post-harvest losses in developing countries affect from 15 to 50 percent of production.

- The prognosis for deployment of a "New Green Revolution" to boost farm productivity is uncertain because major consumer and environmental blocs object to the introduction of genetically modified seed strains—the most promising new technical advance—into the global food system.

- Continued biofuel production in developed countries is likely to reduce food grains and push up prices until new technology is employed. Experts estimate that global corn prices might rise 41 percent as soon as 2020. In developing countries, the production of cassava-based ethanol also poses a food security threat, since the crop provides one third of the caloric needs of 200 million of Africa's poorest people.

Climate change is a major food production wildcard because it affects—for better or worse—crop yields either through changing rainfall patterns and/or by altering critical temperature ranges.

- **Participants observed that sustainable economic growth is a powerful means for mitigating the impact of climate change on food security by providing consumers more resources to procure food.** Application of agriculture research by farmers can improve productivity and reduce poverty and thereby improve farmers' resilience to climate change. Domestic production and international trade flows determine domestic food availability—but per capita income determines consumers' ability to pay for the food.

The absence of food security will almost certainly become an increasingly important underlying stressor that might compel countries to rely less upon global food markets and take other actions to secure food, e.g., ban exports, negotiate transnational land leases, or conclude bilateral barter arrangements.

- Participants judged the sudden increase in foreign private and state-to-state transnational land agreements for agriculture suggest some countries (e.g., China, Saudi Arabia) are seeking alternatives to global food markets. Such agricultural land agreements could lead to significant local political and security consequences, particularly if these arrangements strain already tight water reserves along supporting river basins.

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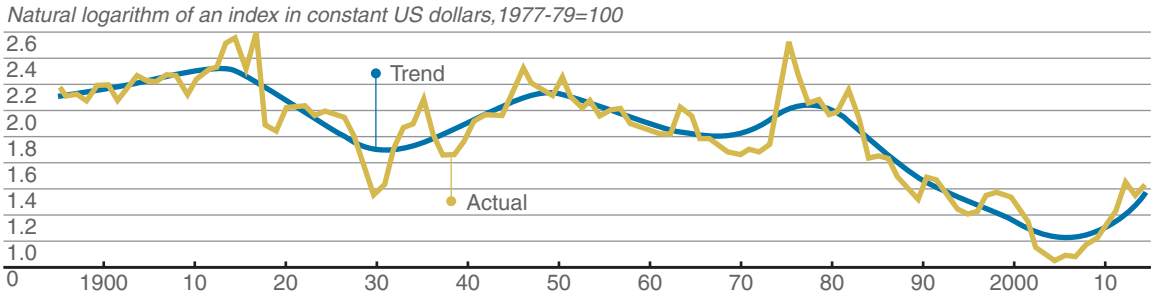
Contents

This report was prepared under the auspices of the Director, Strategic Futures Group. It was reviewed by the National Intelligence Council and other members of the Intelligence Community (IC), but was not formally coordinated. Questions about this paper or requests for copies can be directed to the Director, Environment and Natural Resources Program, on secure 934-2913 or unsecure 703-482-2515.

Eat Up

The real price of food is on an upward trend but is still at its lowest since the Great Depression.



Sources: Grilli and Yang (1988); Pfaffenzeller and others (2007); and IMF, Commodity Price System database; extracted from http://www.coyleasset.com/files/MOAPR11.pdf, page 2, 10 January, 2012.

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Discussion

What Will Global Food Security Look Like in 2040?

Fast rising food demand, slow rising food supply, ineffective government policies, and the uncertain impact of climate change will almost certainly lead to higher and more volatile global food prices over the next ten years, according to a conference of experts convened by the National Intelligence Council (NIC). Participants observed that wars over food are not likely, but higher and more volatile food prices will increase the potential for political and social instability in developing countries and regions of strategic interest to the United States.

Local, regional, and national food systems are now intertwined in a global food network. This complex web of relations includes harvesting, processing, producing, transporting, preparing, and consuming food. The global food network is filled with pockets of both abundance and scarcity and its emerging shape does not reflect a traditional model of the world such as North/South or Developed/Developing.

Many decisions are made in a wide variety of locations—including farm fields, scientific and commercial laboratories, governmental centers, and international brokerage houses—which create the global food network.

Real Global Food Prices on the Rise[2]

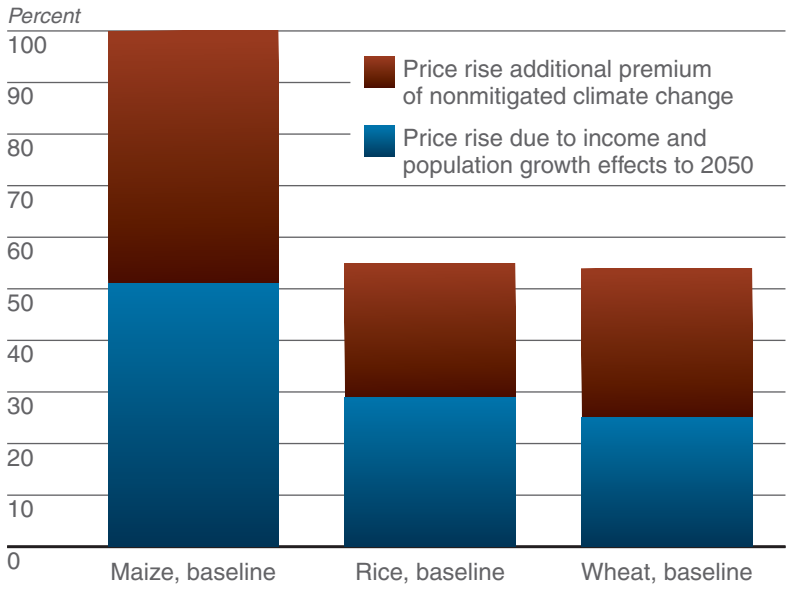
World prices are a useful single indicator of the future of agriculture. Rising prices signal the existence of imbalances in supply and demand. At present, the demand factors such as a growing population and rising income are driving demand higher than the supply, influenced by its factors of productivity enhancements and expanding cultivated land, can keep up. Furthermore, in some places, long-term supply might actually decrease due to climate change, although how much of a global problem this will be is not yet fully understood.

Investing in agricultural productivity improvements would make it possible to meet more of the rising demand from existing agricultural land resources and reduce the environmental threats from increased land use. Participants observed that although it is still possible to cultivate new land in some parts of the world, doing so would risk significant environmental damage.

Public sector agriculture expenditures might slow, but not stop, the increase of malnourishment worldwide. To compensate for the long-term productivity losses associated with climate change, world-wide public spending of at least

[2] The International Monetary Fund (IMF) food price index tracks the prices of the 22 most commonly internationally traded agricultural food items. For example the index includes major grains—wheat, rice, and corn; oil seeds—soybeans; edible oils—palm oil; basic meats—beef carcasses; some basic seafood items—fish meal; some tropical fruits—bananas; and sugar. The index was created to facilitate assessment of food market developments and prospects for the IMF's World Economic Outlook.

Climate Change Adds Significantly to Rising Food Grain Prices, 2010-50 Percent Increase



Source: International Food Policy Research Institute report. Gerald C. Nelson, et al. Food Security, Farming, and Climate Change to 2050; Scenarios, Results, Policy Options, extracted from: http://www.ifpri.org/sites/default/files/publications/rr172.pdf, 10 January 2012.

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seven billion dollars annually is required according to International Food Policy Research Institute (IFPRI) research. Investment in productivity-enhancing projects is required in three areas: biological research, expansion of rural roads, and expansion and efficiency improvements of irrigation. Participants concluded the best way to deal with climate change is to focus on broad-based income growth and to invest in specific kinds of agricultural productivity.

Participants observed that sustainable economic growth is a powerful means for mitigating the impact of climate change on food security by providing consumers more resources to procure food. Application of agriculture research by farmers can improve productivity and reduce poverty and thereby improve farmers' resilience to climate change. Domestic production and international trade flows determine domestic food availability—but per capita income determines consumers' ability to pay for the food.

The Future of Food and Biotechnology

Biotechnology regulatory barriers are likely to increase and delay for years the widespread commercial development of new biotech food products. Few new products are likely to enter the agriculture market. Participants judged governments place little focus on products that would benefit the food security needs of less developed countries.

- Laws and regulations often take five to 10 years to change to enable development of a new product. Then, an additional 10 more years are required to commercialize the product. Hence, today's research efforts, agricultural market forces, and regulatory mechanisms shape commercial application of biotechnology for the next two decades. Participants judged the time and costs for a product to get to market discourage research for new products and reduce competition.

- Developing countries create insufficient market demand for expensive biotech products. Developing countries need dozens of new products, rather than the handful they will likely see if current trends continue.

Regulatory barriers for biotech are likely to increase. Regulation is a serious challenge to the increased production of genetically modified (GM) crops. Europe, to safeguard its own population, is raising food standards every year. Although developed countries believe that higher standards would also benefit other countries, the developing countries perceive they will likely be the losers in the end, as ever higher food safety standards become barriers to their exports.

- Testing for GM foods in Kenya is difficult, for example, and creating the paper trail that would meet some food safety standards is not feasible.

- European regulation also limits trade with developed nations: the United States cannot ship corn to Europe under current protocols for handling GM crops because a tanker vessel that contained GM commodities in a previous shipment would undoubtedly still carry some incidental GM content.

Few products currently in development are targeted to solve the global food security problem. The biggest research efforts target a handful of wealthy countries. Low risk and easy-to-apply, next-generation technologies will likely be vastly underused, especially in the developing world.

Through 2030, a handful of countries will likely experience the biggest growth in agriculture productivity, with the rest of the world falling behind. In the absence of near-term climate shocks, participants projected that in the next ten years productivity in Brazil would grow 40 percent; the United States and Canada would experience 15 to 20 percent growth. European agriculture will likely remain on a low productivity path since Europe continues to increase the standards for growing, shipping, and using GM products.

The Future of the Global Food Trading System

Four key crops compose almost 75 percent of the caloric base of the world's population: corn, wheat, rice, and soybeans. The supply and demand margin—difference between supply and demand—for these products is presently limited. Furthermore, for a variety of cultural and content reasons, the crops are not fully interchangeable. Therefore, small fluctuations in production can lead to large swings in price for any given crop.

Food prices had trended down in past decades until 2000 when real and nominal prices both increased. Factors affecting current prices include increasing growth in demand (above the growth in supply) and higher personal incomes. In some places, the drive for meat demand lifted grain prices—five to ten times more grain is required to obtain a calorie for human consumption through meat as compared to directly consuming the grain. In addition, 40 percent of the US corn crop in 2011 was used

for the production of ethanol. Weather shocks and slowing productivity growth against increasing demand create tight supply margins and higher prices.

Low food inventories lead speculators to increase prices on futures markets. Inventory levels buffer temporary shocks with withdrawals in bad years and accumulation in good years. However, according to conference participants, global food inventories in 2011 were at record lows, and low inventories increase the vulnerability of consumers to food price shocks. If a supply shock occurs during a period of low global inventories, and commodity speculators perceive that the supply will be disrupted beyond the short term, some grain supplies would be removed from the market (through purchases) in anticipation of higher future prices. This would lead near-term prices to rise even more.

- Because agriculture production is widespread, a single shock event is unlikely to disturb the global market. Synchronous shocks in key production countries like Australia and Russia would bode ill for world markets. Participants expressed concern that climate change might increase the possibility of simultaneous shocks.

Research done on the vulnerability of corn and soybean production to extreme heat suggests a real danger to future supplies of these key commodities. A major new finding is that by far the best predictor of yield is a measure of extreme heat. Yields decrease above 84° F for corn, and 86° F for soybeans. The number of extreme temperature days matters most but climate models, which often report average temperatures, obscure these excursions.

- Beyond 2030, US corn production might drop 20 percent from today according to some research. Temperature alone can explain 70 percent of the variation in US yields, and predictions indicate temperatures will probably increasingly exceed 84° F. Further, farmers in the warmer southern portions of the United States have not successfully adapted to the higher frequency of temperatures above 84° F.

- Impacts on US crops will affect global food security because the United States is the world's largest producer and exporter of staple agricultural commodities. The US Midwest region currently accounts for nearly 40 percent of the global corn crop.

The "At Risk" Regions? Africa, Middle East, and South Asia

Africa

Over the next 30 years, food insecurity will likely remain high in Africa because population growth will likely be high and both governments and farmers lack the capacity or incentives to adequately invest in agriculture.

The overall proportion of African households that are food insecure fell only slightly over the last half century. Estimates suggest that roughly 200 million sub-Saharan Africans do not enjoy food security. About 75 percent of the poor and food insecure people in Africa live in rural areas. Most of the people in these households either grow crops on their own farms, selling surplus in the market, or work as agricultural laborers.

For farm owners, higher productivity means more to eat and more to sell in the market. The wages of tenant farm workers' depend directly on the productivity of the farms on which they work. As a result, boosting agricultural productivity is a primary way to raise rural incomes and improve food security. Although yields of primary staple crops have been slowly rising across Africa (although at much slower rates than elsewhere in the developing world), per capita production of these crops is actually

lower that it was in 1960 because of political instability and population increases. This decrease in production directly contributed to the rising numbers of Africans lacking food security.

Although agricultural production levels significantly influence household incomes, perennially low crop yields mean that over 70 percent of African households are net consumers according to some estimates. As a result, food price spikes increase food insecurity, at least in the short run in both urban and rural Africa.

- Recent World Bank estimates suggest that the 2010 spike in global food prices pushed an additional 68 million net consumers below the poverty line across the developing world, but pulled 24 million producers out of poverty, for a net increase of 44 million people in poverty.

Low incomes and adverse economic shocks correlate with civil conflict in Africa. Participants reported that a large body of academic literature emphasizes the relationship between low incomes and higher incidence of civil conflict around the world—particularly in Africa. There are two explanations for this linkage: individuals with low incomes have little to lose from joining a rebellion (the "opportunity cost" argument), and governments in poor countries have difficulty mobilizing resources to put down rebellions (the "state capacity" argument).

Continued failure to improve agricultural productivity might increase the risk of local social conflict in Africa. Recent research links the onset and incidence of African conflict to variation in African agricultural incomes. In years of low agricultural productivity or low export prices for farmers, civil wars are much more likely to break out. One paper finds a doubling in the risk of African civil war outbreak following a 20 percent decline in commodity prices for African exports (many of which are agricultural commodities). Other research shows a 50 percent increase in the probability of civil war with a one degree Celsius increase in temperatures, likely because of the negative effects of high temperatures on agricultural productivity. By 2030 climate change might permanently raise the average temperatures in parts of Africa above this one degree threshold.

Participants judged the majority of African poor will likely continue to reside in rural areas in the coming decades making farm incomes the key driver of food security. With the developing world rapidly urbanizing, many researchers speculate that poverty and food security concerns are going to shift to urban mega-cities in coming decades. This is less likely in Africa because the percentage of the poor living in urban areas has increased slowly over the last few decades, from around 25 to 30 percent. Survey evidence suggests that the majority of the African poor will remain in rural areas for at least the next few decades, implying that trends in agricultural productivity will play a greater role in food security than growth of urban populations.

Participants judged food issues will be a key contributing factor to social and political disruptions in Africa and might contribute to state failure or regime change in some states.

- North Africa might become a hot spot for conflicts over water issues as water is critical for agriculture. Egypt is particularly vulnerable to such tensions due to its reliance on imported food and water for agricultural purposes from the Nile—95 percent of which originates outside of Egypt.

Table 1. Africa Population, Income, and Share Undernourished

	Population (millions)	Population Growth Rate (%/year)	Gross National Income (US$/pc)	GDP Growth 2000-2007 (%/year)	Share of population undernourished (%)
North Africa	159	1.6	2,550	5.0	<5
Sub-Saharan Africa	812	2.6	950	5.1	29
South Africa	50	1.0	5720	4.3	<5

Note: North Africa includes Algeria, Egypt, Libya, Morocco, and Tunisia.
Source World Bank, World Development Indicators, 2009

- The lack of basic infrastructure in Southern Sudan might exacerbate food security issues, since there are only 2,500 miles of road in the entire country.

Food security remains a major problem in Sub-Saharan Africa[3], with an estimated 29 percent of the population under-nourished. Sub-Saharan Africans have a calorie intake of approximately 2,400 calories per person per day, as compared to 3,000 calories in South Africa, and approximately 3,200 calories in North Africa. Approximately 2,200 calories per day is the minimum for a healthy active life according to the Food and Agriculture Organization (FAO) of the United Nations. Although Sub-Saharan Africa has exceeded this level on average, the distribution of calories is not equal: a large share of the population is still undernourished. While imports provide a large share of the food supplies in North Africa, Sub-Saharan Africa lacks the income to import needed food supplies.

Sub-Saharan African countries have underutilized land suitable for crops that could help mitigate the impact of climate change (only 3.5 percent of total cropland is irrigated). Farmers could expand food production on these lands but irrigation is expensive, and tropical soils are less fertile and require expensive fertilizer and new seed technologies to raise productivity.

In North Africa, long-term climate change is likely to worsen food security. North African countries have few alternatives to expand irrigation as water becomes scarce and rising temperatures degrade productivity. Although substantial areas of the Sudan delta between the Blue and White Nile could be farmed, doing so would take water away from Egypt, raising the specter of conflict between Sudan and Egypt.

- North Africa is also heavily dependent on food imports, and rising global food prices would burden national budgets.

Corn is the most important food grain in Sub-Saharan Africa and provides 60 percent of the population's total calories. Most producers have small farms with less than one hectare of rain-fed cropland devoted to the production of corn. Land preparation with hand hoes makes labor availability a key constraint for expanding

[3] Sub-Saharan Africa is defined as excluding South Africa for the purposes of this paper.

cultivated area. Productivity is low because farmers typically plant low-yield seeds kept from their previous season's crop. Improved seeds and fertilizer are not usually available. When they are, farmers often cannot obtain credit to purchase them. Fertilizer costs six times more in Kenya than in Iowa.

Yields in recent years have begun to increase in some Sub-Saharan African countries but they remain far below potential. Sub-Saharan corn yields have stagnated at about 1.0-1.25 tons per hectare since the 1960s. By contrast, corn yields in South Africa average about 4.0 tons per hectare on rain-fed cropland; yields in Egypt average about 8.0 tons per hectare on irrigated cropland.

Past efforts to raise corn yields in Sub-Saharan Africa have been largely unsuccessful due to the multitude of challenges facing small producers. These include the absence of improved seeds, lack of credit to purchase fertilizer, lack of mechanized equipment or draught animals for field preparation, poor harvesting methods that result in a large portion of broken kernels, and poor storage and post-harvest handling.

Once farmers produce a corn crop, they often face low profits due to high marketing and transportation costs. In addition, because African farmers often cannot get their crops to global markets or meet global food standards, they receive prices for their crops that are much lower than those offered in world markets. This remains the case even when they sell to national urban markets. Government policies and taxes further reduce producer incentives and suppress prices by restricting the movement of corn between districts and by imposing high local taxes on corn transported on main roads. Despite such problems and the failure of past efforts, the opportunities to raise corn yields are better now because of the increase in global prices and the renewed efforts of national governments and international donors.

Participants observed that the impact from new foreign investors in African agriculture is unknown. The details involving land leases are both hard to discover and often vague. Additionally, the future enforcement of contracts is unknown. One participant observed that a clause mentioned in a contract between Saudi Arabia and Pakistan for food included a provision to pay for 100,000 troops—indicating an expectation of potential local violence.

Middle East

The level of agricultural production per capita is low in the Middle East so the residents seek food security by importing food paid from earnings from the region's oil exports. Only Iran, Lebanon, and Syria are internally food self-sufficient. For countries that depend upon food imports, the ratio of the cost of total exports to the cost of food imports is an indicator of food security. This indicator reflects the relative cost of access to food in each country and a higher ratio indicates greater food security and less vulnerability to external food price shocks. Of all the countries in the Middle East (excluding Iran, Lebanon, and Syria) only three—Kuwait, United Arab Emirates, and Iran—outperform the world average of 11.5 for total exports/food imports.

- Water availability is a limiting factor in agriculture production. Overall, agriculture contributes to 12 percent of the Middle East economy, yet it uses 89 percent of the available water, well above the global average of 70 percent. This indicates the region must exhaust almost all of its available water for food production and thus has little capacity to adjust to circumstances (natural or manmade) that reduce water availability.

Yemen's Food and Water Crisis. **Yemen will likely be the first Mideast country to face a food crisis before 2040.** Almost four fifths of Yemen's food grain requirements are imported,

which makes the country extremely vulnerable to increases in international food prices and freight costs. Yemen imports 91 percent of its wheat and 10 percent of its rice.

Yemen has the highest rate of exhaustion—consumption[4] of ground water in excess of resupply—of water sources in the Middle East and the highest rate of population growth in the world. Qat, a mildly narcotic leaf chewed by about 70 percent of males, consumes an estimated 40 percent of all water resources, both surface and groundwater. The export of Qat yields about a quarter of Yemen's Gross Domestic Product (GDP), creating a linkage between water availability and economic well being. Yemen's water availability per capita—the lowest in the world—is decreasing every year. Much of this is due to the rapidly growing Yemeni population, which nearly doubled between 1990 and 2010 from 12 million to 23 million. The average person in the Middle East has 1,250 millimeters (mm) of water available per year (ground and surface), whereas the average Yemeni has 140 mm of water available per year. Unlike other Middle Eastern countries such as Lebanon, Syria, and Egypt, Yemen has no rivers, so agriculture depends on limited rainwater and rapidly depleting underground water resources. As water availability decreases, competition between water use for agriculture and other sectors—personal consumption, industrial—continues to increase. Since poor Yemeni families are forced to spend over 65 percent of their household budget on food, Yemen's water and food crisis contributes to the country's instability and potential trajectory toward failure. In order to stave off catastrophe, experts suggest that Yemen employ low-cost rainfall water harvesting methods to improve its irrigation efficiency, investigate groundwater availability, and study water desalination techniques to increase the possible sources of water in the future.

Saudi Arabia's Food Security Solution. Facing a probable 50 percent growth in its population by 2040, Saudi Arabia's barren soil and limited water supply will almost certainly be insufficient to feed its future population. Saudi's population has grown at a rate that outpaces the growth of food production, prompting Saudi Arabia to change its agricultural policies in 2009. The government abandoned its aggressive campaign for food self-sufficiency, and ended support for crops such as wheat and alfalfa that consume large amounts of water. However, to support local political and elite interests, Riyadh increased support for organic farming and vegetables for human consumption. Since water used for irrigation comes from ancient aquifers and is non-renewable, the Saudi agriculture ministry emphasizes scientific water management, water-conserving drip irrigation, and an end to the production of crops for cattle feed.

In 2009 the Saudi government encouraged private Saudi corporations to seek long-term "food security" by developing farm resources in land-rich, cash-poor countries around the world. Targeted countries include Sudan, Ethiopia, Vietnam, the Philippines, Mozambique, and Ukraine. The crops developed through these investments would be exported, in whole or in part, to Saudi Arabia. Some crop production would be used to establish what the government calls a "strategic reserve for basic food commodities," to include rice, wheat and barley.

[4] Consumptive water use is water removed from available supplies without return to a water resources system (e.g., water used in manufacturing, agriculture, and food preparation that is not returned to a stream, river, or water treatment plant). Evaporation from the surface of the earth into clouds of water in the air which then falls to the ground as "rain" is excluded from this model. Crop consumptive water use is the amount of water transpired during plant growth plus what evaporates from the soil surface and foliage in the crop area. The portion of water consumed in crop production depends on many factors, especially the irrigation technology.

- The Saudi Food Security Initiative replaces the Kingdom's previous domestic food self-sufficiency campaign with a dependence on foreign lands. This new policy also demonstrates the government's lack of faith in the global food market to supply the Saudi's future food needs. The Saudi initiative could also contribute to a global solution for the looming commodity shortage by stimulating increases in agricultural output in underperforming countries such as Ethiopia and Mozambique. Yet some potential host countries have expressed opposition. Thailand, for example, has declared that there would be no land sales to the Gulf countries, and farmers in Kenya and Pakistan have voiced opposition to the proposed deals. In addition, international tension could rise if Saudi Arabia, Kuwait, or the UAE sought to build large agro-projects in Sudan, which shares its water source, the Nile, with Egypt.

South Asia

Population growth and economic development are the critical issues impacting water demand and hence food security in South Asia over the next two decades. Climate change will have less of an impact, but will increase the variability of water available from glacier melts and precipitation.

Pakistan. Emerging post-green revolution problems including pests and diseases, declining water resources, and land degradation coupled with high population growth, pose threats to Pakistan's future food supply. Currently estimated at 170 million, the population of Pakistan is estimated by the US Census Bureau to double over the next 25 years. Coupled with looming water shortages, and assuming current technology and current practices, Pakistan will likely find it difficult to feed a projected population of 340 million with internal food sources by 2040.

Rapidly declining water availability is Pakistan's primary food security problem. Water is the lifeline for development of agriculture-based economies such as Pakistan. Pakistan's 16.2 million hectares of irrigated land supply more than 90 percent of the value of agricultural production. According to United Nations Population Fund and the Pakistan Ministry of Population Welfare, Pakistan was a water-scarce country as far back as 1992 with 1700 cubic meters available per capita. The current availability of 1,100 cubic meters of water per capita is quickly approaching the more threatening threshold of less than 1,000 cubic meters per capita.[5] Poor water management and the overuse of water for irrigation resulting in waterlogging[6] and increased salinity aggravate water scarcity. Pakistan's current water storage capacity at 9 percent of average annual flows is very low compared with the

[5] When describing water availability in a country, the Falkenmark Water Stress Indicator, which was developed by the Swedish water expert Falkenmark in 1989, is one of the most commonly used indicators. Originally, the indicator based on the estimation that a flow unit of one million cubic meters of water can support 2,000 people in a society with a high level of development, using Israel as a reference by calculating the total annual renewable water resources per capita. Water availability of more than 1,700m³/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m³/capita/year water stress appears regularly, below 1,000m³/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m³/capita/year water availability is a main constraint to life.

[6] Waterlogging refers to the saturation of soil with water. Soil may be regarded as waterlogged when the water table of the groundwater is too high to conveniently permit an anticipated activity, like agriculture. In irrigated agricultural land, waterlogging is often accompanied by soil salinity as waterlogged soils prevent leaching of the salts imported by the irrigation water.

world average of 40 percent and the storage capacity is likely to fall further over the next decade as flows increase and infrastructure degrades.

Food insecurity affects millions of Pakistanis—particularly the 36 percent of the population that Islamabad considers to be poor. In 2008 world food prices reached their highest levels since the 1970s, and Pakistan's food inflation registered as high as 34 percent. UN World Food Program (WFP) reports from 2008 concluded that 77 million Pakistanis—nearly half the country's total population—were hungry. In 2008 three fourths of Pakistan's 121 districts, according to the WFP, faced hunger and malnutrition-related disease. This widespread food insecurity triggered civil unrest in many urban areas, and Pakistan's army was dispatched to guard grain supplies.

- In February 2010 the prices of wheat and rice—Pakistan's two chief staple crops—were 30 to 50 percent higher than before the global food crisis, and were still increasing. WFP data from early 2010 reported that the prices of essential staples in Pakistan were nearly 40 percent higher than five-year cumulative averages.

India and Water. India has far less water storage per capita than many other countries. Both over-extraction of ground water (pumping in excess of replenishment) and pollution add to water stress. River dams block silt that would otherwise flow downstream; the result is that more sea water intrudes into river deltas. As more of the deltas disappear with rising sea levels, land subsidence will become a growing issue and disproportionately affect people who live and farm in the deltas. India suffers more from monsoon-deficit years than it benefits from monsoon-surplus years. India uses 93 percent of its water for agriculture compared to a worldwide average of 70 percent. Application of water technology could reduce India's vulnerability to future variations in water availability and enable an increase in agriculture productivity.

India uses 15 to 30 percent of its electricity to pump groundwater. The ability of India to price water effectively is a governance question. Surface water irrigation was once free—provided the user lived on the canal. To compensate those who did not live near the canal, the government created an electricity subsidy. This subsidy has proven difficult to remove and is the source of many of India's water problems because it leads to over-pumping of groundwater sources. Some of the poor buy water from a tanker at six times the rates of other water sources.

India's political structure aggravates tensions between state and federal officials because the state has responsibility for agriculture whereas New Delhi holds the purse strings. The political tensions arise more from food governance issues than physical food availability because strong rural lobbies press for subsidies while the central government controls prices with the intent to produce constant revenue streams.

The More Secure Regions? Mexico and Central America, Central Asia, and East Asia

Mexico and Central America

Despite their apparent food security, Mexico and Central America depend on corn. Because it is a crop highly sensitive to climate fluctuations and is used to produce fuel and feed, this dependence increases the food security risk to the region. Mexico is the world's third largest corn importer and the fourth largest corn producer.[7] As these countries

[7] While a large corn producer, Mexico processes much of its production of white corn into human food products, but has

increasingly use corn to produce ethanol, the amount of grain available for food correspondingly decreases. In addition, corn is also a feed crop, the demand for which is rising quickly. As these combined demands for corn increase, so will the price. Corn is mainly irrigated by rainwater and because it is already grown in very warm regions, adverse climate changes negatively influence yields and push prices higher still. The urban poor, landless laborers, and small landowners in Mexico are dependent on non-agricultural income sources. Therefore, most of the Mexican poor are adversely impacted when food prices rise and Mexico's food security is degraded.

Participants noted that if the three factors below continue, they might cause global corn prices to rise significantly above the current high levels and thereby increase the risk of serious food insecurity in Mexico and the other countries in the region:

- China and other countries' demand for corn and soybean as livestock feed continues to grow.

- Climate change increasingly imposes a significant drag on the growth rates or yields of corn and other coarse grains.[8]

- The United States continues to use a large portion (currently around 40 percent) of its corn for ethanol production.

Deteriorating food security conditions within Mexico might cause an increase in illegal immigration to the United States. A recent study demonstrated that historically, migration rates increased by roughly two percent for every ten percent drop in corn production. The study then evaluated scenarios of climate change impact on Mexican agriculture and predicted that by the end of the 21st century, climate change could lead to as much as a ten percent increase per year in migration into the United States.

Central Asia

Overall food security in the Central Asia is mixed and complicated by an inability to establish local food markets. **Central Asian rhetoric about self-sufficiency reduces trade and exacerbates food insecurity.** Nationalist rhetoric emphasizing food self-sufficiency is counterproductive because it discourages interstate trade that might foster a more efficient use of human, land, water and other resources.

The distribution of water in Central Asia is uneven, varies by season, and supports multiple demands. When winters are particularly cold and dry, such as in 2007-2008, the limited water stored upstream in Kyrgyzstan and Tajikistan is used for electrical power generation and heat. Such seasonal usage leaves less water for summer agriculture in the downstream countries of Turkmenistan, southern Kazakhstan, and especially Uzbekistan. The uneven distribution of water generates challenges for agricultural productivity, and a downward spiral of interrelated energy and food insecurity results. Water delivery systems, such as the wide, unlined canals and open-air viaducts, are inefficient and allow considerable evaporation of water before it reaches its destination.

- Food prices in Kazakhstan increased between 20 percent from December 2009 to December 2010. An increase in tariffs on Chinese imports, to include some food products, contributed to climbing food prices, simultaneously protecting the market for indigenously produced foodstuffs. In 2008, Kazakhstan, the main regional wheat exporter, banned grain exports in an attempt

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turned to imported yellow corn and sorghum for livestock feed to support increased meat production.

[8] Coarse grains generally refers to cereal grains other than wheat and rice—in the OECD countries, those used primarily for animal feed or brewing.

to stem rising domestic prices and stave off bread shortages. This forced its neighbors to turn to more expensive wheat suppliers and spurred inflation in those countries.

- Food prices in Uzbekistan have doubled in 2011, and retail grain prices rose 200 percent. Uzbekistan is attempting to reduce grain imports from Kazakhstan, which wields significant control in the Uzbek grain market. Conference participants reported that farmers are encouraged to produce higher yields rather than higher quality winter wheat. Wheat is the main grain staple of much of the region. The flour that is currently grown from lower quality winter wheat in Uzbekistan is insufficient for producing high quality *Tandyr* bread, the traditional flat bread.

- Turkmenistan's arid climate, extremely limited amount of arable land, and its dependence on upstream neighbors to supply 95 percent of its water make self-sufficiency in agriculture a particular challenge. Food prices are also a problem in Turkmenistan, but state revenues from fossil fuel exports subsidize food.[9]

- Tajikistan was particularly hard hit by compounding factors—poor water management, changes in weather patterns, collapse of Soviet-era trading systems—that lead to food insecurity and likely has the fewest resources to combat these challenges. In 2010, Tajik President Rahmon encouraged the population to stockpile household food supplies for two years. The government has also resorted to using strategic grain reserves to reduce domestic grain prices. Flour prices still increased by 80 percent in 2010 which influence the availability of breadstuffs, the key staple in the average Tajik diet.

East Asia

To date, China's food security success relies heavily on investment in irrigation, fertilizer, and high-technology seeds. Conferees judged that with land and water becoming scarcer, this high intensity form of agriculture—heavily dependent upon irrigation and fertilizer—may not be sustainable in the future.

In the face of tight supply in the global food market and the food crises that shook many countries, China maintained a grain self-sufficiency[10] rate of above 95 percent in recent years. Three decades of economic reforms have lifted hundreds of millions of people out of poverty, making China one of the few countries on target to fulfil the Millennium Development Goal of halving hunger by 2015. As of 2005, China transitioned from recipient to a donor in the World Food Programme (WFP).

With only modest imports and using only seven percent of global farmland, China has sufficient grain food for 22 percent of the world's population. Although institutional changes and technological innovations are important factors, China's grain productivity increase relied heavily on the intensive use of physical inputs such as irrigation, fertilizer, and pesticides. Intensive fertilizer use and poor natural resource management in the pursuit of yield growth puts great pressure on crop land. The current challenge is to feed a growing population while conserving natural resources and reducing negative environmental impacts.

[9] Flush with petroleum profits, Turkmenistan's 1992 "Ten Years of Prosperity" program provided virtually free natural gas, electricity, and drinking water to all households in the republic and increased social benefits, minimum wages, and food subsidies. The program was renewed for another ten years in 2000.

[10] Grain self-sufficiency is the ability to meet the basic caloric intake via domestically produced grains.

- Nearly 60 percent of China's cropland exhibits significant soil degradation and over 40 percent of Chinese cropland experiences water erosion and physical degradation.

Chinese cropland will likely decline in the coming decades because of losses due to land degradation, ecological conversion programs,[11] and more importantly, urbanization and industrialization. In addition, water availability and reliability—available at the right time—are increasingly critical constraints to food production in China. With competing water demands from urban dwellers and industry, water scarcity will become an even more pressing problem in North China—in the region's major food-producing areas in particular. Although water is already a constraining factor in many of China's food producing regions, China remains optimistic about grain security because government mechanisms keep prices low. Meat and vegetables, however, do not receive similar price supports.

Despite its enormous food security challenges, participants judged with the right policies in place, China can succeed in preserving its food security. Most experts expect that China can produce most of its grain for human consumption domestically and that its grain-based food security will improve over the next few decades. Nonetheless, China will still have to import considerable amounts of animal feed for its livestock and eventually import meat in response to the dietary changes stemming from the fast growth of income and urbanization.

- Participants observed the Chinese Ministry of Agriculture has a record of formulating effective policies. The Ministry also has a notable research and development effort that includes development of high-yielding hybrid crop strains and the promotion of GM crops and food-related nanotechnology.

China's food security is critical for its own social stability. Yet some international tensions are possible as China is investing in agricultural lands in Africa and southern Asia in order to produce food for its domestic consumers. Such land investments might increase in the future as internal Chinese food demand grows.

Implications for the United States

Interstate food wars are probably not forthcoming; the intersection between food and conflict will likely have more subtle connections. The lack of food security, high food prices, and increasing price volatility will probably become an underlying stressor and threat multiplier that might compel countries to strategically decouple from global food markets where the United States has a major economic interest.

Most food crises do not by themselves lead to violence. Food insecurity when coincident with other problems—poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions—increases the risk of social disruption and local violence. High food prices have a different impact on producers and consumers, helping the former while harming the latter. Violent conflict, however, jeopardizes food security, and food stress can occur after conflicts are concluded. In other words, food insecurity is more the result than the cause of conflict.

Biofuel production takes food grains off the market and pushes up prices. Some studies suggest that demand for ethanol contributed to 30 percent of the increase in cereal prices between 2000 and 2007. However not all experts are convinced the impact from biofuel demand was that significant. Furthermore,

[11] This program consists of a Sloping Land Conversion Program (SLCP) and the Natural Forest Protection Program (NFPP).

experts estimate that the demand for biofuels could contribute to a rise in global corn prices of 41 percent and wheat prices 30 percent as soon as 2020. In developing countries, the production of cassava-based ethanol poses a grave threat to the food security of the poor because the crop provides one third of the caloric needs of 200 million of Africa's poorest people. Yet in regions where a positive supply response is possible, higher prices will stimulate production, with potentially positive implications for economic growth, poverty reduction, and food security.

- **Second-generation biofuel technology, which uses cellulosic rather than starchy material as feedstock, will offer greater opportunities to develop countries while reducing the risk of higher, more volatile food prices.** Current government subsidies and mandates, particularly in the United States, promote biofuel production, and "biobased economy" products other than ethanol might become more significant in the future. Yet the long-term impact of biofuel production is difficult to predict because the policies that drive it may prove to be more transient than the underlying economic and commercial realities.

Food security is not likely to become a major domestic issue for the United States, although the United States might face migration pressures from Latin America and the Caribbean if these regions face food insecurity. China, the United States, and Europe will likely be able to meet the coming food security challenges. Since intersecting factors will likely influence US and global security, the United States might not be able to insulate itself from future global food insecurity elsewhere.

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