A Dynamic Model to Forecast and Evaluate Changes and Trends in the Global Market for Fertilizers




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Foreword

FertTrade, a dynamic fertilizer trade model/algorithm that was developed by IFDC is presented and explained in this paper. FertTrade is part of the continuous effort by IFDC to produce valuable, additional knowledge and information about the many changes that are occurring in the agricultural and fertilizer sectors of countries around the world. FertTrade is an analytical tool that can be used to forecast and evaluate numerous changes in the demand, production and trade of N, P and K fertilizer nutrients in response to expected changes in technology and key demographic and economic variables.

The model is currently useful to forecast and assess the consequences of "what if" scenarios involving rapid changes in variables such as population growth, income, crop areas and yields, rates of fertilizer adoption and use, and technological change affecting fertilizer-nutrient use efficiency. FertTrade can be used to conduct ex-ante impact assessments of policy measures and investments that affect the fertilizer and agriculture sectors. Applications of the model can significantly improve knowledge and understanding about the nature and growth of the demand, production and trade of N, P and K fertilizers. Such knowledge is necessary for the short- and long-term planning of fertilizer production, distribution and marketing within a particular country and for trade between countries.

Information produced by the FertTrade model is useful for preventing or minimizing shortages and spikes in prices that may adversely affect fertilizer use and agricultural production and for facilitating the trade of about 30 to 40 percent of the fertilizer nutrients that are produced and consumed in the world. FertTrade is an innovative tool to improve decision-making in policy measures and investments that public and private sectors must implement to efficiently produce, trade and market fertilizers.

In the current state of development, FertTrade has unique and useful capabilities that can be significantly expanded through additional work in applications, model development and refinement. In collaboration with other organizations and with the support of interested donors and development agencies, IFDC eagerly anticipates the continuation of work to refine and further expand capabilities of the FertTrade model.

Amit Roy
President and
Chief Executive Officer

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Disclaimer

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Acronyms and Abbreviations

AGRA	Alliance for a Green Revolution in Africa
DAP	Diammonium Phosphate
f.o.b.	Freight on Board
GDP	Gross Domestic Product
IFA	International Fertilizer Industry Association
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
K	Potassium
MOP	Muriate of Potash
N	Nitrogen
NEPAD	New Partnership for Africa's Development
P	Phosphorus
R&D	Research and Development
RF	Rockefeller Foundation
SSA	Sub-Saharan Africa
WANA	West Asia/North Africa
WDI	World Development Indicators

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Executive Summary

Fertilizers, improved seed and modernized crop management practices have contributed substantially to increases in agricultural productivity in recent decades, while helping to conserve ever-shrinking land resources and water supplies. Fertilizers will continue to play a key role in expanding agricultural productivity to meet the ever-increasing world demand for food, feed and bio-fuels. Forecasts of the trends that drive the rapidly expanding demand for these agricultural products and the associated supply of crop nutrients are critical for sound decision-making on a wide range of policy issues. Such trend forecasts are crucial to improving strategic planning and resource allocation; prioritizing investments in fertilizer production/supply expansion (based on expected impacts and risks); and reducing risks associated with the development of government policy and public/private sector investment.

The objective of this paper is to illustrate the capability of FertTrade, a fertilizer trade model/algorithm created by IFDC as an analytical tool to address questions about development of the fertilizer and agricultural sectors around the world. FertTrade estimates trends in the demand, production, supply and trade of nitrogen (N), phosphorus (P) and potassium (K) fertilizer nutrients through 2025. FertTrade also assesses "what if" scenarios to evaluate changes in national variables such as populations, incomes, crop areas and yields. FertTrade is a tool that can be used to help understand the nature and concept of derived fertilizer demand and the variables that are primary reasons for changes in that demand. The following factors are taken into account in the FertTrade modeling process:

1. Nature of Fertilizer Demand.
2. Climate Change.
3. Population and Income Growth.
4. Demand for Bio-Fuels.
5. Fertilizer and Food Prices.
6. Improvements in Technology.

FertTrade's analytics can be used to evaluate scenarios of changing demographic, economic, technological and agro-climatic circumstances that affect agricultural production and the global demand, production and trade of the major fertilizer nutrients (N, P and K). For demonstration purposes, FertTrade was used to estimate and evaluate trends in the demand, production and trade of these fertilizer nutrients globally on the basis of estimates aggregated for the world as a whole, regionally and sub-regionally. Crop production outputs produced as simulation outcomes were used to estimate quantities of derived demand for the nutrients in each of the nations/sub-regions. The model included five major components:

1. Scenario design.
2. Estimation of crop production outputs by a commodity market model.
3. Estimation of the derived demand for the three fertilizer nutrients.
4. Projections of production capacities and supplies of N, P and K.
5. Estimation of volumes and patterns of trade for N, P and K.

Trend modeling and projections of demand/supply of world fertilizer nutrients through 2025 are also vital components of FertTrade. Trends in key countries, regions and sub-regions are also addressed. Results of national/sub-regional analyses of demand and supply projections for N, P and K nutrients in 2005, 2015 and 2025 will be detailed and summarized in this paper. Highlights of these trends include:

1. Exponential rates of growth of demand for N, P and K.

2. Projected fertilizer demand growth rates during 2005-2025.
3. Increases in the demand and consumption of N, P and K fertilizers.
4. Increases in the production and supply of N, P and K fertilizers.
5. The supply-demand balance and trade of N, P and K fertilizers.

Currently, FertTrade is a useful tool for policy change and technology development decisions that enhance fertilizer performance and agriculture sectors globally, regionally and nationally. In this context, the model can be used to evaluate *ex-ante* changes induced by policies or technology innovations that affect these sectors using "what if" scenarios. Thus, FertTrade can be used to assess such changes in terms of impacts on agricultural production and productivity and the demand, supply and trade of fertilizers.

A "what if" scenario was designed to assess the primary economic and environmental impacts of successfully increasing fertilizer N use efficiency in cereal production from 40 percent to 60 percent. Then, the potential economic feasibility for society as a whole to invest in such technology was assessed. Subjects of the evaluation include:

1. The efficiency of fertilizer N applied to crops.
2. The context for assessment of impact of increased N-efficiency in cereal production.
3. Impact on consumption of fertilizer N.
4. Impact on losses of fertilizer N to the environment.
5. Economic impact in developing countries.
6. Impact on the environment.

Results will show that even if investments in this effort are substantial (US $4 billion during five years), returns on investment will justify such investments – if the N use efficiency goals are reached – and the projected levels of adoption by cereal farmers are achieved within the proposed time horizon of 10-15 years.

FertTrade currently is utilized for analyses and evaluation of issues and evolving circumstances that affect fertilizer sectors and agricultural production and development globally, regionally and nationally. However, FertTrade's capabilities and applications can be significantly expanded through additional model development and refinement. For example, by expanding its capability to derive estimates of, and pollution associated with, livestock and crop production (as well as fertilizer production and use), environmental impacts could be estimated and assessed. Subsequently, FertTrade could be used to evaluate scenarios of changing circumstances in terms of potential environmental impacts. The model's current capabilities, limitations and possibilities for further development will be described and detailed over the course of the paper.

A Dynamic Model to Forecast and Evaluate Changes and Trends in the Global Market for Fertilizers

Overview

Nutrients and water are essential for crop growth and production. There are numerous efforts underway to enhance the efficiency of nutrients and expand their role in increasing agricultural productivity and reducing poverty in many developing countries (World Bank, 2008). Increased quantities of nutrients are required for crop production to meet a growing, more diversified demand for agricultural products. Fertilizers are crucial sources of the nutrients needed by crops to grow and produce higher yields. In recent decades, fertilizers, in conjunction with improved crop varieties and crop management practices, have substantially contributed to increased agricultural productivity and crop production with ever-more limited land and water resources. Fertilizers have had and will continue to have a key role in expanding agricultural productivity and production to meet the rapidly growing demand for food, feed and bio-fuels production.

In a context of heightened concern and uncertainty about agriculture's capacity to keep pace with a rapidly expanded demand for agricultural products (due to population and income growth), forecasted trends of the demand and required supply of plant nutrients are critical for sound decision-making on a wide range of issues and measures confronted by policymakers. Such trend forecasts are useful to: (a) improve strategic planning and resource allocation; (b) prioritize investments to expand fertilizer production capacity and supply and increase agricultural productivity on the basis of expected impacts and risks; and (c) reduce risk and uncertainty associated with the design and implementation of policy measures and investments by public and private sectors.

Objectives

This paper will describe and illustrate the capability of a fertilizer trade model/algorithm (FertTrade) developed by IFDC as an analytical tool to address questions and concerns about the development of fertilizer and agricultural sectors. Specifically, the FertTrade model is described and then used to: (a) estimate trends in the demand, production/supply and trade of nitrogen (N), phosphorus (P) and potassium (K) fertilizer nutrients through 2025; and (b) assess scenarios of changing circumstances/variables such as national populations and incomes, crop areas and yields, rates of fertilizer adoption and use and technology change affecting fertilizer nutrient use efficiency. The use of the model to evaluate "what if" scenarios is illustrated by assessing a scenario that portrays improving, through technology change, the efficiency of fertilizer N applied to cereals in developing countries from 40 percent to 60 percent.

Understanding the nature and growth of the demand, production and trade of N, P and K fertilizers is necessary for short- and long-term planning of fertilizer production, distribution and marketing within a country and for trade among countries. Such knowledge is important in preventing fertilizer shortages and price spikes that adversely affect their use by farmers and agricultural production as a whole. Because the production of some fertilizer nutrients is concentrated in a limited number of countries and the demand is more widespread among a number of other countries, about 30 to 40 percent of the fertilizers consumed (produced) in the world are imported (exported). Information on trends in the demand, production, supply and trade of the major fertilizer plant nutrients (N, P and K), and about the impact that policies and other factors such as economic growth and changes in technology may have on these trends is critical for sound decision-making about investments in facilities and infrastructure to produce, supply, trade and market fertilizers.

Fertilizer Demand and Sources of Change

Nature of Fertilizer Demand – The demand for fertilizers is derived and depends on the demand for agricultural products such as food, feed, fiber and more recently bio-fuels. As a consequence of this linkage, factors affecting the demand, supply and trade of agricultural products also affect the demand for fertilizers. The most important variables influencing economic development are also core sources of change and expansion in the demand for food, feed, fiber and bio-fuels. Variables such as population and income, technical change, and more recently, factors affecting the demand for bio-fuels are the most important drivers of the demand for agricultural products and thereby, indirectly, the main causes of change in the demand, supply and trade of fertilizers and other agricultural inputs.

Climate Change – Changes in agricultural production and fertilizer demand are expected to continue to occur under the challenging and often unpredictable consequences that climate change may have on the resource base of land and water, and the agro-climatic conditions surrounding agricultural production in different regions of the world. There are speculations that agriculture in developing countries, such as struggling Sub-Saharan Africa (SSA), is more vulnerable to climate change since most of these countries are located in lower, warmer latitudes closer to the equator. Moreover, adjustments in agricultural production and fertilizer demand and use are occurring in countries confronting different stages of economic development and socioeconomic and political stability. Countries facing stages of poor economic development, instability and widespread corruption often experience: (a) land degradation and water contamination affecting the environment; and (b) increased poverty, hunger and malnutrition. Consequences of such events are frequently aggravated by the existence of inherited and present inequities in natural and human capital resource endowment.

Population and income growth do have important impacts on the demand and consumption of agricultural product sources of food, fiber and energy. Such impacts indirectly influence growth in fertilizer demand and use. Growth in population and income increases the demand for food products and fertilizer nutrients. Even though global population growth rates are expected to decline to an average of about 1.1 percent during 2005-2015, policymakers and development agencies are concerned about how the world will feed the growing population (The World Bank, 2008). Population growth rates in poor developing countries are expected to be substantially higher than the average global rate of 1.1 percent.

During the past decade, the overall growth rate of the world economy slowed to 2.8 percent despite higher gross domestic product (GDP) growth rates in low- and middle-income countries (WDI, 2008). But, in recent years (2006-2007), rates of growth of large economies, such as China and India, have increased significantly. Income increases and changes in the age distribution and education of the population have significantly affected the type of food products preferred and consumed by growing populations. Income growth in some countries, such as China, has contributed to the rapid expansion in the demand and consumption of higher value “superior” food commodities such as pork, poultry and beef, and has indirectly contributed to the demand for animal feed products such as soybeans and maize. The growth and diversification of the derived demand for fertilizers is now caused mainly by the increased consumption of “fertilizer nutrient-intensive” food products such as meat and eggs and crop products that are becoming feasible raw materials for the production of bio-fuels. Livestock, pork and poultry food commodities, such as meat and eggs, require higher amounts of fertilizer-supplied plant nutrients per weight-unit produced than crop food commodities such as rice and wheat.

Demand for Bio-Fuels – The growing demand for bio-fuels represents a significant additional component of a more diversified demand for agricultural products, which includes raw materials to produce bio-fuels. Programs to promote the production of bio-fuels in some countries, such as the USA and Brazil, and in Europe, are currently expanding the demand for corn, sugarcane and soybeans. Technical change and public policy will, in the long run, determine the future sustainability and importance of this additional source of demand for agricultural products and, ultimately, its impact on food prices and the derived demand for fertilizers. Prices of other sources of energy (oil, natural gas), technological innovation and public energy policy will determine the sustainable long-term growth of this additional source of demand for agricultural products – and indirectly for fertilizers.

Fertilizer and Food Prices – Fertilizer prices increased significantly in late 2007 and early 2008, then declined in 2009. The price of granular urea increased sharply from $110/metric ton (mt) in 2000 to $319/mt (freight on board [f.o.b.], Arab Gulf) in 2006 and to more than $700/mt in 2008. Similarly, the price of granular diammonium phosphate (DAP) (f.o.b., Gulf of Morocco) jumped from $161/mt in 2000 to $422/mt in 2007, then to more than $900/mt in 2008 (IFDC’s time series data on fertilizer prices). Higher food commodity prices had a direct impact on fertilizer price increases in 2008 by providing incentives for farmers to use more fertilizers and increase their demand. In many developing countries, however, such hikes in fertilizer prices have, at least in the short-run, adversely affected the use of fertilizers by millions of poor farmers.

Improvements in technology for the cost-efficient supply of fertilizer products that more effectively meet crop nutrient requirements can significantly affect the demand, production and trade of fertilizers. Innovations in agricultural production technology that shift upward the agricultural production function will shift outwardly the fertilizer demand curve resulting in higher demand at the same prices. Similarly, innovations that increase efficiency in fertilizer production and/or marketing will shift downward the fertilizer supply curve, resulting in lower average (and marginal) cost to producers/suppliers. Both types of innovations will impact fertilizer prices and consumption.

The FertTrade Model

The fertilizer trade model, FertTrade, is an analytical tool to evaluate scenarios of changing demographic, economic, technological and agro-climatic circumstances affecting agricultural production and the global demand, production and trade of the major fertilizer nutrients (N, P and K). In this paper, FertTrade is used to estimate and evaluate trends in the demand, production and trade for these fertilizer nutrients: (a) globally – on the basis of estimates aggregated for the world as a whole; (b) regionally – using estimates aggregated for seven main units of regional country groups; and (c) sub-regionally – using estimates for 36 primary units of analysis comprising 21 individual countries and 15 sub-regions that include sets of countries grouped together on the basis of geographic sub-regions, countries with a similar level of development and a small group of countries included in the Rest of the World sub-region.

Quantities of derived demand for N, P and K are estimated for each of the 36 country/sub-regions on the basis of crop production outputs generated by simulation outcomes of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI). The 32 agricultural commodities included in the IMPACT model, and subsequently in FertTrade, are presented in Appendix 1.

Model Structure – Major components and linkages of the FertTrade model are described in Figure 1. The model structure includes five main components:

1. **Scenario Design and Specification** – It is conducted as part of a component of IFPRI's IMPACT model and also as part of the component dealing with estimating the derived demand for fertilizer nutrients (Component 3 below). FertTrade enables the design and assessment of scenarios that may include changes in several key variables affecting the demand, production and supply of agricultural products (food, fiber and bio-fuel raw materials) and the derived demand for N, P and K nutrients. Changes in some variables directly affecting fertilizer use and demand and, indirectly, fertilizer production and supply are part of the FertTrade model's Component 3.
2. **Estimation of Crop Production Outputs by a Commodity Market Model** – Levels of production are estimated for all the crops included in the model in each of the 36 individual country/sub-regions specified in the IMPACT model.
3. **Estimation of the Derived Demand for Fertilizer Nutrients N, P and K** – Time-series estimates for 2000–2025 of projected demand for N, P and K are derived from the time-series estimates of crop production generated in Component 2 by equilibrium in the agricultural commodities market. This third component includes methods and procedures developed to estimate derived demands for the fertilizer-supplied nutrients N, P and K. Thus, this component produces estimates of the quantities of N, P_2O_5 and K_2O that farmers are expected to acquire and apply to their crops in the form of manufactured fertilizers to reach the model-generated annual estimates of crop production under prevailing conditions in each country/sub-region. Methods and procedures include the use of coefficients and adjustment factors developed to account for variability in the demand for fertilizers as a result of inter-country and inter-regional diversity in: (a) the type and volume of crop outputs produced; (b) current levels and trends of adoption and use of fertilizers in these crops; (c) overall adoption of modern inputs and improved technology in crop production; (d) fertilizer nutrient use efficiency; (e) stages of agricultural and economic development; (f) availability of water and inherited fertility of soils in agricultural lands; and (g) climate. Because the model does not usually include all of the crops grown in each country/sub-region, N, P and K demand estimates are further adjusted to account for these shortcomings.
4. **Projections of Production Capacities and Supplies of N, P and K Fertilizer Nutrients** – Production capacities and projected supplies of N, P and K nutrients are estimated for the next 15 years, globally and for each of the model's country/sub-regions. Through 2010-2012, supplies of N, P and K in each country/sub-region are projected using data from the International Fertilizer Industry Association (IFA). Quantities of N, P and K that can be supplied by current and planned production capacities (supply

capacities) through 2011 are calculated by assuming that available levels of manufacturing production capacities are operating at the highest achievable operating rate of capacity utilization. Beyond 2011, projected supplies of N, P and K are dynamically generated by the model, first globally and then for each country/sub-region. The methodology is designed to produce a dynamically adjusted potential supply of fertilizer nutrient (Sp_t) while maintaining a limited global excess in production capacity. That is, to maintain global levels of fertilizer production and supply that: (a) can be attained by the fertilizer industry operating at reasonable levels of production capacity utilization; and (b) will effectively supply quantities of fertilizer nutrient (Sa_t), which are at least 2 percent higher than the projected global demand (D_t). The dynamically adjusted potential supply is achieved through: (a) changes in rates of production capacity utilization and, when such changes are not sufficient to meet the required global quantities of fertilizer nutrient supply Sa_t; and through (b) mechanisms that trigger timely expansions in fertilizer production capacity, which are required to guarantee that the actual supply Sa_t is always provided by the industry. Decreases in global supply through contractions in production capacities (i.e., through the closing of old or inefficient plants) are triggered by the model when the excess in global potential supply for the fertilizer nutrient as a percent of the global projected demand reaches pre-established upper limits built into the model. Dynamically adjusted levels of projected fertilizer nutrient supplies by each key country and sub-region during 2012-2025 are estimated by distributing among the countries/sub-regions the projected quantities of global supply adjustments for each year. Such quantities are distributed among countries/sub-regions by using coefficients of adjustment or weights calculated on the basis of two country/sub-region-specific measures: (a) the trends of supply adjustment experienced during 2005-2010; and (b) the 2005-2010 average magnitude of annual adjustment in proportion to the projected total global adjustment in supply.

5. **Estimation of Volumes and Patterns of Trade for N, P and K Fertilizer Nutrients** – The arrays of N, P and K demand and supply information generated by Components 3 and 4 above are matched on a country/sub-region-by-year basis to calculate supply-demand balances (i.e., surpluses or deficits by country/sub-region). Thus, the model produces estimates of the quantities of N, P and K that will be traded by surplus (exporting) and deficit (importing) country/sub-regions. Then, patterns of trade among country/sub-regions are projected on the basis of those estimates.

Trends Through Mid-2020s

World Trends – World demand/supply projections for N, P and K produced by the FertTrade model through 2025 indicate the following:

1. **For Fertilizer N** – The planned world increases in fertilizer N production capacity through 2012 may not be realized and/or the global excess production capacity would be reduced through the closing of marginal plants, to account for a total reduction of about 14 million tons (mt)[1] of production capacity by 2012. During 2013-2017 the required adjustment in fertilizer N world production will be achieved through small (1 to 2 percent) annual increases in production capacity utilization. However, during 2018-2023, adjustments in fertilizer N world production will require expansions of the world's production capacity by 5.9 and 6.1 million tons of fertilizer N by 2018 and 2021, respectively, in addition to annual changes in production capacity utilization.
2. **For Fertilizer P** – Projected growth in the world demand for P fertilizers indicates that the demand will expand from about 38.7 million tons of P_2O_5 in 2005 to about 43.9 million tons in 2012, and 51.5 million tons in 2022, an increase of about 17 percent over the next decade. To meet the projected growth in demand for fertilizer P through 2025, the global production capacity and supply of P fertilizers will have to be expanded substantially more than that which is currently planned. Adjustments in P_2O_5 world supply needed to meet projected demand will require expansion of the world's production capacities by 2.7, 2.3, 2.4 and 2.5 million tons P_2O_5 in 2012, 2015, 2018 and 2021, respectively. Unless production capacity is increased beyond that which is currently planned, shortages in the supply of P fertilizers will seriously affect agricultural production and food supplies in most countries, particularly in developing countries depending on imports of P fertilizers.
3. **For Fertilizer K** – Estimates show that current and planned increases in the world's production capacity

[1]Tons are metric tons.

and potential supply of K fertilizers through 2011 are more than sufficient to satisfactorily meet the projected growth in the global demand for K fertilizers through 2020. Dynamically adjusted supply projections generated by FertTrade show that in order to eliminate substantial potential global surpluses in production capacity and supply with respect to demand, about 5 million tons K_2O/year of planned world production capacity may not be realized or will have to be closed down by 2011, and about 4.2 million tons K_2O of additional capacity will have to be closed down by 2013. Then, expansion in production capacity will not be required until 2021 when a production capacity expansion of about 1.7 million tons K_2O/year will be required.

Trends in Key Countries, Regions and Sub-Regions – Results of the country/sub-regional analyses of demand and supply projections produced by the FertTrade model for N, P and K in 2005, 2015 and 2025 are summarized here.

1. Exponential rates of growth of demand for N, P and K calculated on the basis of projections produced by the FertTrade model are almost the same for each nutrient. This is because N:P:K ratios of the derived demands for fertilizer nutrients are essentially determined by the proportional distribution of crop production in each country/sub-region, which is projected not to vary significantly across years (baseline scenario). However, projected growth in demand in terms of absolute quantities of N, P and K is substantially greater for fertilizer N than for fertilizer P and K.
2. Projected rates of growth in fertilizer demand during 2005-2025 by the major consumers of fertilizers (China, India, Brazil and the USA) are 1.5 percent, 2.2 percent, 2.5 percent and 1.0 percent, respectively. Whereas, Nigeria, the four sub-regions of SSA, Myanmar and Argentina, which have low shares in the global consumption of fertilizers, are projected to experience the fastest rates of growth in the demand for fertilizers, about 3-5 percent, through 2025. Improvements in crop yields and agricultural productivity and expansion of crop areas are expected to be the main drivers of growth in demand for N fertilizer in these countries and sub-regions. The SSA and Latin America regions are projected to experience the highest fertilizer consumption growth rates, 4.6 percent and 2.5 percent, respectively. Demand in Developing Countries is projected to grow at a rate of 2 percent, more than twice as fast as in Developed Countries (0.9 percent).
3. **With respect to the demand and consumption of fertilizer N** – Consumption in China, India, Brazil and the USA is projected to increase by about 8.9, 7.2, 2.7 and 1.5 million tons of fertilizer N, respectively, during 2005-2025. Of the global 2005-2025 increase in fertilizer N consumption, 83 percent, or 27.6 million tons, will take place in the developing countries while the projected increase in the developed countries will be substantially smaller, about 5.6 million tons of fertilizer N, or 17 percent of the projected global increase. The sub-regions of South Asia, East Asia and Southeast Asia account for 28 percent, 27 percent and 7 percent of the 2005-2025 increase in the global demand for N fertilizer. Thus, the All Asia region is expected to contribute 62 percent, or about 20.7 million tons, to the global 2005-2025 expansion in demand for N fertilizer. The Other Latin America region is projected to contribute 11 percent, or about 3.5 million tons, to such expansion, while West Asia/North Africa (WANA), the Former USSR sub-regions and the SSA region will account for only 6 percent, 2 percent and 4 percent of the projected 2005-2025 global expansion, respectively. Three countries (China, India and the USA) and one sub-region (Europe [EU 15]) are projected to have the largest three-year (2005, 2015, 2025) average market shares for N fertilizers accounting for two-thirds (66 percent) of the global market, while the other one-third of the market is held by countries and sub-regions having global N fertilizer demand shares lower than 4 percent.
4. **With respect to the production and supply of fertilizer N** – Two countries (China and India) and two sub-regions (Rest Former USSR [including Russia, Ukraine and Belarus] and Other WANA [including the Persian Gulf countries]) are classified as *large-size suppliers* of N fertilizers. Together they are projected to account for 62 percent of the global N fertilizer supply through 2022. Global supply shares of these countries and sub-regions are not projected to follow the same 2012-2022 trends. China's and India's shares in the global supply of N fertilizers are projected to remain stable at about 25-26 percent and 9-10 percent, respectively, whereas the Rest of Former USSR's share is projected to decrease somewhat from 12.6 percent in 2012 to about 12.1 percent by 2022, and the share of the

Other WANA sub-region is projected to increase significantly from 13.8 percent in 2012 to 15.4 percent by 2022. *Medium-size suppliers* with supply shares lower than 5 percent but no less than 2 percent of the global supply include four sub-regions (Other Latin America [Latin America excluding Brazil, Argentina and Colombia], Eastern Europe, Europe [EU 15] and the Other Developed countries group [including Canada and South Africa]), and four individual countries (Indonesia, USA, Egypt and Pakistan). The four sub-regions and four individual countries together will account for about 28 percent of the global N fertilizer supply in 2012, but their share is projected to decline slightly to about 27 percent in 2022. Global supply shares of these sub-regions and countries do not follow the same trends. Shares of the Other Latin America sub-region and Pakistan are projected to remain stable at about 4.6 percent and 2.1 percent, respectively, while shares of the other sub-regions and countries in this group, with the exception of Egypt, are projected to decline. Egypt's share in the global supply of N fertilizers is projected to increase somewhat from 3.3 percent in 2012 to 3.8 percent in 2015. *Small-size suppliers* with global supply shares lower than 2 percent include four sub-regions and 13 individual countries. The sub-regions are Central Asia, Other East Asia, Other South Asia and Southern SSA. The 13 individual countries that are classified as *small-size suppliers* of N fertilizers include Argentina, Australia, Bangladesh, Brazil, Colombia, Japan, Malaysia, Mexico, Myanmar, Nigeria, South Korea, Turkey and Vietnam. The global supply share of the *small-size suppliers* group of sub-regions and countries together is projected to remain essentially unchanged at about 10.2 percent of the world supply of N fertilizers.

5. **Regarding supply-demand balance and trade of fertilizer N** – Projections show that China and India are two of the most important producers and consumers of N fertilizers. Growth in demand is expected to substantially outpace domestic production and supply in Europe (EU 15), India and the USA, making them increasingly dependent on imports of N fertilizers (mainly from Russia and countries on the Persian Gulf). China is expected to expand production through 2012 in an attempt to meet its growing demand for N fertilizers. By 2022, China is projected to remain the most important global producer of N fertilizers, but because of projected growth in domestic demand, it will be a net importer of fertilizer by early in the 2020s. Most of the world's sub-regions and countries are and will continue to be either significant net exporters or net importers of N fertilizers. About 10 sub-regions and countries are projected to each export annually more than 300,000 tons of N fertilizer. About 14 other sub-regions and countries are expected to import annually at least 300,000 tons of N fertilizer. These projections highlight the importance and essential need for trade to meet the demands for N fertilizers in many countries. Trade of N fertilizers will be particularly important for many developing countries, which depend on imports to meet domestic demands, and where about 83 percent of the global 2005-2025 increase in N fertilizer demand is projected to occur. Most developing countries in SSA, Southeast Asia and Latin America have negative supply-demand balances and will continue to depend on imports of N fertilizer.

6. **With respect to the demand and consumption of fertilizer P** – Consumption in Brazil, China, India and the USA is projected to increase by about 3.6, 2.6, 1.6 and 1.0 million tons P_2O_5 in the 20-year period 2005-2025. Of the global 2005-2025 increase in fertilizer P consumption, 83 percent, or 11.8 million tons P_2O_5 will take place in developing countries and only about 2.3 million tons P_2O_5 of fertilizer P, or 17 percent, in the developed countries. Asian sub-regions of East Asia, South Asia and Southeast Asia account for 26 percent, 21 percent and 6 percent, respectively, of the projected 2005-2025 increase in the global demand for P fertilizer. Thus, the All Asia region is expected to contribute 53 percent, or about 7.5 million tons, P_2O_5 to the global 2005-2025 expansion in demand for P fertilizer. The Other Latin America sub-region is projected to contribute 18 percent, or about 2.6 million tons, P_2O_5 to such expansion. Shares of the WANA, the Former USSR sub-regions and the SSA region on the projected 2005-2025 global expansion demand for P fertilizers are substantially smaller and account for only 6 percent, 1.0 percent and 5 percent, respectively. Four countries – Brazil, China, India and the USA – and one sub-region, Europe (EU 15), are projected to remain the largest markets for P fertilizers through 2025. These four countries and sub-region are classified here as *large-size markets*, and together they are projected to account for about 68 percent of the global market for P fertilizers. The other 32 percent of the market is held by countries and sub-regions with global N fertilizer demand shares lower than 8 percent.

7. **With respect to the production and supply of fertilizer P** – Three countries (China, India and the USA) and two sub-regions (Other WANA [including Morocco] and Rest Former USSR [including Belarus, Russia and Ukraine]) are classified as *large-size suppliers* of P fertilizers. Together they are projected to account for about 74 percent of the world production and supply of P fertilizers through 2022. World supply shares of these countries and sub-regions are not projected to follow the same 2012-2022 trends. The USA share is projected to decline substantially from about 16 percent in 2012 to 10.7 percent in 2022, while shares of China, India and the Rest Former USSR sub-region will remain around 22-23 percent, 6.3 percent and 9-10 percent, respectively. The global share of the Other WANA sub-region will increase significantly from 19.3 percent in 2012 to 27.3 percent in 2022. *Medium-size suppliers* with global supply shares lower than 6 percent but higher than 1.5 percent include four sub-regions, Other Developed countries (including Canada and South Africa), Southern SSA (including Angola, Mozambique and Zimbabwe), Eastern Europe and Central Asia and two individual countries (Brazil and Egypt). These four sub-regions and two individual countries together are projected to account for about 18 percent of the global P fertilizer production and supply through 2022. Unless unforeseen expansion of production capacity takes place, the supply share of these four sub-regions and two countries together is projected not to change significantly through 2022. *Small-size suppliers* with global supply shares lower than 1.5 percent include four sub-regions and 10 individual countries, and their share in the fertilizer P global supply is projected to remain essentially unchanged at about 8 percent through 2025. However, because most of the countries that are part of Central Asia and Southern SSA are classified as *medium-size suppliers*, but are in fact *small-size producers and suppliers*, only about 12 percent (rather than 18 percent) of the global supply will be produced by countries that are *medium-size producers/suppliers*. About 14 percent (rather than 8 percent) will be produced by *small-size producers/suppliers.* About 74 percent of the global supply will be produced by countries classified here as *large-size producers/suppliers.*
8. **Regarding supply-demand balance and trade of fertilizer P** – Growth in demand is expected to substantially outpace domestic production and supply in Brazil, China, Europe (EU 15) and India. These deficit countries and sub-region will become increasingly dependent on imports of P fertilizers from surplus countries and sub-regions such as the Other WANA and the Rest Former USSR sub-regions. The USA and four sub-regions (Other WANA, Rest Former USSR, Southern SSA and Central Asia) are projected to be the most important exporters of P fertilizer through 2022. The Other WANA sub-region is projected to have exportable surpluses of more than 7.9 million tons P_2O_5 by 2012. Those for the Rest Former USSR will be about 4.0 million tons P_2O_5, and the USA exportable surpluses will decline markedly from 2.5 million tons P_2O_5 in 2012 to 1.7 and 0.2 million tons P_2O_5 in 2017 and 2022, respectively. If planned expansion in production capacity is realized, fertilizer P surpluses of the Southern SSA region will increase from 1.5 million tons P_2O_5 in 2012 to 1.6 and 1.8 million tons P_2O_5 in 2017 and 2022, respectively. At the same time, the Central Asia sub-region is projected to have annual surpluses of about 1.0 million tons P_2O_5 during 2012-2022. The Other WANA sub-region will have a major role in supplying the international market for P fertilizers, whereas, Brazil, China, Europe (EU 15) and India are projected to remain the primary importers of P fertilizers, accounting for 60-61 percent of the world's total international demand for exportable surpluses of these fertilizers. These sub-regions and countries are projected to be the dominant players in the international market for P fertilizers through 2022. The Other WANA sub-region and the Rest Former USSR are projected to account together for 62 percent, 67 percent and 76 percent of the world's exportable surplus of fertilizer P in 2012, 2017 and 2022, respectively, with the Other WANA sub-region increasing its share of the world's exportable surplus from about 41 percent in 2012 to 58 percent in 2022. Trade of P fertilizers will be essential for most of the developing countries that depend on imports, and where about 83 percent of the global 2005-2025 increase in P fertilizer demand is projected to occur. Most developing countries in Latin America, Southeast Asia and SSA have negative supply-demand balances and will continue to depend on imports of P fertilizers.
9. **With respect to the demand and consumption of fertilizer K** – Consumption in Brazil, China, USA and India are projected to increase by about 1.9, 1.3, 1.2 and 0.90 million tons of K_2O, respectively, during

2005-2025. About 75 percent, or 6.3 million tons, K_2O of the world 2005-2025 increase in K fertilizer demand will take place in the developing countries. The projected increase in the developed countries will be substantially smaller, about 2.1 million tons K_2O, or 25 percent of the projected world increase in demand. The Asian sub-regions of East Asia, South Asia and Southeast Asia account for 16.5 percent, 12.5 percent and 7.8 percent of the projected 2005-2025 increase in the global demand for K fertilizer, respectively. Thus, the All-Asia region is expected to contribute 37 percent, or about 3.1 million tons, K_2O to the projected 2005-2025 world expansion in demand for K fertilizer. The Latin America region is projected to contribute 29.6 percent, or about 2.5 million tons, K_2O to this expansion. Shares of the SSA region and the Former USSR and WANA sub-regions on the projected 2005-2025 global expansion in demand for K fertilizers are smaller and account for only 6.5 percent, 2.8 percent and 1.7 percent, respectively. Four countries (Brazil, China, India and the USA) and one sub-region (Europe [EU 15]) are projected to remain as the largest markets for K fertilizers through 2025. Together these *large-size markets* are projected to account for about 70 percent of the global market for K fertilizers, while the other 30 percent of the market is held by countries and sub-regions having global K fertilizer demand shares lower than 8 percent.

10. **With respect to the production and supply of fertilizer K** – Three sub-regions, the Other Developed countries group (including Canada), Rest Former USSR (including Belarus, Russia and Ukraine) and Europe (EU-15), with global supply shares greater or equal to 10 percent, are classified as *large-size suppliers* of K fertilizers. Together, they are projected to account for about 88 percent of the global production and supply of K fertilizers through 2012 and for 84 percent in 2017 and 2022. Global supply shares of these countries and sub-regions are projected to change somewhat between 2005 and 2022, due in part to projected increases in the global shares of China and Thailand in the production of K fertilizer. The share of the Other Developed countries group is projected to change from 43 percent in 2005 to 44.5 percent in 2012, and 40.3 percent and 45.1 percent in 2017 and 2022, respectively. Shares of the Rest Former USSR and Europe (EU 15) sub-regions will decrease from 32 percent and 14.4 percent in 2005 to 29.3 percent and 13 percent in 2022, respectively. *Medium-size suppliers* with global supply shares lower than 10 percent but not less than 1.0 percent include two sub-regions (Other WANA [including Jordan] and Other Latin America [including Chile]) and three individual countries (Brazil, China and Thailand). Shares of the two sub-regions and three individual countries together on the global production capacity and supply of K fertilizers are projected to increase from 10 percent in 2005 to 12 percent in 2012 and 15.5 percent in 2022. The share of China is projected to increase from 1.8 percent in 2005 to 3.9 percent and 4.6 percent in 2017 and 2022, respectively. Thailand's share is projected to become 3.2 percent and 3.0 percent in 2017 and 2022, respectively. *Small-size suppliers* with global supply shares lower than 1 percent include the other Southeast Asia and Central Asia sub-regions, and Colombia and the USA as individual countries. These two sub-regions and countries together account for a very small share (0.1-0.2 percent) of the global supply for K fertilizers.

11. **Regarding supply-demand balances and trade of fertilizer K** – Two sub-regions – the Other Developed countries group (including Canada and Israel) and the Rest Former USSR (including the Russia Federation and Belarus) – are projected to remain as the dominant exporting sub-regions through 2022 and beyond. The Other Developed countries group is projected to have exportable surpluses of more than 12 million tons K_2O per year through 2022. The Rest Former USSR sub-region is projected to have exportable surpluses of more than 9 million tons K_2O per year through 2022. The Other WANA sub-region (including Jordan) is projected to have exportable surpluses of about 1.3 million tons K_2O through 2022, while surpluses of the Europe (EU 15) sub-region through 2022 will be substantially smaller. Brazil, China, India and the USA are and will remain through 2025 as primary importers of K fertilizers, with each importing more than 2 million tons K_2O per year. These four countries together are projected to account for about 73-75 percent of the world's imports through 2022, while a substantial majority of the world's countries and sub-regions will account for the residual 25-27 percent of global imports. Trade of K fertilizers will be particularly important for the developing countries, where about 75 percent of the global 2005-2025 increase in K fertilizer demand is projected to occur and that depends on imports to meet domestic demands. Nearly all

developing countries in Latin America, Southeast Asia and SSA have negative supply-demand balances and will continue to depend on imports of K fertilizers.

"What If" Scenarios and Policy Development

The FertTrade model, at its current level of development, is a useful tool for decision-making concerning policy changes and technology development efforts designed to enhance the performance of fertilizer and agriculture sectors globally, regionally and nationally. In this context, the model can be used to evaluate *ex-ante* the impact of "what if" scenarios of changes induced by policies or technology innovations that affect the fertilizer and agriculture sectors. Such changes can be assessed in terms of their expected impacts on agricultural production and productivity and the demand, supply and trade of N, P and K fertilizers.

The Impact of Increasing Fertilizer N Use Efficiency – For illustration purposes, a "what if" scenario designed to assess the main economic and environmental impacts of a successful effort to increase the fertilizer N use efficiency in cereal production from 40 percent to 60 percent was evaluated. Estimates of impacts on: (a) the consumption of fertilizer N; (b) the losses of fertilizer N to the environment; and (c) the total expenditures in fertilizers by farmers were obtained. Then, the potential economic feasibility to invest in such a technology for society as a whole was assessed. The highlights of this assessment are summarized here.

1. **The efficiency of fertilizer N applied to crops** is in general quite low. This is particularly evident in developing countries where only about one-third (30-40 percent) of the fertilizer N applied is used by the crop and two-thirds are essentially lost to the environment. Improvement in fertilizer N use efficiency by crops will provide important benefits to farmers, consumers and the environment by: (a) increasing crop yields while decreasing the rate and cost of fertilizer N applied by farmers; (b) increasing the production of crop outputs for consumers; and (c) reducing the losses of fertilizer N to the environment (air, land and water). In collaboration with some national and international organizations, IFDC has and is still conducting research and technology transfer to increase the efficiency of fertilizer N applied to crops, in particular to paddy-rice production in Bangladesh and Southeast Asia.
2. **The context for assessment of impact** of increased N-efficiency in cereal (wheat, rice, maize and other grains) production in developing countries is best described by changes in fertilizer N consumption and the levels of fertilizer N efficiency in the developing and developed countries. Fertilizer N consumption in developing countries is projected to increase in importance, in terms of both the amount consumed and their share in the world's market. Moreover, due to advantages in crop management practices and mechanization in developed countries, the prevailing efficiency of fertilizer N applied to crops is, on average, higher in these countries than in the developing countries.
3. **Impact on consumption of fertilizer N** – Adoption of the improved technology would reduce the world's projected consumption of fertilizer N in the production of cereals by 13.2 million tons in 2010 (about 5.7 and 7.5 million tons in developed and developing countries, respectively) and by 15.7 million tons in 2025 (about 6.4 and 9.3 million tons in developed and developing countries, respectively). Thus, the increased efficiency of the improved fertilizer technology will decrease the annual world demand and consumption of fertilizer N by about 12-13 percent. Its impact in decreasing fertilizer N consumption would be 30 percent greater in the developing countries than in the developed countries. This is because consumption of fertilizer N in the developing countries is projected to be more than double the consumption projected for developed countries.
4. **Impact on losses of fertilizer N to the environment** – Estimates derived from the projected levels of fertilizer N consumption in developing countries produced by FertTrade for scenarios depicting first, the continuing use of current (60 percent N lost) technology and second, the adoption of improved, more efficient (40 percent N lost) fertilizer N technologies in cereal production. These estimates show that a 40-60 percent improvement in fertilizer N use efficiency will decrease the projected amounts of fertilizer N lost to the environment in developing countries by approximately 7.5 million tons (from 41.5 to 34.0 million tons) in 2010 and 9.3 million tons (from 54.7 to 45.4 million tons) in 2025.
5. **Economic impact in developing countries** – Economic impact estimates are based on a urea price of $500/ton ($1,086.96/ton of N) and the added cost of $300/ton of improved fertilizer N (i.e., a price of $1,386.96/ton of N). The total added cost of $300/ton of N for developing and transferring the technology accounts for only 55 percent of the maximum break-

even added cost ($543.48/mt of N). Hence, there is still some margin for a higher total added cost. Although some results have shown that crop yields are often 20-25 percent higher at lower rates of fertilizer N when the efficiency of fertilizer N applied is increased, four conservative levels of cereal yield increases – zero percent, 5 percent, 10 percent and 15 percent – are used in this assessment. One of the main economic impacts on farmers producing cereals in developing countries is that despite a $300 increase per ton of fertilizer N applied, use of the improved technology, rather than urea, will reduce farmers' expenditures in N fertilizers by $3.7 billion in 2010 and $4.5 billion in 2025. Farmers' expenditures in fertilizer would decrease from $24.6 billion to $20.9 billion in 2010, and from $30.2 billion to $25.7 billion in 2025. Such savings will significantly increase the incomes of millions of cereal farmers in developing countries. If yield increases of 5 percent and 10 percent are accounted for, the economic impact on farmers is increased two- and three-fold, respectively.

6. **Impact on the environment** – The improved fertilizer N technology will prevent the loss of substantial amounts of urea N to the environment, about 7.5 and 9.3 million tons in 2010 and 2025, respectively. The value of the urea N saved as a result of using the improved fertilizer N technology for cereal production in developing countries, calculated at a price of $500/mt of urea, is projected to be $8.2 billion and $10.1 billion in 2010 and 2025, respectively. This valuation, however, does not account for the benefit that the prevention of N losses to the environment will provide, such as the decrease on N losses as emissions of N_2O-NO_X gases occurring at an average estimated rate of 1.0 percent of the fertilizer N applied, which would decrease by about 75,320 and 92,730 tons in 2010 and 2025, respectively.

Ex-Ante Assessment of Feasibility to Invest in Technology – Streams of costs and benefits are calculated to assess the feasibility of investments to develop and transfer fertilizer N products/use technologies that increase fertilizer N use efficiency in cereals production to 60 percent from a current average of 40 percent of the N applied. Results of this assessment are summarized here.

1. **Basis for assessment** – The assessment is based on several factors. There is a pre-established plan of global investments and expectations of impact involving annual research and development investments of $4.0 billion during five years (2009–2013). Investments in technology transfer initiated in the sixth year (2014) will replace the use of urea N with improved fertilizer N in cereal production in developing countries. This amounts to $4.0 billion in 2014 to rapidly achieve a 10 percent compounded annual rate of adoption of the improved technology in developing countries, followed by gradually reduced amounts of investments in the following years. Annual amounts invested in technology transfer are reduced in inverse proportion to the total rate of adoption until the improved fertilizer N technology accounts for 90 percent of the fertilizer N used on cereals in developing countries by 2020. This will be maintained at $120 million to make the 90 percent total rate of adoption sustainable and permanent.
2. **Estimates of economic benefits** are determined by the value of the urea N that is saved by gradually replacing it with the more efficient fertilizer N technology in cereal production in developing countries, and the value of the projected increase in cereal production in developing countries associated with yield increases of zero percent, 5 percent, 10 percent and 15 percent. Projections of cereal production in developing countries generated by the model and world prices of cereals are used to calculate the projected streams of net benefits. These estimates should be considered lower-bound estimates of the total benefits because the economic value of environmental benefits associated with the prevention of urea N losses to the environment, although important, is not accounted for. Annual benefits during 2026-2030 are assumed to be equal to those of 2025, implying no growth in N consumption during this period. Despite this underestimation, the projected stream of benefits and costs through 2030 show that, if the more realistic expectations of cereals' yield increases of 5 percent, 10 percent and 15 percent are realized, significant internal rates of return of 24 percent, 31 percent and 36 percent could be obtained to the scheduled investment of about $34 billion in a successful research and technology transfer effort over 10 years. Although investment amounts in this effort are substantial, it is clear that returns to investments will be more than is required to justify such investments if the N use efficiency goals of the improved fertilizer N technology are reached and the projected levels of adoption by cereal farmers are

achieved in the proposed time horizon of 10-15 years.

Model Capabilities, Limitations and Expansion Possibilities

At its current state of development, the FertTrade model has uniquely useful capabilities as a tool for analysis and evaluation of the issues and evolving circumstances that affect fertilizer sectors and agricultural production and development globally, regionally and nationally. However, the capabilities and applications of the model can be significantly expanded through additional work in model development and refinement. For instance, by expanding its capability to derive estimates of animal waste production and pollution associated with livestock and crop production, as well as fertilizer production and use, impacts on the environment (land, water and air) could be estimated and assessed. Then, the FertTrade model could also be used to evaluate scenarios of changing circumstances in terms of their potential impact on the environment. Environmental impact assessments are becoming increasingly important for decision-making on policies and investments. The model's current capabilities and limitations and possibilities for further development are described in detail in a chapter of the paper.

I. Introduction

A. Background and Justification

Increasing agricultural productivity is the primary focus of global efforts to promote economic development and reduce poverty in many developing countries. For the first time in more than 25 years, the World Bank's 2008 World Development Report put agriculture and the productivity of small-scale farmers at the core of a global agenda to reduce poverty. In 2007, the Bill and Melinda Gates Foundation and the Rockefeller Foundation (RF) formed the Alliance for a Green Revolution in Africa (AGRA) to spur agricultural productivity and move millions of small-scale farmers out of poverty. In 2006, the African Union, the New Partnership for Africa's Development (NEPAD), the RF and IFDC joined forces at the Africa Fertilizer Summit in Abuja, Nigeria, to raise awareness of the extent of soil degradation on the African continent and to stress the imperative to reverse the trend.

Crop nutrients are at the center of efforts to decrease soil degradation, and their essential role in contributing to poverty reduction goals is well demonstrated by the success of the "Green Revolution" in Asia and Latin America. Many have already established that water and nutrients are essential for plant growth and crop production (World Bank, 2008). Increased quantities of plant nutrients are required to produce the higher levels of crop production needed to meet a more diversified demand for agricultural products. Fertilizers are crucial sources of the nutrients needed to produce higher crop yields. In recent decades, fertilizers, in conjunction with improved crop varieties and technologies to enhance resources (land and water) and crop management practices, have substantially increased agricultural productivity and crop production in most countries. Fertilizers have had, and will continue to have, a key role in expanding agricultural production to meet the rapidly growing demand for food, feed and fiber and, more recently, the emerging demand for raw materials for the production of bio-fuels.

What has proven increasingly difficult, however, is implementing sound policies, allocating resources and taking action that ensures the efficient and environmentally safe use of plant nutrients, the production of safe foods for consumers and economic accessibility for poor farmers. There is an increased uncertainty about agriculture's capacity to keep pace with a rapidly expanded demand for agricultural products due to population and income growth. Therefore, the ability to forecast demand and supply trends of plant nutrients is critical for sound decision-making on many issues confronting policymakers. For example, a variety of stakeholders can use such trend forecasts to:

- Improve strategic decision-making and the allocation of scarce resources.
- Prioritize investments today in efforts to increase agricultural productivity on the basis of expected impact and the risks associated with the uncertain future.
- Reduce risk and uncertainty in decision-making by improved planning in the design and implementation of policy measures and investments by the public and private sectors.

B. Objectives

The primary objective of this paper is to describe the capability of a fertilizer trade model/algorithm

(FertTrade) recently developed by IFDC. FertTrade is an analytical tool to conduct assessments that address issues regarding the development of the fertilizer and agricultural sectors. Specifically, this paper focuses on the following:

1. Estimating future trends in the demand, production and trade of N, P and K fertilizer nutrients through 2025 using the FertTrade model.
2. Describing the FertTrade model and its use to evaluate the expected consequences of anticipated policy changes affecting the demand, production and trade of N, P and K fertilizers. This can be accomplished through the simulation of properly designed "what if" scenarios representing variables in key countries, such as: (a) population and income growth; (b) crop areas and yields; (c) the rates of adoption and use of fertilizers; and (d) innovation in technology affecting fertilizer nutrient use efficiency.
3. Assessing the model's capabilities and limitations.
4. Illustrating the use of the model to evaluate "what if" scenarios by assessing the potential impact and benefits of improving the efficiency of fertilizer N applied to cereals in developing countries from 40 percent to 60 percent through technology change.

Understanding the nature and growth of the demand, production and trade of N, P and K fertilizers is necessary for short- and long-term planning of fertilizer production, distribution and marketing within a country, and for trade among countries. This understanding and knowledge is important to prevent shortages and reduce price spikes that adversely affect fertilizer use and agricultural production. Because the production of some fertilizer nutrients is concentrated in a limited number of countries and the demand is widespread among many countries, about 30 to 40 percent of the fertilizers consumed in the world are imported. In this context, it is important to conduct analyses that provide information on: (a) future trends in the demand, production, supply and international trade of the major fertilizer plant nutrients (N, P and K); and (b) the impact that policies and factors such as economic growth and technology changes may have on these trends. This information is useful to make decisions about investments in facilities and infrastructure to produce, trade and market fertilizers. Such knowledge is useful to design national, regional and/or global policies and investments for food production and agricultural development.

C. Organization of the Paper

This study begins with an overview of trends affecting fertilizer demand, production and trade, emphasizing general changes in the economy and specific variables related to the energy sector and circumstances influencing recent hikes in prices of food commodities and fertilizers. Then, the FertTrade model is described in terms of its conceptualization, components and general procedures used to obtain quantitative time-series estimates of the projected derived annual demand for N, P and K, which would be demanded for agricultural production under a given scenario of expected conditions.

In subsequent sections, the model is used to calculate projected trends in the demand, production and trade of N, P and K through 2025. In these sections, global, regional and sub-regional/country trends in demand, production/supply and trade are estimated, presented and discussed for N, P and K, respectively. In the last sections of the paper, the capabilities, limitations and possibilities for expansion of the FertTrade model are discussed, and a "what if" scenario is designed to illustrate the capabilities of the model as a tool for analyses.

II. Major Trends Affecting Fertilizer Demand, Production and Trade

The demand for all inputs to agricultural production, including fertilizers, is derived and depends on demand for agricultural products such as food, feed, fiber and now bio-fuels. As a consequence of this forward linkage, factors affecting the demand, supply and trade of agricultural products also affect the demand for fertilizers. In this context, the most important variables influencing economic development are also core sources of change and expansion in the demand for food, feed, fiber and bio-fuels. Variables such as population and income growth, technical change and, more recently, changes in factors affecting the demand for bio-fuels are also the most important drivers of the demand for agricultural products. Therefore, changes in these variables are indirectly the main causes of change in the demand, supply and trade of fertilizers and other variable agricultural inputs.

The variables and circumstances described (population, income, technical change, increased bio-fuel demand) are also key factors contributing to changes in the environment (i.e., climate change) and the management of increasingly scarce land and water resources. Because of inequities in resource endowments, improper information and market imperfections, the impact of these drivers on agricultural production and the resource base is not always free of negative "by-products" that cause environmental degradation, poverty, hunger and malnutrition.

A. Climate Change

Changes in agricultural production and fertilizer demand are expected to continue to occur under the challenging and often unpredictable consequences that climate change may have on the land and water and the agro-climatic conditions surrounding agricultural production in different regions of the world. Predictions on the impact of climate change on changes in rainfall patterns, rising sea levels, loss of biodiversity and reduction in crop production are worrisome. The supply of food is at risk given adverse consequences to water availability, climate variability, soil fertility/erosion and the incidence of pests and diseases. There are speculations that developing countries/regions, such as struggling SSA, are more vulnerable to climate change since most are located in warmer latitudes closer to the equator.

Moreover, it is important to recognize that adjustments in agricultural production and fertilizer demand and use are occurring in countries confronting different stages of economic development and socio-economic and political stability. Countries facing poor economic development, instability and widespread corruption are often experiencing: (a) land degradation and water contamination that affect the environment; and (b) increased poverty, hunger and malnutrition. Such circumstances are frequently aggravated by the existence of inherited and present inequities in natural and human capital resource endowment.

B. Population and Income Growth

Population and income growth do have important impacts on the demand and consumption of agricultural products that are sources of food, fiber and energy. Such impacts indirectly influence future growth in fertilizer demand and use. Growth in population and income increases the demand for food products and fertilizer nutrients. Even though global population growth rates are expected to decline to an average of about 1.1 percent during 2005-2015, policymakers and development agencies are concerned about how the world will feed this growing population (World Development Indicators [WDI], 2008). Population growth rates in poor developing countries are expected to be substantially higher than the average global rate.

During the past decade, the overall economic growth rate slowed to 2.8 percent despite higher GDP growth rates in low- and middle-income countries (WDI, 2008). Rates of growth of large economies, such as China and India, have increased significantly in recent years. Such income increases have had important impacts on food demand. The age distribution and education of the population and the order of magnitude of income growth and its distribution have significant impacts on the type of food products that are preferred and increasingly consumed by growing populations. Income growth in some countries, such as China, has contributed to the rapid expansion of demand for, and consumption of, higher value "superior" food commodities such as pork, poultry and beef, and indirectly to the demand for animal feed products such as soybeans and maize. Cultural factors and religion also have an important role in the changing patterns of food consumption in many countries. The growth and diversification of the derived demand for fertilizers are now occurring mainly as a result of the growing consumption of more "fertilizer nutrient-intensive" food products such as meat, eggs and products that are becoming feasible raw materials for the production of bio-fuels. Livestock, pork and poultry food commodities require higher amounts of plant nutrients (supplied by fertilizers) per unit produced than crop food commodities.

Marked differences among low-, middle- and high-income countries are highlighted by the indicators in the table on page 14.

C. Demand for Bio-Fuels

In recent years, emerging expansion in the demand for bio-fuels is becoming a significant additional component of a more diversified demand for agricultural products, which include the raw materials needed to produce bio-fuels. Programs to promote the production of bio-fuels in countries such as the United States and Brazil, and in Europe are currently expanding the demand for corn, sugarcane and soybeans. In the long-run, technological innovation and public policy will determine the future sustainability and importance of this additional source of demand for agricultural products and, ultimately, its impact on food prices and the derived demand for fertilizers. Prices of other sources of energy (oil, natural gas), technological innovation and public

GDP growth rate (average annual percent)	1990–2000	2000–2005
World	2.9	2.8
Low income	4.8	6.1
Middle income	3.8	5.2
High income	2.7	2.2
Population growth rate (average annual percent)	1990–2005	2005–2015
World	1.4	1.1
Low income	2.0	1.7
Middle income	1.1	0.8
High income	0.7	0.4
Average annual agriculture growth rate (%)	1990	2005
World	2.0	2.2
Low income	3.2	3.6
Middle income	2.0	2.0
High income	1.3	-0.1
Prevalence of undernourishment (%)	1990	2005
World	17	14
Low income	27	24
Middle income	14	10
High income	3	3

Source: WDI (2007).

energy policy are the main factors determining the sustainable long-term growth of bio-fuels and their additional demand for agricultural products and indirectly for fertilizers.

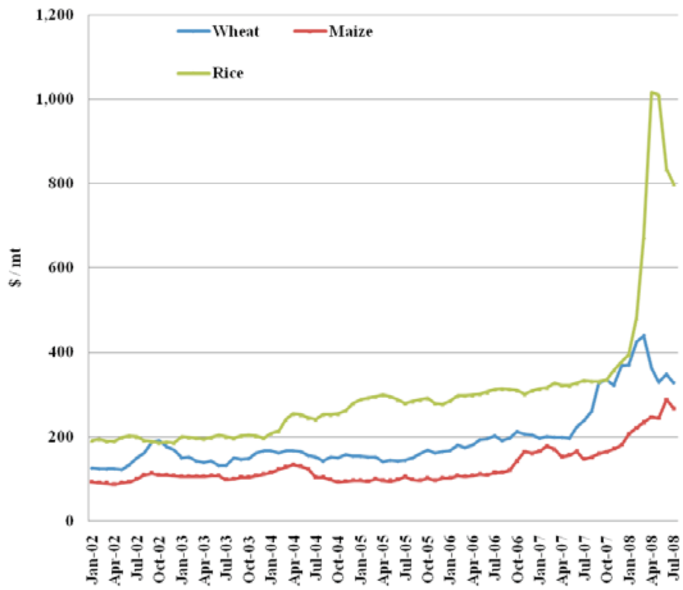
Higher energy prices and increased demand for bio-fuels have resulted in marked increases in prices of food commodities and fertilizers. Between 2000 and 2008, natural gas and petroleum prices increased significantly. Natural gas increased from US $4 to about $10 per million Btu (MMBtu) and petroleum increased from $29 to about $100/barrel. Price increases of key cereals and fertilizers in recent years are shown in the graphs on page 15.

From July 2002 to July 2008, maize, rice and wheat prices increased from $100 to $267/mt, $200 to $799/mt and $149 to $328/mt, respectively. Price increases of these cereals and key fertilizers from 2002 to 2008 are summarized in the table on page 15.

The price of urea (f.o.b. bulk, prilled, Arabian Gulf) increased sharply from $110/mt in 2002 to $783/mt in 2008. Similarly, the price of granular DAP (f.o.b. bulk granular, USA Gulf) jumped from $169/mt in 2002 to $422/mt in 2007 (IFDC, 2008). Higher cereal prices and resulting farmer profitability had a direct impact on the demand for fertilizers. However, expanded demand and elevated energy prices also increased fertilizer prices, reducing farmer profitability and fertilizer use rates. The price of anhydrous ammonia, a raw material for urea production, went from $96/mt in 1991 to $339/mt in 2007 (IFDC, 2008). By July 2008 the fertilizer price hikes made economic access to fertilizer increasingly difficult for millions of poor farmers in developing countries. The substantial fertilizer price increases in recent years are illustrated above for urea, DAP and muriate of potash (MOP). Trends of increasing prices for energy, agricultural products and fertilizers are now (September/October 2008) being reversed as a result of the global financial crisis and impending economic recession.

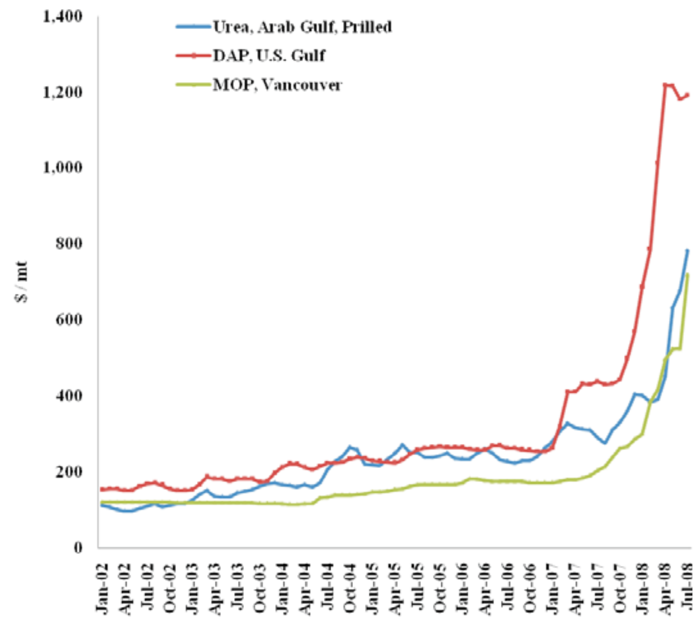
D. Innovations and Changes in Technology

The efficient production, trade and supply of fertilizers to farmers are essential to meet the growing and more diversified demand for plant nutrients with products that more effectively meet the crops' nutrient requirements on a timely and cost-efficient basis. Innovation and changes



Monthly Average 2002–2008 Prices of Wheat (wheat, No. 1 Hard Red Winter, ordinary protein, freight on board [f.o.b.] Gulf of Mexico), Maize (U.S. No. 2 Yellow, f.o.b. Gulf of Mexico) and Rice (5% broken milled white rice, Thailand nominal price quote) in US $/mt.

Source: IMF.



Monthly Average Prices of Urea, DAP and MOP, January 2002–July 2008.

Source: IFDC.

Cereals	July 2002	July 2004	July 2006	July 2008
Wheat, No.1 Hard Red Winter, ordinary protein, f.o.b. Gulf of Mexico (US $/mt)	149	151	202	328
Maize, U.S. No. 2 Yellow, f.o.b. Gulf of Mexico, US $/mt	100	104	114	267
Rice, 5% broken milled white rice, Thailand nominal price quote (US $/mt)	200	240	312	799
Fertilizers				
Urea, f.o.b. bulk, prilled, Arabian Gulf ($/mt)	110	205	229	783
DAP, f.o.b. bulk, granular, U.S. Gulf ($/mt)	169	224	263	1,192
MOP, f.o.b. bulk, standard, Vancouver ($/mt)	121	134	175	720

Sources: IMF and IFDC.

in technology to improve agricultural production and the manufacturing and marketing of more efficient fertilizers will affect the demand, production, use and trade of fertilizers. Specifically, innovations in agricultural production, by shifting upward the agricultural production function, will result in an outward shift of the fertilizer demand function or curve (i.e., higher demand at the same prices). Similarly, innovations in fertilizer production and/or marketing will shift downward the fertilizer supply function (i.e., lower marginal cost to producers/suppliers). Both types of innovations will impact fertilizer prices and consumption. Fertilizer supply involves exploitation of natural resources (mining), production (manufacturing), trade, distribution and wholesaling and retailing. These components of the supply chain must operate efficiently to minimize cost and maximize benefits to fertilizer producers and distributors and, ultimately, to farmers and society as a whole.

Other factors that are expected to induce changes in agricultural and fertilizer technology are: (a) the increasing scarcity of water and agricultural land; and (b) improvements in communication and information/data processing technology and capabilities. These improvements will facilitate the adoption of improved technologies and have a significant complementary role in the development and success of these technologies.

III. The FertTrade Model

A. Model Overview

The FertTrade model was developed by IFDC to serve as an analytical tool to evaluate trends of evolving demographic, economic, agro-climatic and geo-political circumstances affecting agricultural production and the associated global trade and inter-regional flow of plant nutrients and fertilizers. N, P and K fertilizer demand and trade trends through 2025 are estimated using the FertTrade model. Trend estimates on the demand, planned production and trade for the three major plant nutrients (N, P and K) supplied to crops by fertilizers are obtained and evaluated at three levels: (a) global – on the basis of estimates aggregated for the world as a whole; (b) regional – on the basis of estimates for seven units of regional country-groups; and (c) country and sub-regional – using results for 36 units comprising 21 individual countries and 15 country-groups or sub-regions. The units that serve as bases for the regional and country/sub-regional analyses and evaluations are described in the next sections.

The primary units of analysis are the 21 individual countries and the 15 mutually exclusive sub-regions that include sets of countries grouped together as geographic sub-regions or as groups of countries with similar levels of development. One group of countries is included in a residual small “Rest of the World” sub-region. Regional analyses and evaluations are conducted using estimates aggregated for seven main regions and global analyses on the basis of world-aggregated estimates. Thus, FertTrade model estimates can be used to conduct analyses of fertilizer trends in demand, projected production and trade globally, regionally and for the individual countries and sub-regions specified in the model.

The model is conceptually based on the following postulates:

1. Fertilizers as key sources of the major plant nutrients, N, P and K, are essential variable inputs to agricultural production. Their demand is therefore derived from the demand for agricultural products.
2. Factors and circumstances that affect the demand for agricultural products as sources of food, feed, fiber and as raw materials for the production of bio-fuels are, indirectly, key sources of change in the demand for N, P and K fertilizers.
3. Changes in population, incomes, consumers’ preferences for agricultural products and in technologies affecting the production and consumption of food, feed, fiber and bio-fuels are key determinants of the demand for N, P and K fertilizers. Agricultural production and fertilizer demand are also affected by changes in agro-climatic circumstances and climate change. Moreover, these changes may also induce innovation in fertilizer production and use technologies, and ultimately determine the actual quantities of N, P and K in fertilizers used by farmers.
4. Derived demand quantities for fertilizer N, P and K are estimated for each of the 36 country/sub-regions on the basis of crop production outputs generated by simulation outcomes of IMPACT developed by IFPRI. Agricultural commodities included in the IMPACT model, and subsequently in FertTrade, are presented in Appendix 1. The IMPACT model covers 32 commodities to account for the broad scope of global food production and consumption.

Grounded in the postulates enumerated above, the FertTrade model is designed as a tool to conduct simulations and quantitative analyses on key issues affecting agriculture and fertilizer sector development. *First,* to estimate and evaluate projected levels of demand, planned production and trade for N, P and K fertilizer nutrients under alternative scenarios of: (a) growth and shifts in the demand for food, fiber and bio-fuel raw materials, due to changes in populations and incomes; (b) technical changes in the production of agricultural products, fertilizers and bio-fuels; and (c) constraints that may emerge on agricultural productivity and available cropland areas as a result of special circumstances such as climate change.

Second, the model is designed to evaluate changes in policies and circumstances that directly or indirectly affect the demand, production and trade of N, P and K fertilizer nutrients, globally or in key countries. This is accomplished by using outputs of FertTrade to quantify and assess the expected consequences of scenarios that explicitly include changes in key variables as a result of known policies and circumstances. The outputs and outcomes produced by the model can be used to conduct further analyses to quantify/assess impacts and, in some instances, derive estimates to conduct benefit/cost analyses.

Third, the model outputs can assist decision-making on public and private investments in agriculture and fertilizer sectors by deriving estimates of the economic impact and effectiveness of proposed policies and investments globally and in the country or group of countries where they take place. The model can be used to quantify the impacts of investments by evaluating scenarios that explicitly include changes in key variables that proposed investments will bring about globally and in the country/sub-regions where they occur. Quantified impacts derived from the model's outcomes and data on investment costs can then be used to conduct benefit/cost analyses. Results of such analyses serve to ascertain investment priorities and the prefeasibility of various investments in agriculture and fertilizer sectors, such as investments in irrigation, fertilizer production facilities and marketing infrastructure.

Fourth, the model outputs could be used further to derive estimates of key variables of environmental impact associated with changes in agricultural production and the demand, production and trade of N, P and K fertilizers. However, to achieve this goal, FertTrade must be further developed to properly measure variables of environmental impact on air, land and water as a result of changes in agricultural production and fertilizer use. Additional methods and procedures must be developed and included to estimate the impact of changes in agriculture intensification, fertilizer use, animal waste production and recycling and other practices on air, land and water pollution. For example, methods and procedures could be added to estimate the impact of expansion and changes in animal production for plant nutrient recycling to crop production or as a source of pollution.

Finally, FertTrade could also be used to assist in identifying (globally and on a country and regional/sub-regional basis) priorities for technical change and research and development work. FertTrade's outputs could be used for conducting additional analyses to ascertain the need and priorities for basic and adaptive research to promote the sustainable development and growth of agriculture and fertilizer sectors in different countries and regions. For this purpose, the model can be used to evaluate scenarios representing *ex-ante* the expected goals of various research and investment efforts on the levels of use and efficiency of fertilizers and of agricultural production and productivity. Then, results of those scenario simulations on fertilizer use and agricultural production outcomes can serve to conduct *ex-ante* benefit/cost analyses useful in guiding research priorities and investments. This approach is used in the last section of this paper to illustrate the use of the model for evaluating "what if" scenarios.

B. Model Structure

The major components and linkages of the FertTrade model are presented in Figure 1 below. This schematic representation of FertTrade is designed to better describe the model in terms of its five main components:

1. Scenario Design and Specification.
2. Generation of Crop Production Outputs using IFPRI's IMPACT model.
3. Methods to Estimate the Derived Demand for N, P, K Fertilizer Nutrients.
4. Methods to Project Production Capacities and Supplies of N, P, K Fertilizer Nutrients.
5. Methods to Estimate Volumes and Patterns of Trade for N, P, K Fertilizer Nutrients.

Methods and procedures associated with the five main components of the model are described in general terms below.

1. **Scenario Design and Specification –** Scenarios are designed and specified in terms of: (a) variables that affect the outcomes of the commodity market equilibrium model (i.e., IFPRI's IMPACT model); and

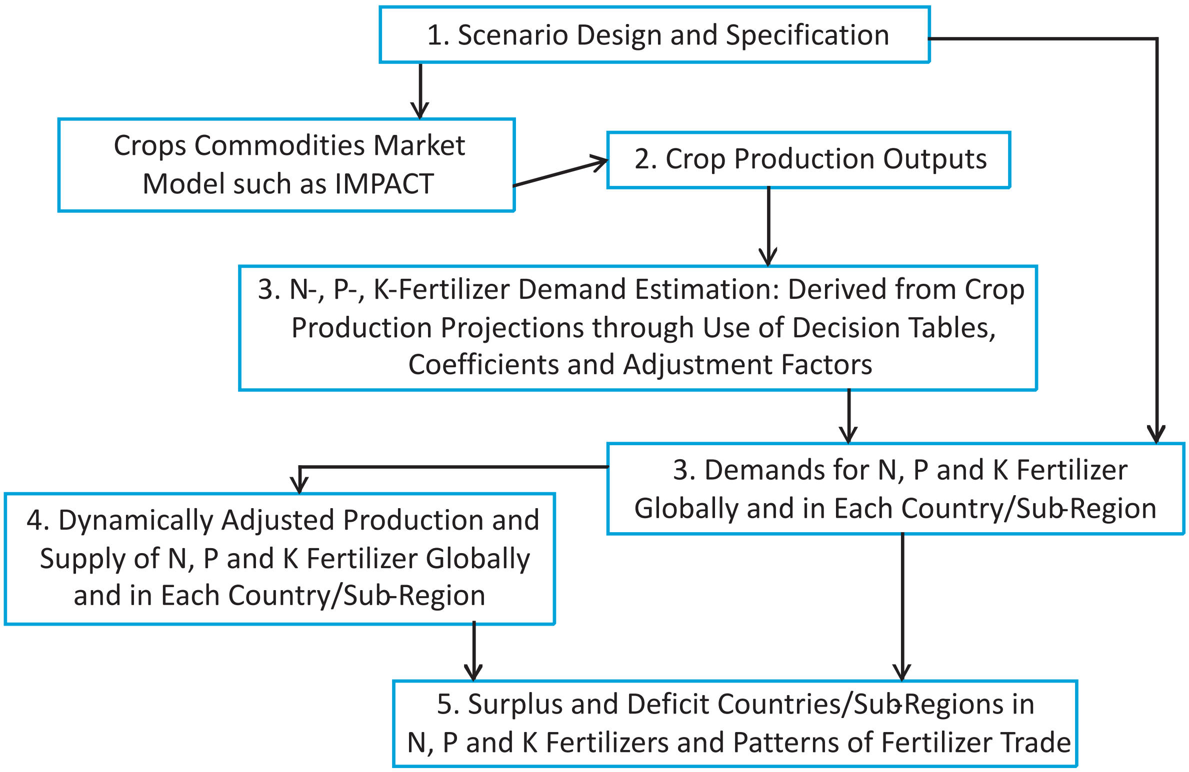


Figure 1. Schematic Representation of the FertTrade Model Components

(b) variables affecting fertilizer use and demand. This component enables the design and assessment of scenarios that may include changes in several key variables affecting the demand, production and supply of agricultural products (food, fiber and bio-fuel raw materials) and the derived demand for N, P and K fertilizer nutrients. For example, country/region-specific changes in variables such as: (a) rates of growth of population and income; (b) changes in crop and livestock production; (c) areas cultivated with main crops and heads of livestock under exploitation; (d) improvements in irrigation; and (e) changes in fertilizer nutrient use efficiency may be explicitly included in the specification of scenarios. Then, the expected impact of these changes (and the policies that induce them) on the demand and trade of N, P and K fertilizer nutrients can be evaluated.

2. **Generation of Crop Production Outputs** – This is accomplished with a crop commodities market model such as IFPRI's IMPACT model, which quantifies estimates of crop production outputs required to achieve market equilibrium in the crop and livestock commodity markets. Such quantities are affected by the variables of a given pre-established scenario. In this manner, levels of production are estimated for all the crops included in the model for each of the 36 individual countries and sub-regions specified in the IMPACT model. Levels of crop production are aggregated for the model's pre-established groupings of countries into the sub-regions and regions described in Section C below. In the model some key countries are included individually and others are grouped together to represent geographic sub-regions and regions with a similar stage of economic development. The 32 crop and livestock commodities included in the IMPACT model, and subsequently in FertTrade, are described in Appendix 1.

3. **Methods to Estimate the Derived Demand for N, P and K Fertilizer Nutrients** – The IMPACT model-generated annual time-series estimates of levels of crop production for 2000-2025 are used to derive annual time-series estimates of projected demand for N, P and K fertilizer nutrients for that time period.

This component of the FertTrade model includes methods and procedures developed to estimate the derived demand for the fertilizer-supplied major plant nutrients N, P and K. Estimates are given of the quantities of these nutrients that, under prevailing conditions in each country/region, farmers would need to apply to their crops to reach the model-generated annual estimates of crop production. This component involves the use of coefficients and adjustment factors developed to account for variability in the demand for fertilizers as a result of inter-country and inter-regional diversity in: (a) the type and volumes of crop outputs produced; (b) current levels and trends of adoption and use of fertilizers in these crops; (c) overall adoption of modern inputs and improved technology in crop production; (d) fertilizer use efficiency; (e) stages of agricultural and economic development; (f) availability of water and inherited fertility of soils in agricultural lands; and (g) climate. Because the model does not usually include all of the crops grown in each country/sub-region, N, P and K fertilizer nutrient demand estimates are further adjusted to account for these shortcomings. For this purpose, adjustment coefficients were calculated empirically by correlating the model's unadjusted estimates of N, P and K demand for recent years with corresponding data on actual observed levels of consumption in each of the country/sub-regions in the model. Following these methods and procedures, a large array of information on N, P and K fertilizer demands for 2000-2025 in each of the model's country/sub-regions is generated to assess global, regional and country and sub-regional trends in demands for N, P and K fertilizer nutrients through 2025. These trends are presented and discussed in this paper.

4. **Methods to Project Adjustments in Production Capacities and Supplies of N, P and K Fertilizer Nutrients** – Production capacities and projected supplies of N, P and K fertilizer nutrients are estimated by the model for the next 15 years, globally and for each of the model's country/sub-regions. Through 2010-2012, supplies of N, P and K fertilizer nutrients in each country/sub-region are projected using data from IFA. Quantities of N, P and K nutrients in fertilizers that can be supplied by the current and planned production capacities (supply capacities) through 2011 are calculated by multiplying levels of manufacturing production capacities with the highest achievable operating rate of capacity utilization.

   Beyond 2011, projected supplies of N, P and K fertilizer nutrients are dynamically generated by the model, first globally and then for each country/sub-region. The methodology is designed to produce a dynamically adjusted potential supply of fertilizer nutrient (Sp_t) while maintaining a limited global excess in production capacity. That is, to maintain global levels of fertilizer production and supply that: (a) can be attained by the fertilizer industry operating at reasonable levels of production capacity utilization; and (b) will effectively supply quantities of fertilizer nutrient (Sa_t), which are at least 2 percent higher than the projected global demand (D_t). The dynamically adjusted potential supply is generated through changes in rates of production capacity utilization. When such changes are not sufficient to meet the required global quantities of fertilizer nutrient supply Sa_t, then mechanisms that trigger timely expansions in fertilizer production capacity are required to guarantee that the actual supply Sa_t is always provided by the industry. Decreases in global supply through contractions in production capacities (i.e., through the closing of old or inefficient plants) are triggered by the model when the excess in global potential supply for the fertilizer nutrient as a percentage of the global projected demand reaches pre-established upper limits built into the model.

   Dynamically adjusted levels of projected fertilizer nutrient supplies by each key country and sub-region during 2012-2025 are estimated by distributing among the countries/sub-regions the projected quantities of global supply adjustments for each year. Such quantities are distributed among countries/sub-regions by using coefficients of adjustment or weights calculated on the basis of two country/sub-region-specific measures: (a) the trends of supply adjustment experienced during 2005-2010; and (b) the 2005-2010 average magnitude of annual adjustment in proportion to the projected global adjustment in supply. Projected adjusted levels of fertilizer nutrient supplies in each key country and sub-region are then aggregated to derive estimates by region and conduct regional analyses.

5. **Methods to Estimate Volumes and Patterns of Trade for N, P and K Fertilizer Nutrients** – The array of N, P and K fertilizer supply information

generated above by Component 4 matches on a country/sub-region annual basis the corresponding array of fertilizer demand information produced by Component 3. Then, in this last component of the model, all information and data are used to determine the model's outcomes in terms of surplus (exporting) and deficit (importing) country/sub-regions and the expected volumes of N, P and K fertilizer nutrients traded (exported or imported). Trade volumes calculated in this way do not reflect the amounts of fertilizers that countries often import to meet seasonal demands, shortfalls in stocks or the need for specific fertilizer products. Nevertheless, these are good estimates to assess the large volumes of trade and long-term trends in supply, demand and patterns of trade. Future patterns of trade are determined on the basis of historical prevailing trade patterns and cost considerations. It should be noted that there is room for improvement in methods to estimate future patterns of fertilizer trade.

C. Model Applications Presented

The importance of the FertTrade model as a practical tool is demonstrated by conducting various assessments and analyses that provide information. For this purpose, first, a pre-established baseline scenario described in Appendix 2 is used as input to the IMPACT model to obtain projected levels of crop production through 2025 under conditions of historical trends in population and income growth, crop and livestock production and productivity improvements. Subsequently, the FertTrade model is used to estimate projected derived demands for N, P and K fertilizer nutrients and associated dynamic adjustments in supplies through 2025. Such estimates are obtained globally, regionally and for the key countries and sets of countries grouped as sub-regions in the model.

Derived demand estimates of N, P and K fertilizer nutrients through 2025 are further evaluated in conjunction with projected levels of dynamically adjusted fertilizer production capacity and supply to determine trends in patterns of demand, production and trade through 2025. Such trends are examined below through global, regional and country/sub-regional analyses of the model-generated results for N, P and K fertilizer nutrients presented in Chapters IV, V and VI of the paper, respectively. Finally, to demonstrate the use of the model as a tool to evaluate *"what if"* scenarios, the consequences of a scenario depicting changes in nitrogen use efficiency are evaluated by using the model to obtain simulated outputs and outcomes of a scenario representing improvements in the efficiency of fertilizer N applied to cereal production.

The geographic coverage of the regional and country/sub-regional analyses is described below and follows the structure established by the IMPACT model.

Regional analyses are conducted on the basis of aggregated estimates pertaining to the seven major groups of countries identified in the IMPACT model to represent the world's six key geographic regions and a developed countries group comprising the more developed countries. These seven mutually exclusive major countries identified as regions are included in the regional analyses and assessments. The seven regions are described below in terms of the countries and sub-group of countries they comprise. For each of these regions, estimates are aggregated to represent the seven corresponding mutually exclusive sets of countries and sub-groups of countries as described on pages 21 and 22.

Country and sub-regional analyses are conducted on the basis of aggregated estimates obtained for each of the following 36 units of individual countries and sub-groups of countries representing the specific country groups and sub-regions shown in the table on page 23.

In the following sections, analyses of trends through 2025 on the demand, production and trade of fertilizer N, P and K are presented and discussed. First, trends are evaluated from a global perspective on the basis of estimates aggregated for the world as a whole. Then, more detailed levels of stratification, regional and country/sub-regional analyses are conducted for nitrogen, phosphorus and potassium in Chapters IV, V and VI, respectively.

IV. Trends in the Market for Nitrogen (N) Fertilizers

Estimates produced as outputs of the FertTrade model are used here to project and evaluate through 2025 the quantities of fertilizer N that will be demanded, produced and traded (imported or exported) by each of the mutually exclusive units representing individual key countries and groups of countries (sub-regions) specified in the model. World, regional and country/sub-regional

1. Developed Countries Group

1. USA	
2. Europe (EU 15)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
3. Japan	
4. Australia	
5. Other Developed	Canada, Iceland, Israel, Malta, New Zealand, Norway, South Africa and Switzerland
6. Eastern Europe	Albania, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia and Yugoslavia
7. Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan
8. Rest Former USSR	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova, Russian Federation and Ukraine

2. Latin America Region

1. Mexico	
2. Brazil	
3. Argentina	
4. Colombia	
5. Other Latin America	Antigua and Barbuda, Bahamas, Barbados, Belize, Bolivia, Chile, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts Nevis, Saint Lucia, Saint Vincent, Surinam, Trinidad and Tobago, Uruguay and Venezuela

3. Sub-Saharan Africa Region

1. Nigeria	
2. Northern Sub-Saharan Africa	Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Somalia and Sudan
3. Central & Western Sub-Saharan Africa	Benin, Cameroon, Central African Republic, Comoros Island, Democratic Republic of Congo, Congo Republic, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Sao Tome and Principe, Senegal, Sierra Leone and Togo
4. Southern Sub-Saharan Africa	Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia and Zimbabwe
5. Eastern Sub-Saharan Africa	Burundi, Kenya, Rwanda, Tanzania and Uganda

4. West Asia/North Africa Region

1. Egypt	
2. Turkey	
3. Other West Asia/North Africa	Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen

5. South Asia Region

1. India	
2. Pakistan	
3. Bangladesh	
4. Other South Asia	Afghanistan, Maldives, Nepal and Sri Lanka

6. Southeast Asia Region

1. Indonesia	
2. Thailand	
3. Malaysia	
4. Philippines	
5. Vietnam	
6. Myanmar	
7. Other Southeast Asia	Brunei, Cambodia and Laos

7. East Asia Region

1. China	China, Taiwan and Hong Kong
2. South Korea	
3. Other East Asia	Democratic People's Republic of Korea, Macao and Mongolia

Units	Countries Included in Groups
1. USA	
2. Europe (EU 15)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
3. Japan	
4. Australia	
5. Other Developed	Canada, Iceland, Israel, Malta, New Zealand, Norway, South Africa and Switzerland
6. Eastern Europe	Albania, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia and Yugoslavia
7. Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan
8. Rest Former USSR	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova, Russian Federation and Ukraine
9. Mexico	
10. Brazil	
11. Argentina	
12. Colombia	
13. Other Latin America	Antigua and Barbuda, Bahamas, Barbados, Belize, Bolivia, Chile, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts Nevis, Saint Lucia, Saint Vincent, Surinam, Trinidad and Tobago, Uruguay and Venezuela
14. Nigeria	
15. Northern Sub-Saharan Africa	Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Somalia and Sudan
16. Central & Western Sub-Saharan Africa	Benin, Cameroon, Central African Republic, Comoros Island, Congo Democratic Republic, Congo Republic, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Côte d'Ivoire, Liberia, Sao Tome and Principe, Senegal, Sierra Leone and Togo
17. Southern Sub-Saharan Africa	Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia and Zimbabwe
18. Eastern Sub-Saharan Africa	Burundi, Kenya, Rwanda, Tanzania and Uganda
19. Egypt	
20. Turkey	
21. Other West Asia/North Africa	Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen
22. India	
23. Pakistan	
24. Bangladesh	
25. Other South Asia	Afghanistan, Maldives, Nepal and Sri Lanka
26. Indonesia	
27. Thailand	
28. Malaysia	
29. Philippines	
30. Vietnam	
31. Myanmar	
32. Other Southeast Asia	Brunei, Cambodia and Laos
33. China	China, Taiwan and Hong Kong
34. South Korea	
35. Other East Asia	Democratic People's Republic of Korea, Macao and Mongolia
36. Rest of the World	Cape Verde, Fiji, French Polynesia, Kiribati, New Guinea, Papua New Guinea, Seychelles and Vanuatu

projections are used to conduct these assessments at three levels of aggregation.

A. World Demand and Supply Projections for N Fertilizers

World demand and supply projections for fertilizer N generated by the FertTrade model through 2023 are shown in Figure 4.1 and the associated projected adjustments in supply to meet demand are portrayed in Figure 4.2. Such projections indicate that in order to secure a global supply to farmers, which is at least 2 percent higher than the projected demand, the following adjustments in the world's production capacity of fertilizer N and the average rate of production capacity utilization are projected to take place.

1. The planned world increases in fertilizer N production capacity through 2012 may not be realized and/ or the global excess production capacity would be reduced through the closing of marginal plants, to account for a total reduction of about 14 million mt of production capacity by 2012.
2. During 2013-2017, the required adjustment in fertilizer N world production will be attainable through small (1 to 2 percent) annual increases in production capacity utilization. Nevertheless, during 2018-2023, adjustments in fertilizer N world production will require expansions of the world's production capacity by 5.9 and 6.1 million tons of fertilizer N by 2018 and 2021, respectively, in addition to annual changes in production capacity utilization.

B. Regional Analysis of Demand, Supply and Trade of N Fertilizers

Projections of demand, supply and associated supply-demand balances of fertilizer N for 2012, 2017 and 2022 estimated by the FertTrade model are presented in Table 4.1 for the Developed Countries group and the six geographic regions included in the model. These results

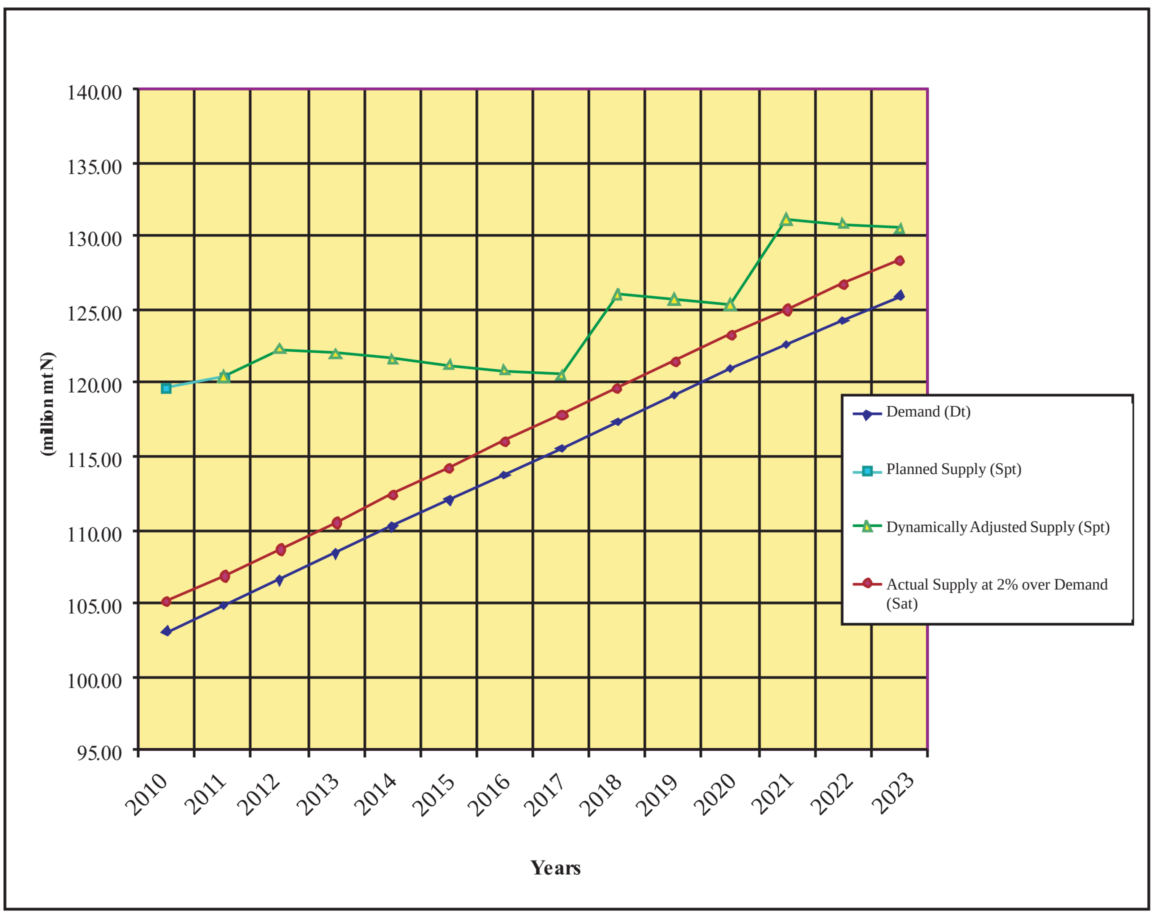


Figure 4.1. Nitrogen World Demand and Supply Projections

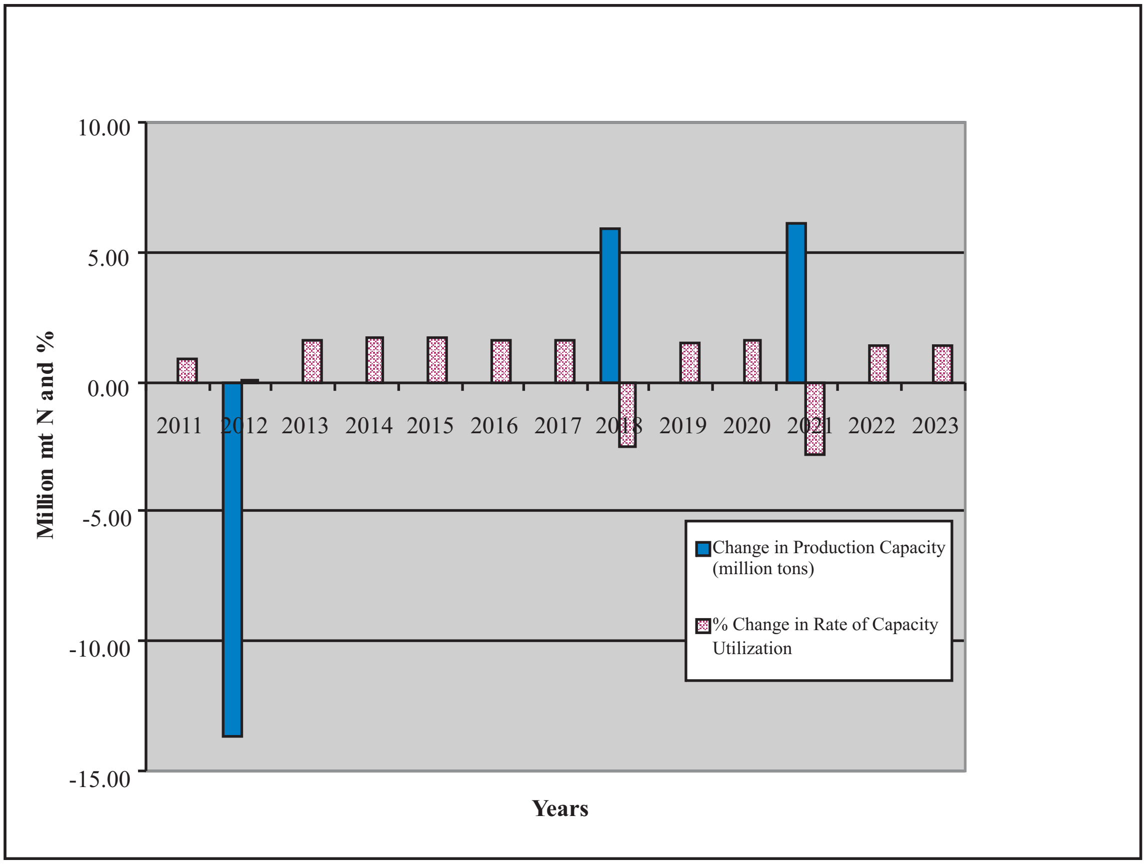


Figure 4.2. Adjustments in N World Supply to Meet Projected Demand

are illustrated in Figures 4.3 and 4.4 and are the basis of the regional analysis and assessment presented in this section. Several useful observations and conclusions drawn from these projections are presented and discussed in the following paragraphs.

First, the results indicate that the West Asia/North Africa (WANA) region is and should remain as the dominant exporting region of fertilizer N. The Developed Countries group and the Southeast Asia region are projected to be significant exporters of N through the latter part of the 2010s, but will have very small surpluses by 2022. Latin America will be a surplus region through 2012 but is projected to confront increasing deficits of about 0.5 and 1.4 million tons of fertilizer N by 2017 and 2022, respectively. East Asia is projected to be a surplus region through 2012 but, due to growth in demand without increase in supply, the region will have a deficit of 2.2 million tons of fertilizer N in 2017. This is expected to be reduced to about 0.5 million tons in 2022 as a result of a projected expansion in production capacity of about 3.8 million tons in the region, mainly in China. South Asia and, to a much lesser degree, the SSA region are projected to be the most important fertilizer N deficit regions and, therefore, the destination of most of the global exports through 2022.

Second, for the SSA region, the projections point to the fact that unless the production capacity of fertilizer N in the region is significantly increased and efficiently supplied to farmers, regional deficits and imports from other regions are projected to increase from about 0.8 million tons of N in 2012 to 1.2 and 1.4 million tons in 2017 and 2022, respectively. To meet development goals, the use of fertilizers in SSA should be accelerated to rates that are substantially higher than observed historical trends. The imports of N fertilizers by the region will probably increase more than is estimated here. For SSA, intra-regional trade of N fertilizers is expected to continue to be substantially smaller than imports from the rest of the world through 2025, unless the efficient production, supply and trade of fertilizer N within the region is dramatically increased.

Table 4.1. Regional Fertilizer N Demand and Supply Projections for 2012, 2017 and 2022

Year	Country Groups and Regions	Projected Demand	Projected Supply	Supply-Demand Balance	Volume of Trade	Imports as Percent of Demand
		('000 mt of N)				(%)
2012	West Asia/North Africa	5,166	21,059	15,893		
	Developed Countries	34,541	37,128	2,587		
	East Asia	31,288	32,303	1,015		
	South Asia	20,756	16,165	-4,591	4,591	22.1
	Southeast Asia	6,153	7,499	1,346		
	Latin America	7,153	7,603	450		
	Sub-Saharan Africa	1,365	570	-795	795	58.3
	Rest of the World	147	0	-147	147	
	World	106,568	122,327		5,533	5.2
	World Excess Supply Capacity			15,759		
2017	West Asia/North Africa	5,686	20,172	14,487		
	Developed Countries	36,036	37,050	1,014		
	East Asia	33,824	31,625	-2,199	2,199	6.5
	South Asia	23,219	16,092	-7,127	7,127	30.7
	Southeast Asia	6,781	7,476	695		
	Latin America	8,084	7,589	-496	496	6.1
	Sub-Saharan Africa	1,727	529	-1,198	1,198	69.4
	Rest of the World	163	0	-163	163	
	World	115,520	120,532		11,182	9.7
	World Excess Supply Capacity			5,012		
2022	West Asia/North Africa	6,215	25,259	19,044		
	Developed Countries	37,452	37,500	48		
	East Asia	36,013	35,518	-495	495	1.4
	South Asia	25,720	16,514	-9,206	9,206	35.8
	Southeast Asia	7,434	7,608	175		
	Latin America	9,060	7,674	-1,385	1,385	15.3
	Sub-Saharan Africa	2,168	761	-1,407	1,407	64.9
	Rest of the World	181	0	-181	181	
	World	124,242	130,836		12,673	10.2
	World Excess Supply Capacity			6,593		

Third, South Asia is a deficit region that will import 4.6 million tons of fertilizer N in 2012. This region's deficit is projected to increase to about 7.1 and 9.2 million tons of fertilizer N in 2017 and 2022, respectively, becoming the world's most significant importing region. The WANA region will continue to be the most important exporting region. A significant volume of trade in fertilizer N will continue to take place between these two regions.

Fourth, the volume of inter-regional trade is projected to grow from 5.5 million tons of N, or 5.2 percent of the global demand in 2012 to about 12.7 million tons or 10.2 percent of the global demand in 2022. The most important importing region will be South Asia through 2022; East Asia and SSA will become important importing regions by 2017; but by 2022, South Asia, Latin America and SSA will be the most important areas with inflows of about 9.20, 1.38 and 1.41 million tons,

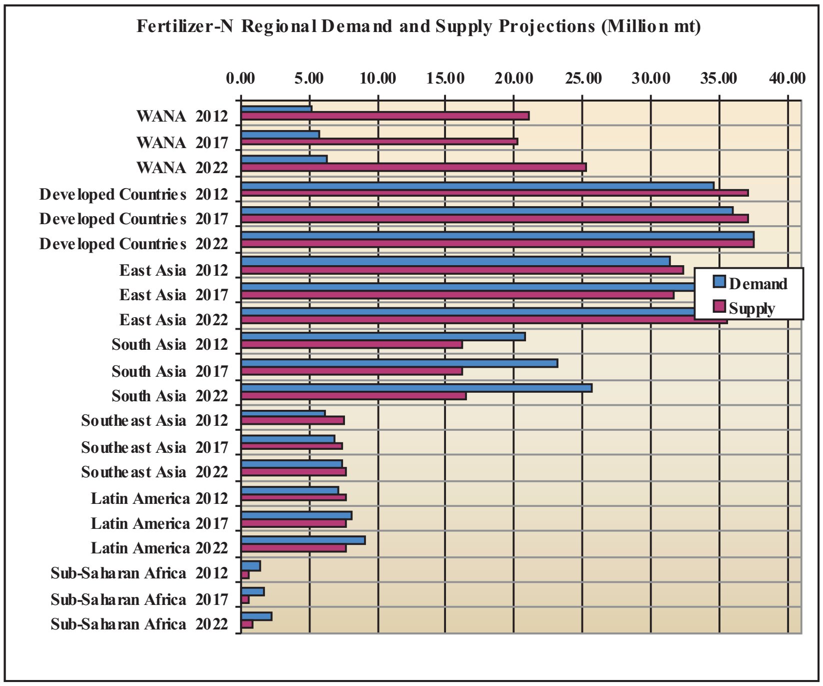


Figure 4.3. Regional Supply and Demand Projections for Fertilizer N

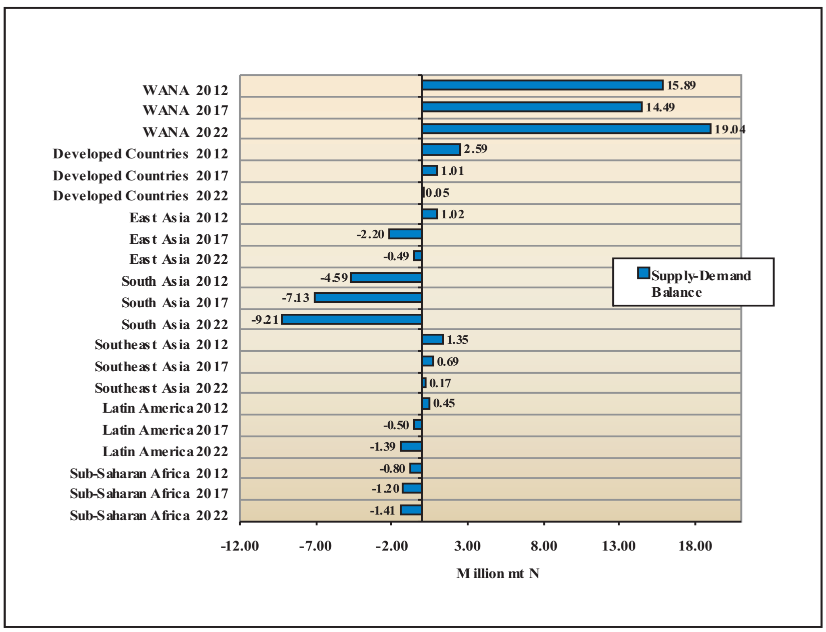


Figure 4.4. Projected Regional Supply-Demand Balances for Fertilizer N

Additional observations and conclusions that can be drawn from the global shares of the regional supply and demand projections shown in Table 4.2 for 2012, 2017 and 2022 are discussed in the following paragraphs.

First, the four regional units (the Developed Countries group, East Asia, WANA and South Asia) are the largest producers (suppliers) of fertilizer N. Together the four regions are projected to account for 87 percent of the global supply of fertilizer N through 2022. However, because the four regions together are estimated to account for 85-86 percent of the global demand for fertilizer N, with the exception of WANA, most of the fertilizer N produced in each region is consumed within the region. Thus, production/supply surpluses are projected to be higher and increase more in the WANA region than in the other three regions. Between 2012 and 2017, the WANA region share on the global supply of fertilizer N will increase somewhat while the share of the Developed Countries group will decrease.

Second, although the WANA region accounts for only 5 percent of the global demand for fertilizer N, this region is an important producer and supplier of N fertilizers. The region's estimated share of 17.2 percent in the global production/supply in 2012 is projected to increase to about 19.3 percent in 2022. Thus, unless the dynamically adjusted supply projections are significantly affected by production capacity investments in other regions, such as Latin America and Russia, where low-cost raw materials are available, the WANA region will increase its dominance in the inter-regional exports of N fertilizers through 2022.

respectively, of fertilizer N from other regions. The WANA region will continue to be the most important exporting region, increasing its dominance by 2022 as the region supplying most of the fertilizer N imported by countries in other regions.

Estimates of fertilizer N regional production/supply, demand and supply-demand balances presented and discussed above are useful to characterize and compare important regions in terms of: (a) their contributions and relative importance to the global supply and demand; and (b) the magnitudes of regional balances of exportable surpluses and deficits, which are the drivers of inter-regional trade. However, a much better understanding of

Table 4.2. Global Shares of Projected Regional Fertilizer N Demand and Supply in 2012, 2017 and 2022

Year	Country Groups and Regions	Projected N Demand			Projected Dynamically Adjusted N Supply		
		Quantity	Share	Cumulative Share	Quantity	Share	Cumulative Share
		('000 mt)	(%)	(%)	('000 mt)	(%)	(%)
2012	Developed Countries	34,541	32.4	32.4	37,128	30.4	30.4
	East Asia	31,288	29.4	61.8	32,303	26.4	56.8
	West Asia/North Africa	5,166	4.8	66.6	21,059	17.2	74.0
	South Asia	20,756	19.5	86.1	16,165	13.2	87.2
	Latin America	7,153	6.7	92.8	7,603	6.2	93.4
	Southeast Asia	6,153	5.8	98.6	7,499	6.1	99.5
	Sub-Saharan Africa	1,365	1.3	99.9	570	0.5	100.0
	Rest of the World	147	0.1	100.0	0	0.0	100.0
	World	106,568	100		122,327	100	
	World Excess Supply Capacity					12.9	
2017	Developed Countries	36,036	31.2	31.2	37,050	30.7	30.7
	East Asia	33,824	29.3	60.5	31,625	26.2	57.0
	West Asia/North Africa	5,686	4.9	65.4	20,172	16.7	73.7
	South Asia	23,219	20.1	85.5	16,092	13.4	87.1
	Latin America	8,084	7.0	92.5	7,589	6.3	93.4
	Southeast Asia	6,781	5.9	98.4	7,476	6.2	99.6
	Sub-Saharan Africa	1,727	1.5	99.9	529	0.4	100.0
	Rest of the World	163	0.2	100.0	0	0.0	100.0
	World	115,520	100.0		120,532	100.0	
	World Excess Supply Capacity					4.2	
2022	Developed Countries	37,452	30.1	30.1	37,500	28.7	28.7
	East Asia	36,013	29.0	59.1	35,518	27.1	55.8
	West Asia/North Africa	6,215	5.0	64.1	25,259	19.3	75.1
	South Asia	25,720	20.7	84.8	16,514	12.6	87.7
	Latin America	9,060	7.3	92.1	7,674	5.9	93.6
	Southeast Asia	7,434	6.0	98.1	7,608	5.8	99.4
	Sub-Saharan Africa	2,168	1.7	99.9	761	0.6	100.0
	Rest of the World	181	0.2	100.0	0	0.0	100.0
	World	124,242	100.0		130,836	100.0	
	World Excess Supply Capacity					5.0	

fertilizer production/supply, demand and trade is attained by conducting this analysis using as "entities of supply, demand and trade," the important individual countries and sub-regions included in the model. Such sub-regional analysis is presented and discussed in the following section.

C. Sub-Regional Analysis of Demand, Supply and Trade of N Fertilizers

Estimates produced by the FertTrade model on the country/sub-regional demand and supply projections for fertilizer N in 2012, 2017 and 2022 are summarized in Table 4.3. These estimates are used in following subsections to discuss trends in the demand, supply and supply-demand balances and trade of fertilizer N through 2025.

Table 4.3. Projected Fertilizer N Demand, Supply and Balances by Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	2012 Demand	2012 Supply	2012 Supply-Demand Balances	2017 Demand	2017 Supply	2017 Supply-Demand Balances	2022 Demand	2022 Supply	2022 Supply-Demand Balances
	('000 mt of Fertilizer N)								
USA	13,471	3,219	-10,251	14,188	3,301	-10,886	14,866	2,830	-12,036
Europe (EU 15)	10,178	4,824	-5,354	10,268	4,830	-5,439	10,334	4,795	-5,539
Japan	488	1,181	693	488	1,181	693	488	1,181	693
Australia	1,084	1,799	715	1,159	1,699	540	1,232	2,273	1,041
Other Developed	3,066	3,616	550	3,273	3,629	356	3,472	3,551	79
Eastern Europe	2,931	5,271	2,340	3,135	5,280	2,144	3,341	5,229	1,888
Central Asia	1,165	1,780	615	1,255	1,773	518	1,344	1,813	470
Rest Former USSR	2,159	15,439	13,281	2,269	15,357	13,088	2,376	15,828	13,452
Mexico	1,725	125	-1,599	1,919	136	-1,784	2,118	75	-2,043
Brazil	2,205	1,351	-854	2,505	1,327	-1,178	2,821	1,467	-1,353
Argentina	803	478	-325	944	482	-463	1,101	460	-641
Colombia	377	60	-318	418	60	-358	459	57	-402
Other Latin America	2,043	5,641	3,598	2,298	5,588	3,290	2,561	5,894	3,333
Nigeria	182	508	326	240	466	226	314	705	391
Northern SSA	313	0	-313	368	0	-368	430	0	-430
Central & Western SSA	282	0	-282	369	0	-369	476	0	-476
Southern SSA	417	62	-355	531	63	-468	670	57	-614
Eastern SSA	171	0	-171	219	0	-219	278	0	-278
Egypt	1,231	4,015	2,784	1,338	3,811	2,472	1,445	4,983	3,538
Turkey	1,596	132	-1,464	1,748	130	-1,618	1,902	144	-1,758
Other West Asia/North Africa	2,338	16,911	14,573	2,599	16,232	13,632	2,868	20,132	17,264
India	16,090	12,108	-3,982	18,004	12,071	-5,933	19,946	12,282	-7,663
Pakistan	3,172	2,555	-617	3,584	2,520	-1,064	4,006	2,721	-1,285
Bangladesh	1,148	1,464	316	1,243	1,462	219	1,339	1,473	134
Other South Asia	346	39	-307	387	39	-348	430	38	-392
Indonesia	2,244	4,965	2,721	2,432	4,952	2,520	2,618	5,026	2,408
Thailand	974	0	-974	1,041	0	-1,041	1,107	0	-1,107
Malaysia	447	999	552	483	999	517	518	999	481
Philippines	770	0	-770	851	0	-851	934	0	-934
Vietnam	1,352	1,086	-265	1,520	1,076	-444	1,694	1,136	-557
Myanmar	290	448	158	371	448	78	470	447	-23
Other Southeast Asia	75	0	-75	84	0	-84	94	0	-94
China	30,539	31,314	775	33,031	30,635	-2,396	35,177	34,534	-644
South Korea	559	440	-119	587	441	-146	614	437	-176
Other East Asia	190	549	359	206	549	343	222	547	325
Rest of the World	147	0	-147	163	0	-163	181	0	-181
World	106,568	122,327	15,759	115,520	120,532	5,012	124,242	130,836	6,593

Demand Projections and Trends Through 2025 – Estimates of growth in demand for N fertilizers through 2025 derived from the FertTrade model's demand projections by countries and sub-regions are presented in Table 4.4 and further summarized by country groups and regions in Table 4.5. Projected 2005-2025 amounts of increased demand in thousands of metric tons and exponential annual rates of growth presented on these tables are used to draw the following observations and conclusions.

1. China and India are projected to experience the largest increases in demand for N fertilizers. In the 20-year period, demand in China and India is projected to increase by about 8.9 and 7.2 million tons of fertilizer N, growing at annual rates of 1.5 percent

Table 4.4. Projected 2005-2025 Demand Growth for Fertilizer N in Key Countries and Sub-Regions

Countries and Sub-Regions Ranked by Size of Demand Increase	Demand Increase 2005–2025	Annual Growth Rate	Countries and Sub-Regions Ranked by Size of Growth Rate	Demand Increase 2005-2025	Annual Growth Rate
	('000 mt N)	(%)		('000 mt N)	(%)
33. China	8,924	1.50	14. Nigeria	187	5.50
22. India	7,185	2.20	16. Central & Western Sub-Saharan Africa	415	5.30
10. Brazil	2,719	2.50	18. Eastern Sub-Saharan Africa	442	5.00
1. USA	1,544	1.00	31. Myanmar	250	4.90
21. Other West Asia/North Africa	1,130	2.10	17. Southern Sub-Saharan Africa	536	4.80
5. Other Developed	986	1.30	15. Northern Sub-Saharan Africa	338	3.30
13. Other Latin America	959	2.30	11. Argentina	733	3.20
23. Pakistan	778	2.40	10. Brazil	2,719	2.50
4. Australia	768	1.40	23. Pakistan	778	2.40
11. Argentina	733	3.20	13. Other Latin America	959	2.30
20. Turkey	706	1.80	30. Vietnam	628	2.30
30. Vietnam	628	2.30	32. Other Southeast Asia	58	2.30
6. Eastern Europe	572	1.30	22. India	7,185	2.20
17. Southern Sub-Saharan Africa	536	4.80	25. Other South Asia	226	2.20
18. Eastern Sub-Saharan Africa	442	5.00	9. Mexico	406	2.10
16. Central & Western Sub-Saharan Africa	415	5.30	21. Other West Asia/North Africa	1,130	2.10
9. Mexico	406	2.10	36. Rest of the World	63	2.10
27. Thailand	359	1.30	12. Colombia	211	2.00
15. Northern Sub-Saharan Africa	338	3.30	29. Philippines	286	2.00
8. Rest Former USSR	337	1.00	20. Turkey	706	1.80
2. Europe (EU 15)	332	0.20	19. Egypt	153	1.70
26. Indonesia	311	1.60	24. Bangladesh	133	1.60
28. Malaysia	305	1.50	26. Indonesia	311	1.60
29. Philippines	286	2.00	7. Central Asia	153	1.50
31. Myanmar	250	4.90	28. Malaysia	305	1.50
25. Other South Asia	226	2.20	33. China	8,924	1.50
12. Colombia	211	2.00	35. Other East Asia	34	1.50
14. Nigeria	187	5.50	4. Australia	768	1.40
7. Central Asia	153	1.50	5. Other Developed	986	1.30
19. Egypt	153	1.70	6. Eastern Europe	572	1.30
24. Bangladesh	133	1.60	27. Thailand	359	1.30
34. South Korea	102	0.90	1. USA	1,544	1.00
36. Rest of the World	63	2.10	8. Rest Former USSR	337	1.00
32. Other Southeast Asia	58	2.30	34. South Korea	102	0.90
35. Other East Asia	34	1.50	2. Europe (EU 15)	332	0.20
3. Japan	0	0.00	3. Japan	0	0.00

and 2.2 percent, respectively. The other two countries with the largest projected increases in demand in this period are Brazil and the USA, with projected increases of about 2.7 and 1.5 million tons and growth rates of 2.5 percent and 1.0 percent, respectively. Population and income growth, technology and public policy affecting the demand for agricultural products as raw materials for the production of bio-fuels are expected to be key drivers of N fertilizer demand growth in these countries.

2. Nigeria, the four sub-regions of SSA, Myanmar and Argentina are projected to experience the fastest rates of growth in the demand for N fertilizer, about 3 to 5.5 percent, through 2025. These high rates of growth are in part due to low current levels of fertilizer use and the evidence of substantial potential

Table 4.5. Projected 2005-2025 Demand Growth for Fertilizer N by Country Groups and Regions

Country Groups and Regions Ranked by Size of Increase	Demand Increase 2005-2025	Share in Global Increase	Annual Exponential Growth Rate	Country Groups and Regions Ranked by Size of Growth Rate	Demand Increase 2005-2025	Exponential Growth Rate
	('000 mt N)	(%)			('000 mt N)	(%)
Developing Countries	27,629	83	2.00	Sub-Saharan Africa	1,399	4.60
All Asia	20,693	62	1.80	Latin America	3,511	2.50
South Asia	9,242	28	2.20	Subtotal South Asia	9,242	2.20
East Asia	9,084	27	1.50	Developing Countries	27,629	2.00
Developed Countries	5,640	17	0.90	West Asia/North Africa	1,964	2.00
Latin America	3,511	11	2.50	Southeast Asia	2,368	1.90
Southeast Asia	2,368	7	1.90	All Asia	20,693	1.80
West Asia/North Africa	1,964	6	2.00	East Asia	9,084	1.50
Sub-Saharan Africa	1,399	4	4.60	Former USSR	752	1.10
Former USSR	752	2	1.10	Developed Countries	5,640	0.90
World	33,269	100	1.60	World	33,269	1.60

for expansion of fertilizer use in these countries and sub-regions. Improvements in crop yields and agricultural productivity and expansion of crop areas are expected to be the main drivers of growth in demand for N fertilizer in these countries and sub-regions.

3. Fertilizer N demand increases and 2005-2025 growth rates calculated for sets of selected groups of countries, including two mutually exclusive groups containing the developing and the developed countries in each group, are summarized in Table 4.5. These results show the following:
   a. About 83 percent, or 27.6 million tons, of the global 2005-2025 increase in N fertilizer demand will take place in the *developing countries* and about 17 percent, or 5.6 million tons, in the *developed countries*.
   b. The Asian sub-regions of South Asia, East Asia and Southeast Asia account for 28 percent, 27 percent and 7 percent of the projected 2005-2025 increase in the global demand for N fertilizer, respectively. Thus, the All Asia region is expected to contribute 62 percent, or about 20.7 million tons, to the global 2005-2025 expansion in demand for N fertilizer. The Latin America region is projected to contribute 11 percent, or about 3.5 million tons, to this expansion. Contributions of the WANA, the Former USSR sub-regions and the SSA region are substantially smaller and account for only 6 percent, 2 percent and 4 percent of the projected 2005-2025 global expansion in demand for N fertilizer, respectively.
   c. In terms of projected 2005-2025 fertilizer N demand growth rates, the SSA and Latin America regions are anticipated to experience the highest growth rates, 4.6 percent and 2.5 percent, respectively. Developing Countries' demand is projected to grow at a rate of 2 percent, more than twice as fast as the Developed Countries' demand (rate of 0.9 percent).

4. Observations and conclusions based on the projected shares of the model's 36 countries and sub-regions in the fertilizer N world demand in 2012, 2017 and 2022 shown in Table 4.6 are discussed in following paragraphs:
   a. ***Large-Size Markets for N Fertilizers*** – The relative importance of key countries and sub-regions as markets for N fertilizers in 2012, 2017 and 2022 is illustrated in Table 4.6 by ranking and listing them by the size of their three-year average share in the world demand. Three countries (China, India and the USA) and one sub-region (Europe [EU 15]) are projected to be the largest markets for N fertilizers through 2022. They are classified here as *large-size markets* and together account for about two-thirds (65.3 percent) of the global market. However, shares of these three countries and sub-region on global demand are not projected to follow the same trends. China's share in the global market for N fertilizers is expected to remain at about 28-29 percent, whereas India's share is projected to increase slightly from about 15 percent in 2012 to 16 percent in 2022. Shares for the USA and Europe (EU 15) are projected to

Table 4.6. Countries and Sub-Regions Ranked by Their Average Shares in the Global Demand for N Fertilizer in 2012, 2017 and 2022

Countries and Sub-Regions	Demand Shares 2012	Demand Shares 2017	Demand Shares 2022	Average Demand Shares	Cumulative Demand Shares
			(%)		
China	28.7	28.6	28.3	28.5	28.5
India	15.1	15.6	16.1	15.6	44.1
USA	12.6	12.3	12.0	12.3	56.4
Europe (EU 15)	9.6	8.9	8.3	8.9	65.3
Total Large-Size Markets	65.9	65.3	64.7	65.3	
Pakistan	3.0	3.1	3.2	3.1	68.4
Other Developed	2.9	2.8	2.8	2.8	71.2
Eastern Europe	2.8	2.7	2.7	2.7	73.9
Other West Asia/North Africa	2.2	2.3	2.3	2.3	76.2
Indonesia	2.1	2.1	2.1	2.1	78.3
Brazil	2.1	2.2	2.3	2.2	80.5
Rest Former USSR	2.0	2.0	1.9	2.0	82.4
Other Latin America	1.9	2.0	2.1	2.0	84.4
Mexico	1.6	1.7	1.7	1.7	86.1
Turkey	1.5	1.5	1.5	1.5	87.6
Vietnam	1.3	1.3	1.4	1.3	88.9
Egypt	1.2	1.2	1.2	1.2	90.1
Central Asia	1.1	1.1	1.1	1.1	91.2
Bangladesh	1.1	1.1	1.1	1.1	92.3
Australia	1.0	1.0	1.0	1.0	93.3
Total Medium-Size Markets	27.6	27.9	28.3	28.0	
Thailand	0.9	0.9	0.9	0.9	94.2
Argentina	0.8	0.8	0.9	0.8	95.0
Philippines	0.7	0.7	0.8	0.7	95.7
South Korea	0.5	0.5	0.5	0.5	96.2
Japan	0.5	0.4	0.4	0.4	96.6
Malaysia	0.4	0.4	0.4	0.4	97.1
Southern SSA	0.4	0.5	0.5	0.5	97.5
Colombia	0.4	0.4	0.4	0.4	97.9
Other South Asia	0.3	0.3	0.3	0.3	98.2
Northern SSA	0.3	0.3	0.3	0.3	98.5
Myanmar	0.3	0.3	0.4	0.3	98.9
Central & Western SSA	0.3	0.3	0.4	0.3	99.2
Other East Asia	0.2	0.2	0.2	0.2	99.4
Nigeria	0.2	0.2	0.3	0.2	99.6
Eastern SSA	0.2	0.2	0.2	0.2	99.8
Rest of the World	0.1	0.1	0.1	0.1	99.9
Other Southeast Asia	0.1	0.1	0.1	0.1	100.0
Total Small-Size Markets	6.4	6.7	7.1	6.7	

decline somewhat from 12.6 percent to 12 percent and 9.6 percent to 8.3 percent, respectively, during the same period. Variations in trends of fertilizer N demand among countries and sub-regions are explained mainly by variations in trends of crop areas harvested, crop yields and crop and livestock patterns of production, which are associated with the scenario variables built into the IMPACT model.

b. ***Medium- and Small-Size Markets*** – Results presented in Table 4.6 are obtained by further classifying as *medium-size markets* those countries and sub-regions having global N fertilizer demand shares lower than 4 percent but no less than 1 percent; and, as *small-size markets* those having market shares of less than 1 percent. These results show that there are 15 countries and sub-regions with *medium-size markets* and 17 with *small-size markets*. Six sub-regions (Eastern Europe, Other WANA, Rest Former USSR, Other Latin America [Latin America excluding Argentina, Brazil and Colombia], Central Asia and the Other Developed countries group) and nine countries (Australia, Bangladesh, Brazil, Egypt, Indonesia, Mexico, Pakistan, Turkey and Vietnam) with *medium-size markets* account together for about 28 percent of the global market for N fertilizers.

   However, most of the individual countries included as part of sub-regions are actually *small-size markets* with demand shares of less than 1 percent of the global market for N fertilizers. Individual countries with medium-size markets are projected to account for only about 13 percent of the global market while market shares of *large-size* and *small-size markets* are 65 percent and 22 percent, respectively.

c. ***Small-Size Markets for Fertilizer N*** are often considered a serious constraint to the establishment and expansion of fertilizer production and supply in many developing countries of SSA, Latin America, Central Asia and WANA. However, it is interesting to observe that developed countries, such as Japan and South Korea, with relatively small-size markets for N fertilizers are important producers of N fertilizers and, in the case of Japan, an important exporter of these fertilizers. If fertilizers can be produced in a country efficiently and competitively, the small size of the domestic market is not necessarily a constraint to the sound production and supply to domestic and export markets.

Trends in Production and Supply – Production/supply shares of the 36 countries and sub-regions on the global N fertilizer production/supply in 2012, 2017 and 2022 derived from estimates of the dynamically adjusted levels of fertilizer N production and supply generated by FertTrade for each of the 36 countries and sub-regions are presented in Table 4.7. The methodology used by the model to produce these supply estimates is briefly described above and takes into consideration the availability of resources and raw materials and the countries and sub-regions historical record and trends in fertilizer production capacity building and supply. However, it is important to recognize that decisions on fertilizer production investments, which are the result of policy decisions by governments and investors and do not match the model mechanisms that trigger outcomes of production capacity expansion, can be sources of error in the model's simulation outcomes of the dynamically adjusted supply.

Observations and conclusions drawn on the basis of the model's dynamically adjusted supply projections are presented and discussed in the following paragraphs.

1. ***Large-Size Producers and Suppliers*** – The 36 countries' and sub-regions' shares of the global N fertilizer production/supply in 2012, 2017 and 2022 are used to rank and list them by the size of their three-year (2012, 2017 and 2022) average share. Two countries (China and India) and two sub-regions (Rest Former USSR [including Belarus, Russia and Ukraine] and Other WANA [including the Persian Gulf countries]) are classified as *large-size suppliers* of N fertilizers. Together they are projected to account for 62 percent of the global N fertilizer supply through 2022. Global supply shares of these countries and sub-regions are not projected to follow the same 2012-2022 trends. China and India's shares in the global supply of N fertilizers are projected to remain stable at about 25-26 percent and 9-10 percent, respectively, whereas the Rest of Former USSR's share is projected to decrease somewhat from 12.6 percent in 2012 to about 12.1 percent by 2022, while the share of the Other WANA sub-region is projected to increase significantly from 13.8 percent in 2012 to 15.4 percent by 2022.
2. ***Medium- and Small-Size Suppliers*** – Estimates presented in Table 4.7 are used further to classify country and sub-regions into two additional groups

Table 4.7. Countries and Sub-Regions Ranked by Their Average Shares in the Projected Global Supply of Fertilizer N in 2012, 2017 and 2022

Countries and Sub-Regions	2012 Supply	2012 Supply Shares	2017 Supply	2017 Supply Shares	2022 Supply	2022 Supply Shares	Average Supply Shares	Cumulative Supply Shares
	('000 mt N)	(%)	('000 mt N)	(%)	('000 mt N)	(%)	(%)	(%)
China	31,314	25.6	30,635	25.4	34,534	26.4	25.8	25.8
Other West Asia/North Africa	16,911	13.8	16,232	13.5	20,132	15.4	14.2	40.0
Rest Former USSR	15,439	12.6	15,357	12.7	15,828	12.1	12.5	52.5
India	12,108	9.9	12,071	10.0	12,282	9.4	9.8	62.3
Total Large-Size Suppliers	75,772	61.9	74,295	61.6	82,776	63.3	62.3	
Other Latin America	5,641	4.6	5,588	4.6	5,894	4.5	4.6	66.9
Eastern Europe	5,271	4.3	5,280	4.4	5,229	4.0	4.2	71.1
Indonesia	4,965	4.1	4,952	4.1	5,026	3.8	4.0	75.1
Europe (EU 15)	4,824	3.9	4,830	4.0	4,795	3.7	3.9	79.0
Egypt	4,015	3.3	3,811	3.2	4,983	3.8	3.4	82.4
Other Developed	3,616	3.0	3,629	3.0	3,551	2.7	2.9	85.3
USA	3,219	2.6	3,301	2.7	2,830	2.2	2.5	87.8
Pakistan	2,555	2.1	2,520	2.1	2,721	2.1	2.1	89.9
Total Medium-Size Suppliers	34,105	27.9	33,910	28.1	35,029	26.8	27.6	
Australia	1,799	1.5	1,699	1.4	2,273	1.7	1.5	91.4
Central Asia	1,780	1.5	1,773	1.5	1,813	1.4	1.4	92.9
Bangladesh	1,464	1.2	1,462	1.2	1,473	1.1	1.2	94.0
Brazil	1,351	1.1	1,327	1.1	1,467	1.1	1.1	95.1
Japan	1,181	1.0	1,181	1.0	1,181	0.9	0.9	96.1
Vietnam	1,086	0.9	1,076	0.9	1,136	0.9	0.9	97.0
Malaysia	999	0.8	999	0.8	999	0.8	0.8	97.8
Nigeria	508	0.4	466	0.4	705	0.5	0.4	98.2
Other East Asia	549	0.4	549	0.5	547	0.4	0.4	98.7
Argentina	478	0.4	482	0.4	460	0.4	0.4	99.0
Myanmar	448	0.4	448	0.4	447	0.3	0.4	99.4
South Korea	440	0.4	441	0.4	437	0.3	0.4	99.8
Turkey	132	0.1	130	0.1	144	0.1	0.1	99.9
Mexico	125	0.1	136	0.1	75	0.1	0.1	99.9
Southern SSA	62	0.1	63	0.1	57	0.0	0.0	99.9
Colombia	60	0.0	60	0.0	57	0.0	0.0	99.9
Other South Asia	39	0.0	39	0.0	38	0.0	0.0	100.0
Total Small-Size Suppliers	12,501	10.2	12,331	10.2	13,311	10.2	10.2	
No Producing Countries/Sub-Regions								
Northern SSA	0	0.0	0	0.0	0	0.0	0.0	100.0
Central & Western SSA	0	0.0	0	0.0	0	0.0	0.0	100.0
Eastern SSA	0	0.0	0	0.0	0	0.0	0.0	100.0
Thailand	0	0.0	0	0.0	0	0.0	0.0	100.0
Philippines	0	0.0	0	0.0	0	0.0	0.0	100.0
Other Southeast Asia	0	0.0	0	0.0	0	0.0	0.0	100.0
Rest of the World	0	0.0	0	0.0	0	0.0	0.0	100.0
World	122,327	100.0	120,532	100.0	130,836	100.0	100.0	

on the basis of their three-year (2012, 2017 and 2022) average shares, namely, a group of *medium-size suppliers* comprising country/sub-regions with supply shares lower than 5 percent but no less than 2 percent of the global supply and a group of *small-size suppliers* comprising those with supply shares lower than 2 percent of the global supply. This classification is used below to make additional remarks about the global allocation of production and supply of N fertilizers among countries and sub-regions.

a. The *medium-size suppliers* group comprises four sub-regions (Other Latin America [Latin America excluding Brazil, Argentina and Colombia], Eastern Europe, Europe [EU 15] and the Other Developed countries group [including Canada and South Africa]) and four individual countries (Indonesia, USA, Egypt and Pakistan). The four sub-regions and four individual countries together will account for about 28 percent of the global N fertilizer supply in 2012, but their share is projected to decline slightly to about 27 percent in 2022. Global supply shares of these sub-regions and countries do not follow the same trends. Shares of the Other Latin America sub-region and Pakistan are projected to remain stable at about 4.6 percent and 2.1 percent, respectively, while shares of the other sub-regions and countries in this group, with the exception of Egypt, are projected to decline. Egypt's share in the global supply of N fertilizers is projected to increase somewhat from 3.3 percent in 2012 to 3.8 percent in 2022.
b. The *small-size suppliers* group includes four sub-regions and 13 individual countries. The sub-regions are Central Asia, Other East Asia, Other South Asia and Southern SSA. The 13 individual countries which are classified as *small-size suppliers* of N fertilizers include Argentina, Australia, Bangladesh, Brazil, Colombia, Japan, Malaysia, Mexico, Myanmar, Nigeria, South Korea, Turkey and Vietnam. The global supply share of the *small-size suppliers* group of sub-regions and countries together is projected to remain essentially unchanged at about 10.2 percent of the world supply of N fertilizers.

Supply-Demand Projections, Balances and Trade – Projections for 2012, 2017 and 2022 presented above in Table 4.3 for the 36 countries and sub-regions specified in the model are summarized from the 2012-2022 time series array of country and sub-regional estimates of fertilizer N demand, dynamically adjusted supply and supply-demand balances (surpluses and deficits) generated by the FertTrade model. These projections show that China and India are two of the most important producers and consumers of N fertilizers. Growth in demand is expected to substantially outpace domestic production and supply in India, the USA and Europe (EU 15), making them increasingly dependent on imports of N fertilizers (mainly from Russia and countries on the Persian Gulf). China is expected to expand production through 2012 in an attempt to meet its growing demand for N fertilizers. By 2022, China is projected to remain the most important global producer of N fertilizers, but because of projected growth in domestic demand, it will be a net importer of fertilizer early in the 2020s.

Projected N fertilizer supply-demand balances or net surpluses of countries and sub-regions for 2012, 2017 and 2022 are used in Table 4.8 to classify countries and sub-regions into three groups:

1. *Exporters Through 2022* – Comprising all countries and sub-regions projected to remain as exporters of N fertilizers through 2022.
2. *Exporters Becoming Importers* – Include China and Myanmar that are projected to be N fertilizer exporters through 2012 but will become importers by 2017-2022.
3. *Importers Through 2022* – Comprising all countries and sub-regions that are projected to have negative supply-demand balances and thus remain as deficit net importers of N fertilizers through 2022.

Projections show that most of the world's sub-regions and countries are and will continue to be either significant net exporters or net importers. About 10 sub-regions and countries are projected to export annually more than 300,000 tons of N fertilizer; about 14 other sub-regions and countries are expected to import annually at least 300,000 tons of N fertilizer. These projections highlight the importance and essential need of N fertilizer trade to meet the demands in many countries. Trade of N fertilizers will be particularly important for many developing countries, which depend on imports to meet domestic demands and where about 83 percent of the global 2005-2025 increase in N fertilizer demand is projected to occur. Most developing countries in SSA, Southeast Asia and Latin America have negative supply-demand balances and will continue to depend on imports of N fertilizers.

Table 4.8. Projected Supply-Demand Balances and Fertilizer N Volumes of Trade Among Key Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	Supply-Demand Balances 2012	2017	2022	Annual Linear Trend	Volume of Trade (Imports) 2012	2017	2022	Annual Linear Trend
	('000 mt of Fertilizer N)							
Exporters Through 2022								
Other West Asia/North Africa	14,573	13,632	17,264	269.0				
Rest Former USSR	13,281	13,088	13,452	17.1				
Other Latin America	3,598	3,290	3,333	-26.5				
Egypt	2,784	2,472	3,538	75.4				
Indonesia	2,721	2,520	2,408	-31.2				
Eastern Europe	2,340	2,144	1,888	-45.2				
Australia	715	540	1,041	32.6				
Japan	693	693	693	0.1				
Central Asia	615	518	470	-14.5				
Malaysia	552	517	481	-7.1				
Other Developed	550	356	79	-47.1				
Other East Asia	359	343	325	-3.4				
Nigeria	326	226	391	6.6				
Bangladesh	316	219	134	-18.2				
Exporters Becoming Importers								
China	775	-2,396	-644	-141.9		2,396	644	
Myanmar	158	78	-23	-18.1			23	
Importers Through 2022								
USA	10,251	10,886	-12,036	-178.5	10,251	10,886	12,036	178
Europe (EU 15)	-5,354	-5,439	-5,539	-18.5	5,354	5,439	5,539	18
India	-3,982	-5,933	-7,663	-368.1	3,982	5,933	7,663	368
Mexico	-1,599	-1,784	-2,043	-44.3	1,599	1,784	2,043	44
Turkey	-1,464	-1,618	-1,758	-29.4	1,464	1,618	1,758	29
Thailand	-974	-1,041	-1,107	-13.2	974	1,041	1,107	13
Brazil	-854	-1,178	-1,353	-50.0	854	1,178	1,353	50
Philippines	-770	-851	-934	-16.4	770	851	934	16
Pakistan	-617	-1,064	-1,285	-66.8	617	1,064	1,285	67
Southern SSA	-355	-468	-614	-25.9	355	468	614	26
Argentina	-325	-463	-641	-31.6	325	463	641	32
Colombia	-318	-358	-402	-8.4	318	358	402	8
Northern SSA	-313	-368	-430	-11.7	313	368	430	12
Other South Asia	-307	-348	-392	-8.4	307	348	392	8
Central & Western SSA	-282	-369	-476	-19.4	282	369	476	19
Vietnam	-265	-444	-557	-29.2	265	444	557	29
Eastern SSA	-171	-219	-278	-10.7	171	219	278	11
Rest of the World	-147	-163	-181	-3.4	147	163	181	3
South Korea	-119	-146	-176	-5.7	119	146	176	6
Other Southeast Asia	-75	-84	-94	-1.9	75	84	94	2
World	15,811	5,016	6,873	-893.8	28,542	35,619	38,624	894

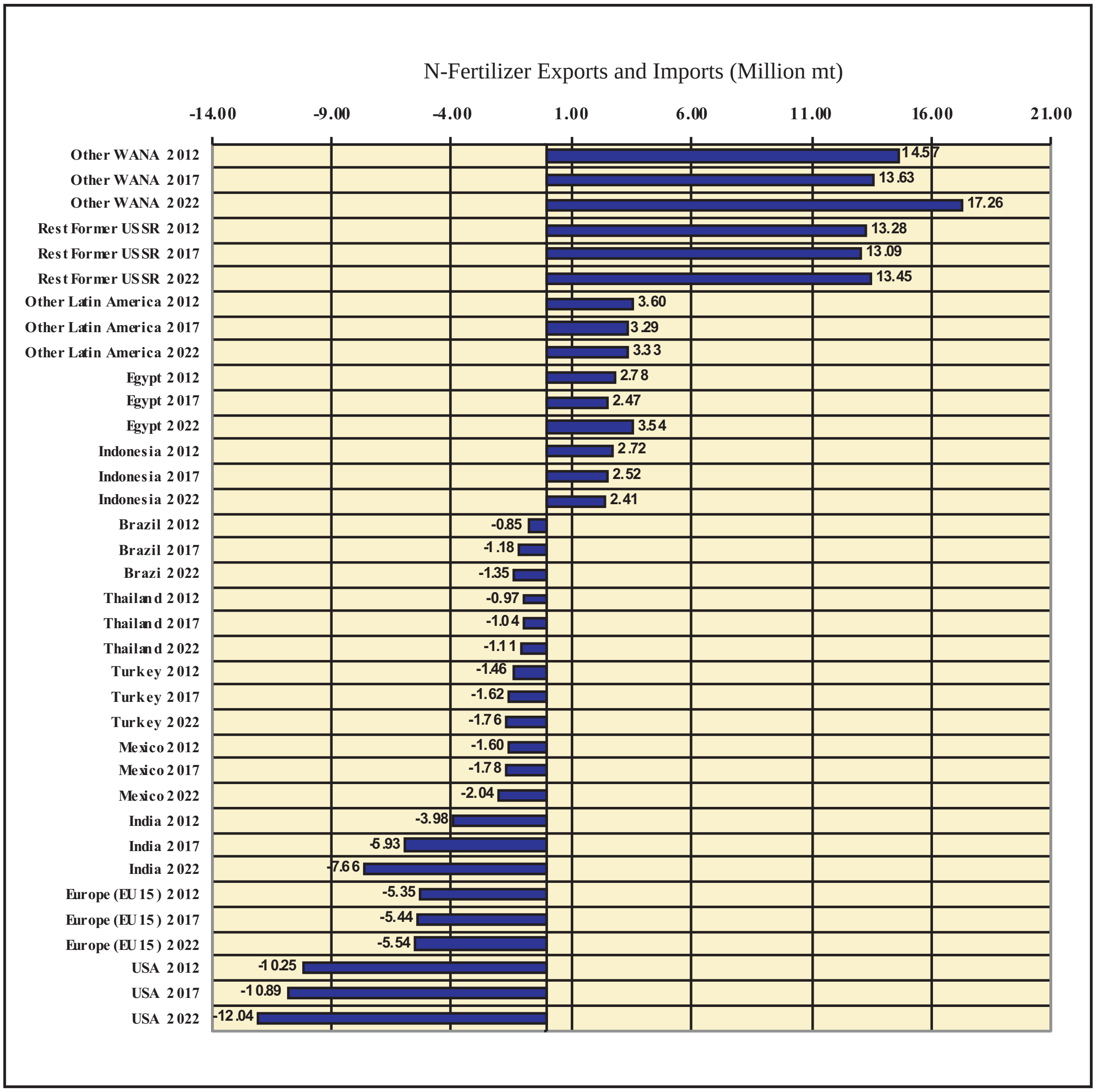


Figure 4.5. Projected Supply-Demand Balances of Fertilizer N in Most Important Trading Countries and Sub-Regions

As indicated by projections presented on Table 4.8 and illustrated in Figure 4.5, four sub-regions (Other WANA, Rest Former USSR, Other Latin America and Eastern Europe) and two individual countries (Egypt and Indonesia) are projected to be the most important exporters of N fertilizer through 2022. The USA, Europe (EU 15), India, Mexico, Turkey, Thailand and Brazil are projected to be the most important importers of these fertilizers through 2022.

Regarding trends in exports and imports, it is useful to note the following:

- Exporting countries in the Rest of the Former USSR (Belarus, Russia Federation, Ukraine) and those in Other WANA (Persian Gulf) countries and Egypt and Australia are projected to experience positive trends in exportable surpluses through 2022. Exporting countries in Other Latin America, Eastern Europe and in the Other Developed group as well as Indonesia are projected to experience significant negative average annual linear trends.
- Importing countries such as India and the USA are projected to experience substantial increases in net imports of N fertilizers through 2025. That is, in

terms of average linear trends of imports expansion, about 368,100 tons/year for India and 178,500 tons/year for the USA. Volumes of imports by Europe (EU 15) will remain relatively stable. Linear import trends calculated for all other sub-regions and countries classified as "importers through 2025" in Table 4.8 show that all of them will experience increases in volumes of imports through 2022. These trends range from 1,900 tons/year in the Other Southeast Asia sub-region to 66,800 tons/year in Pakistan and 50,000 tons/year in Brazil.

V. Trends in the Market for Phosphate (P) Fertilizers

Estimates produced by the FertTrade model are used here to project and evaluate through 2022-2025 the quantities of fertilizer P that will be demanded, produced/supplied and traded (imported or exported) by each of the mutually exclusive units representing individual countries and groups of countries (sub-regions) specified in the model. Fertilizer P quantities are measured in terms of P_2O_5 quantities. Estimates of world, regional and country/sub-regional projections produced by the FertTrade model are used to conduct analyses and assessments at three levels of aggregation.

A. World Demand and Supply Projections for P Fertilizers

Projections of the world demand for, and supply of, fertilizer P produced by the FertTrade model through 2025 are depicted in Figure 5.1. These projections and estimates of projected adjustments in P_2O_5 world supply required to meet projected demand shown in Figure 5.2 indicate that supply increases will be required through expansions in production capacity and changes in rates of production capacity utilization. Projected growth in the world demand for P fertilizers indicates that the demand will expand from about 38.7 million tons of P_2O_5 in 2005 to about 43.9 million tons in 2012 and 51.5 million tons in 2022, an increase of about 17 percent over the next decade. To meet the projected growth in demand for fertilizer P through 2025, the global production capacity and supply of P fertilizers will have to be expanded substantially more than what is currently planned. The model estimates of required adjustments in P_2O_5 world supply to meet demand illustrated in Figure 5.2 show projected expansions of the world's production capacities by 2.7, 2.3, 2.4 and 2.5 million tons P_2O_5 in 2012, 2015, 2018 and 2021, respectively. Unless production capacity is increased beyond what is currently planned, shortages in the supply of P fertilizers will seriously affect agricultural production and food supplies in most countries, particularly in developing countries depending on imports of P fertilizers.

B. Regional Analysis of Demand, Supply and Trade of P Fertilizers

Demand and supply projections and associated supply-demand balances of P fertilizers for 2012, 2017 and 2022 estimated by the FertTrade model are presented in Table 5.1 for the Developed Countries group and the six geographic regions included in the model. These results are illustrated in Figures 5.3 and 5.4 and are used in this section to conduct the regional analysis and

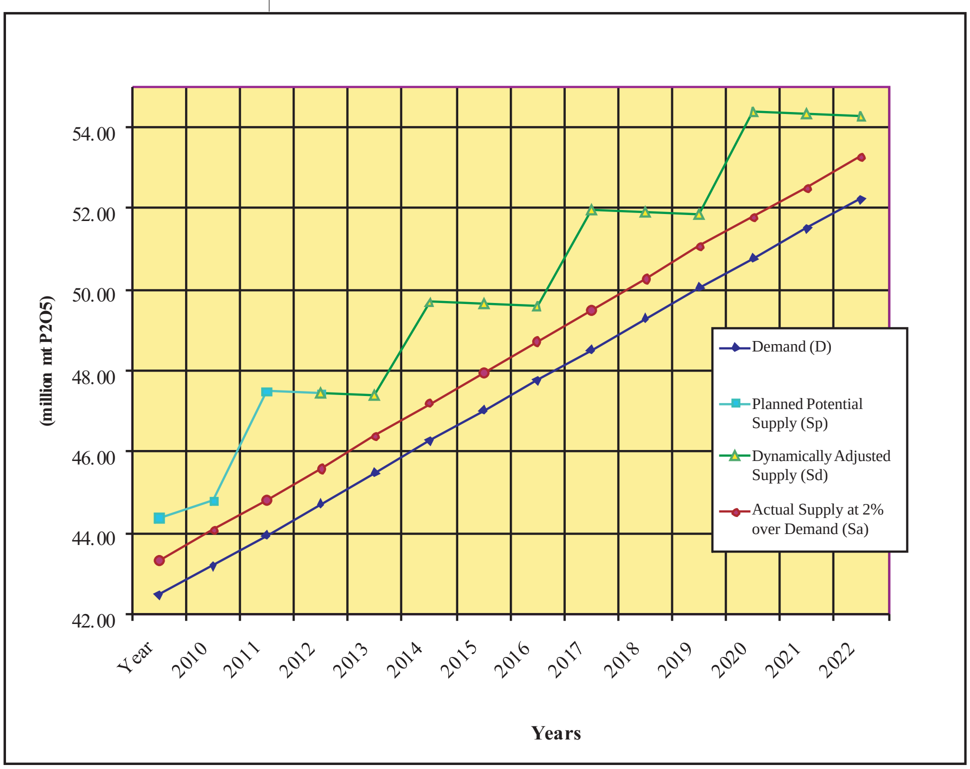


Figure 5.1. World Demand and Supply Projections of Fertilizer P

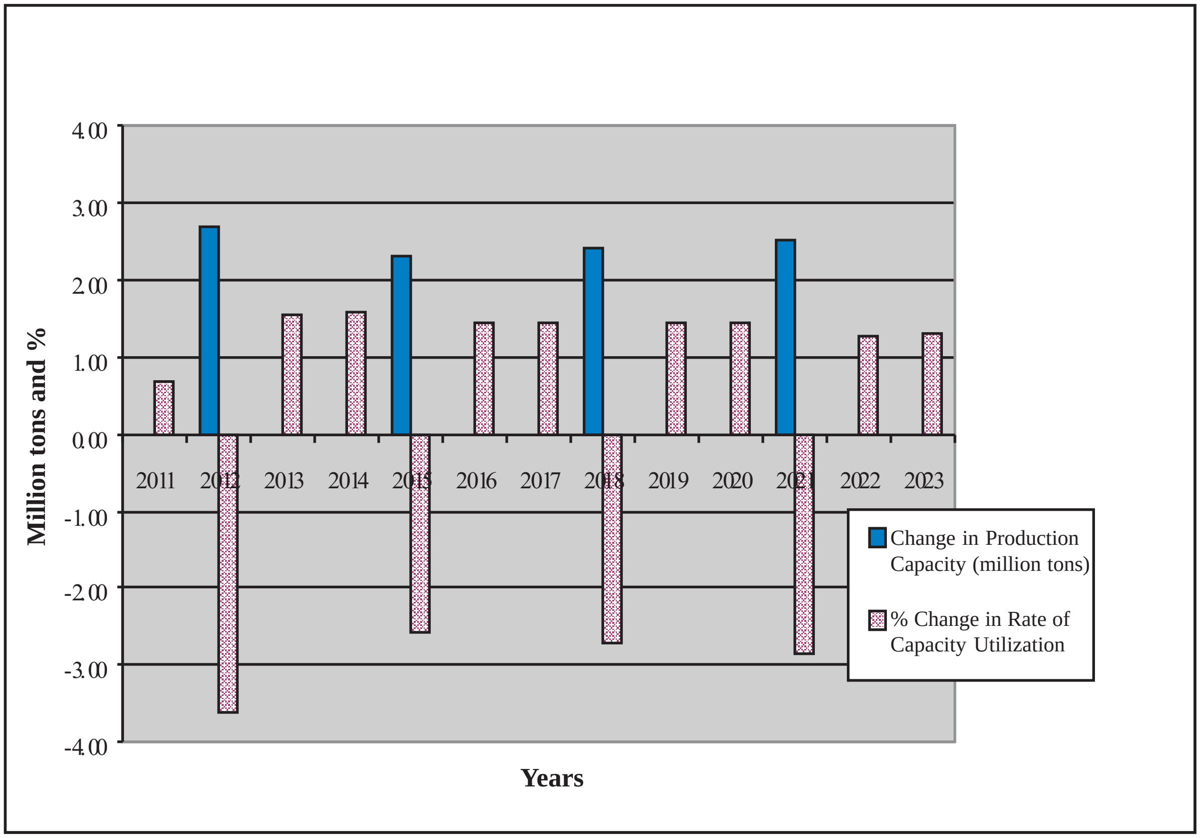


Figure 5.2. Adjustments in P_2O_5 World Supply to Meet Projected Demand

assessment. Several observations and conclusions drawn from these projections are presented and discussed in the following paragraphs.

First, demand and supply projections indicate that East Asia, the WANA region and the Developed Countries group are and will remain the most important world producers and suppliers of P fertilizer. East Asia and the Developed Countries group are projected to continue as the most important consumers of fertilizer P through 2022. Because of growth in consumption, regional surpluses will decline, becoming negative for East Asia by 2017. The WANA region will experience the highest increase in production of fertilizer P – about a 60 percent increase between 2012 and 2022 – to become the world's dominant region producing and supplying fertilizer P to other world regions. Most of the 2012-2022 projected world expansion in P fertilizers production capacity (about 6.8 million tons P_2O_5) will take place in the WANA region.

Second, trends of regional supply-demand balances for P fertilizers illustrated on Figure 5.4 show substantial differences among regions. The Developed Countries group and the WANA region will continue to be the main exporting regions through 2022. However, regional surpluses in the Developed Countries group are projected to decline through 2022, from 4.2 million tons P_2O_5 in 2012 to 1.3 million tons P_2O_5 in 2022. Such trends and the projected 2012-2022 increase of the WANA region's annual surplus from about 8.1 to 13.7 million tons P_2O_5 will substantially enhance the relative importance of the WANA region as the world's dominant exporting region. The SSA region as a whole is projected to continue to be a net exporter of P_2O_5. However, this projection could easily be reversed if some of the projected regional expansion in production capacity and supply is not realized and rapid growth in demand for fertilizer P takes place to increase current low crop yields and improve soil fertility. It should be noted that in SSA there is need for improving intra-regional trade of P fertilizers.

Third, as shown in Figure 5.4, Latin America, South Asia, East Asia and Southeast Asia are projected to be fertilizer P importing regions through 2022. Imports by Latin America and South Asia are projected to increase continuously from about 3.6 and 4.0 million tons P_2O_5 in

Table 5.1. Regional Fertilizer P_2O_5 Demand and Supply Projections for 2012, 2017 and 2022

Year	Country Groups and Regions	Projected Demand	Projected Supply	Supply-Demand Balance	Volume of Trade	Imports as Percent of Demand
		('000 mt of P_2O_5)				(%)
2012	WANA	2,214	10,272	8,057		
	Developed Countries	14,216	18,438	4,222		
	East Asia	12,618	11,135	-1,483	1,483	11.8
	South Asia	6,929	2,914	-4,015	4,015	57.9
	Southeast Asia	2,090	924	-1,165	1,165	55.8
	Latin America	5,057	1,492	-3,565	3,565	70.5
	Sub-Saharan Africa	763	2,328	1,565		
	Rest of the World	69	0	-69	69	100.0
	World	43,955	47,503		10,296	23.4
	World Excess Supply Capacity			3,548		
2017	WANA	2,444	11,413	8,969		
	Developed Countries	14,841	17,921	3,079		
	East Asia	13,640	12,201	-1,439	1,439	10.5
	South Asia	7,757	3,118	-4,638	4,638	59.8
	Southeast Asia	2,298	980	-1,319	1,319	57.4
	Latin America	5,741	1,514	-4,227	4,227	73.6
	Sub-Saharan Africa	963	2,447	1,484		
	Rest of the World	77	0	-77	77	100.0
	World	47,761	49,593		11,699	24.5
	World Excess Supply Capacity			1,833		
2022	WANA	2,678	16,425	13,747		
	Developed Countries	15,432	16,745	1,313		
	East Asia	14,521	12,200	-2,321	2,321	16.0
	South Asia	8,598	3,582	-5,016	5,016	58.3
	Southeast Asia	2,514	1,105	-1,409	1,409	56.1
	Latin America	6,462	1,565	-4,897	4,897	75.8
	Sub-Saharan Africa	1,205	2,717	1,512		
	Rest of the World	85	0	-85	85	100.0
	World	51,496	54,340		13,727	26.7
	World Excess Supply Capacity			2,844		

2012 to about 4.9 and 5.0 million tons P_2O_5 in 2022, respectively. Imports by East Asia are projected to be about 1.5 and 2.3 million tons P_2O_5 in 2012 and 2022, respectively. Projections for this region are due mainly to expected changes in the demand and production of P fertilizers in China. The Southeast Asia region is expected to remain a net importer of P fertilizers. Inflows of fertilizer P into this region are projected to increase from about 1.2 to 1.4 million tons P_2O_5 between 2012 and 2022.

Fourth, a significantly increased volume of "inter-regional trade" in P fertilizers – inflows and outflows of fertilizer P – will continue to take place between surplus and deficit regions. Such "inter-regional trade" will take place through commercial trade between surplus countries in a region and deficit countries in another. Inter-regional trade of P fertilizers is projected to increase from 10.3 million tons P_2O_5 or 23.4 percent of the world's demand in 2012 to 13.7 million tons P_2O_5 or 26.7 percent of the world's demand in 2022.

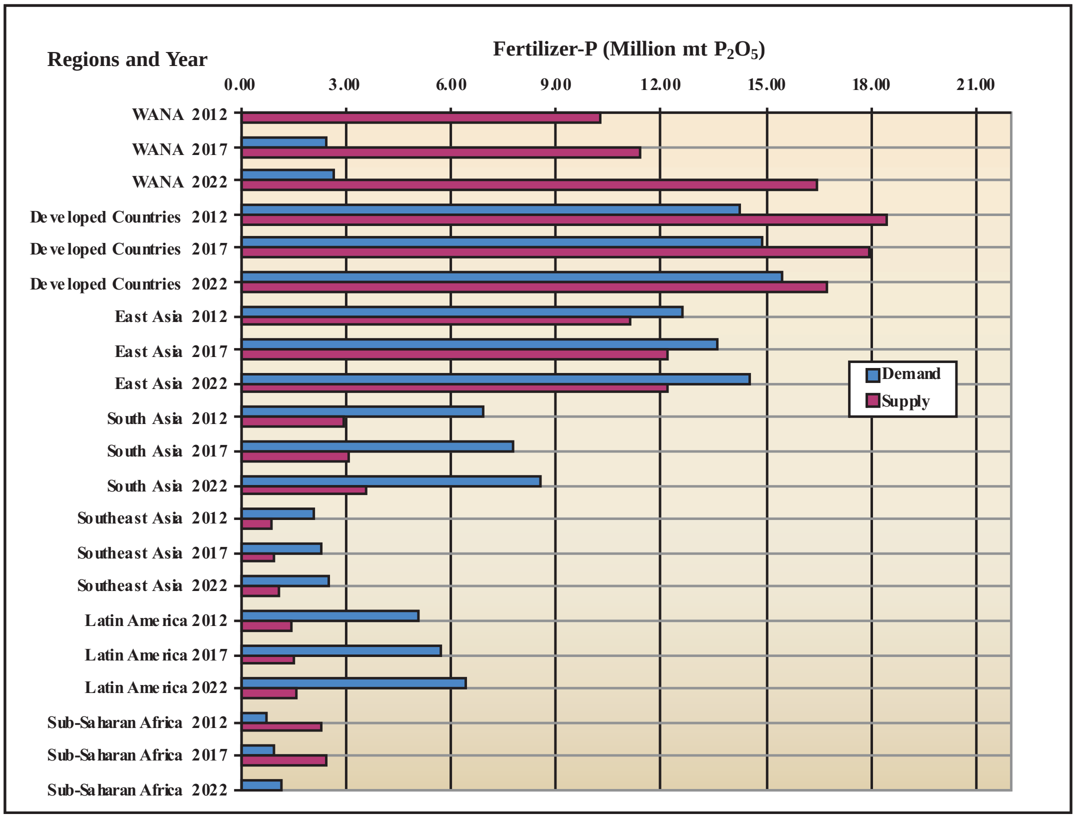


Figure 5.3. Regional Supply and Demand Projections for Fertilizer P

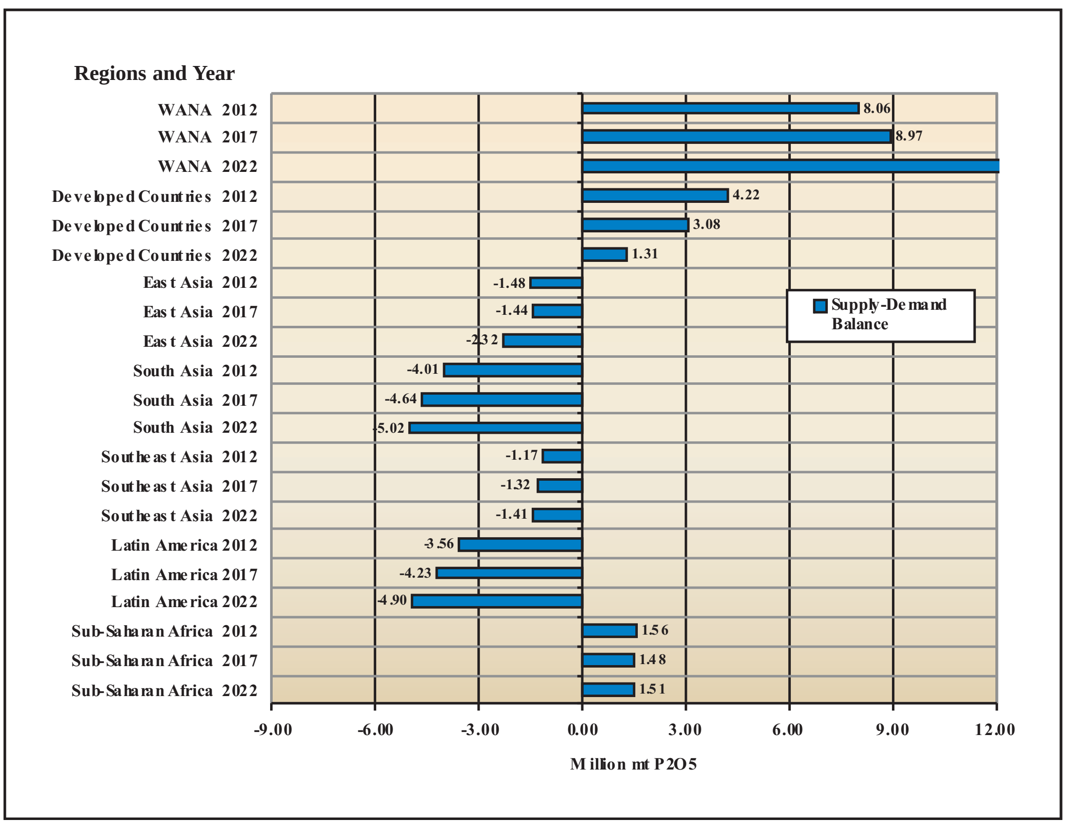


Figure 5.4. Projected Regional Supply-Demand Balances for Fertilizer P

Additional observations drawn from the global shares of the regional supply and demand projections for P fertilizers shown in Table 5.2 for 2012, 2017 and 2022 are discussed in the following paragraphs.

1. Three regional units, the Developed Countries group and the East Asia and WANA regions, are the largest producers of P fertilizers accounting for 83-84 percent of the projected world production and supply through 2022. The Developed Countries and East Asia groups are also the two most important regions in terms of P fertilizer consumption accounting for about 58-61 percent of the projected global demand. Three regional units, the Developed Countries group and the East Asia and WANA regions together are projected to account for at least 83 percent of the

Table 5.2. Global Shares of Projected Regional Fertilizer P_2O_5 Demand and Supply in 2012, 2017 and 2022

Year	Regions	Projected P_2O_5 Demand			Projected Dynamically Adjusted P_2O_5 Supply		
			Share	Cumulative Share		Share	Cumulative Share
		('000 mt)	(%)	(%)	('000 mt)	(%)	(%)
2012	Developed Countries	14,216	32.3	32.3	18,438	38.8	38.8
	East Asia	12,618	28.7	61.0	11,135	23.4	62.3
	West Asia/North Africa	2,214	5.0	66.1	10,272	21.6	83.9
	South Asia	6,929	15.8	81.8	2,914	6.1	90.0
	Sub-Saharan Africa	763	1.7	83.6	2,328	4.9	94.9
	Latin America	5,057	11.5	95.1	1,492	3.1	98.1
	Southeast Asia	2,090	4.8	99.8	924	1.9	100.0
	Rest of the World	69	0.2	100.0	0	0.0	100.0
	World	43,955	100		47,503	100	
	World Excess Supply Capacity				3,548	7.5	
2017	Developed Countries	14,841	31.1	31.1	17,921	36.1	36.1
	East Asia	13,640	28.6	59.6	12,201	24.6	60.7
	West Asia/North Africa	2,444	5.1	64.8	11,413	23.0	83.7
	South Asia	7,757	16.2	81.0	3,118	6.3	90.0
	Sub-Saharan Africa	963	2.0	83.0	2,447	4.9	95.0
	Latin America	5,741	12.0	95.0	1,514	3.1	98.0
	Southeast Asia	2,298	4.8	99.8	980	2.0	100.0
	Rest of the World	77	0.2	100.0	0	0.0	100.0
	World	47,761	100.0		49,593	100.0	
	World Excess Supply Capacity				1,833	3.7	
2022	Developed Countries	15,432	30.0	30.0	16,745	30.8	30.8
	West Asia/North Africa	2,678	5.2	35.2	16,425	30.2	61.0
	East Asia	14,521	28.2	63.4	12,200	22.5	83.5
	South Asia	8,598	16.7	80.1	3,582	6.6	90.1
	Sub-Saharan Africa	1,205	2.3	82.4	2,717	5.0	95.1
	Latin America	6,462	12.5	95.0	1,565	2.9	98.0
	Southeast Asia	2,514	4.9	99.8	1,105	2.0	100.0
	Rest of the World	85	0.2	100.0	0	0.0	100.0
	World	51,496	100.0		54,340	100.0	
	World Excess Supply Capacity				2,844	5.2	

world's supply and 63 percent of the world's demand from 2012 through 2022.

2. Although the WANA region accounts for only 5 percent of the global demand for P fertilizers, this is one of the most important regions producing and supplying P fertilizers. The region is projected to account for 21.6 percent of the global production/supply in 2012, 23 percent in 2017 and to reach a global share of 30.2 percent by 2022. Moreover, as is clearly illustrated by the projected estimates of regional supply-demand balances shown on Figure 5.4, the WANA region is expected to become the most dominant P fertilizer surplus-exporting region globally. This region's share in the total global exportable surplus of fertilizer P to other regions is estimated to increase from about 8.0 million tons P_2O_5 in 2012 to about 9.0 and 13.7 million tons P_2O_5 in 2017 and 2022, respectively. Therefore, unless production capacity is significantly increased in other regions where low cost raw materials may also be available, the WANA region will increase its dominance in the export market for P fertilizers through 2022 and beyond.

C. Sub-Regional Analysis of P Fertilizer Demand, Supply and Trade

Estimates produced by the FertTrade model on the projected country/sub-regional demand and supply situation for P fertilizers in 2012, 2017 and 2022 are summarized in Table 5.3. These estimates are used in the following sub-sections to discuss trends in the demand, supply and supply-demand balances and trade of fertilizer P in key countries and sub-regions through 2025.

Demand Projections and Trends Through 2025 – Estimates of growth in demand for P fertilizers through 2025 derived from the FertTrade model's demand projections by countries and sub-regions are presented in Table 5.4 and further summarized by major country groups and regions in Table 5.5. The projected 2005-2025 amounts of increased demand in thousands of metric tons of P_2O_5 and corresponding exponential annual growth rates presented in these tables are used to draw the following observations and conclusions.

1. China, India, Brazil and the USA are projected to experience the largest 2005-2025 increases in quantities demanded for P fertilizers. In this 20-year period, P fertilizer demand in China, India, Brazil and the USA is projected to increase by about 3.6, 2.6, 1.6 and 1.0 million tons of P_2O_5, respectively. However, in terms of annual rates of growth, P fertilizer demand is projected to grow faster in Brazil (2.5 percent) and India (2.2 percent) than in China (1.5 percent) and the USA (1 percent). It should be noted that the estimated rates of growth in the demand for N, P and K fertilizers are very similar because in the model, N:P:K ratios of the derived quantity demanded of fertilizer nutrients are determined mainly by the relative distribution of crop production in each country/sub-region. This is not projected to vary significantly across years (baseline scenario).
2. Nigeria, Vietnam and the four sub-regions of SSA are projected to experience the highest rates of growth in the demand for P fertilizer. This is due in part to the current low levels of fertilizer use in these countries and sub-regions and the evidence of substantial potential for expansion in the adoption and use of fertilizers. These countries and sub-regions are projected to experience annual rates of growth of 3.3 percent to 5.5 percent through 2025. The need for improvements in crop yields and agricultural productivity and the expansion in crop areas will be the main sources of growth in demand for fertilizer in these countries and sub-regions.
3. Increases in demand for P fertilizers between 2005 and 2025 estimated in terms of quantities of P_2O_5 and growth rates calculated for two mutually exclusive groups of countries, one comprising developing countries and another for developed countries and for eight other selected regional and sub-regional groups of countries, are summarized in Table 5.5. The following observations are made on the basis of these estimates.
   a. About 83 percent, or 11.8 million tons, P_2O_5 of the global 2005-2025 increase in P fertilizer demand will take place in the developing countries. The corresponding projected increase in the developed countries will be substantially smaller, about 2.3 million tons P_2O_5 of P fertilizers, or about 17 percent of the projected global increase in demand.
   b. The Asian sub-regions of East Asia, South Asia and Southeast Asia account for 26 percent, 21 percent and 6 percent, respectively, of the projected 2005-2025 increase in the global demand for P fertilizer. Thus, the All Asia region is expected to contribute 53 percent, or about 7.5 million tons, P_2O_5 to the global 2005-2025 expansion in demand for P fertilizer. The Latin America

Table 5.3. Projected Fertilizer P_2O_5 Demand, Supply and Balances by Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	2012			2017			2022		
	Demand	Supply	Supply-Demand Balances	Demand	Supply	Supply-Demand Balances	Demand	Supply	Supply-Demand Balances
	('000 mt of P_2O_5)								
USA	5,049	7,565	2,515	5,318	7,031	1,713	5,572	5,819	247
Europe (EU 15)	3,740	433	-3,307	3,773	379	-3,395	3,797	255	-3,542
Japan	584	393	-191	584	393	-191	583	393	-191
Australia	1,407	570	-837	1,506	607	-899	1,600	690	-909
Other Developed	1,761	1,849	88	1,881	1,842	-39	1,995	1,825	-170
Eastern Europe	796	1,595	799	851	1,618	767	907	1,671	764
Central Asia	215	1,323	1,108	232	1,322	1,090	248	1,320	1,071
Rest Former USSR	663	4,711	4,048	697	4,730	4,033	730	4,773	4,043
Mexico	370	250	-120	412	248	-164	455	245	-210
Brazil	3,073	1,203	-1,870	3,492	1,229	-2,263	3,932	1,288	-2,644
Argentina	510	0	-510	600	0	-600	699	0	-699
Colombia	175	0	-175	194	0	-194	213	0	-213
Other Latin America	928	39	-889	1,044	37	-1,007	1,163	32	-1,131
Nigeria	50	0	-50	67	0	-67	87	0	-87
Northern SSA	190	0	-190	223	0	-223	261	0	-261
Central & Western SSA	160	576	416	209	575	366	270	574	304
Southern SSA	190	1,734	1,543	243	1,853	1,611	306	2,125	1,819
Eastern SSA	173	18	-154	221	18	-203	281	17	-264
Egypt	181	678	497	197	834	637	212	1,189	976
Turkey	810	421	-389	887	418	-470	965	410	-556
Other West Asia/North Africa	1,223	9,173	7,950	1,360	10,161	8,801	1,501	14,827	13,326
India	5,776	2,894	-2,882	6,463	3,099	-3,365	7,160	3,563	-3,597
Pakistan	838	0	-838	947	0	-947	1,058	0	-1,058
Bangladesh	153	20	-133	166	20	-146	178	19	-159
Other South Asia	162	0	-162	181	0	-181	201	0	-201
Indonesia	368	149	-219	399	149	-250	430	148	-281
Thailand	526	191	-335	561	190	-371	597	189	-408
Malaysia	310	0	-310	334	0	-334	358	0	-358
Philippines	209	375	167	231	375	144	253	374	121
Vietnam	567	209	-358	638	265	-373	711	393	-318
Myanmar	75	0	-75	96	0	-96	122	0	-122
Other Southeast Asia	35	0	-35	39	0	-39	44	0	-44
China	12,345	10,762	-1,583	13,352	11,828	-1,525	14,220	11,828	-2,392
South Korea	246	373	127	258	373	115	270	373	103
Other East Asia	27	0	-27	29	0	-29	32	0	-32
Rest of the World	69	0	-69	77	0	-77	85	0	-85
World	43,955	47,503	3,548	47,761	49,593	1,833	51,496	54,340	2,844

Table 5.4. Projected 2005–2025 Demand Growth for Fertilizer P in Key Countries and Sub-Regions

Countries and Sub-Regions Ranked by Size of Demand Increase	P_2O_5 Demand Increase 2005–2025	Annual Growth Rate	Countries and Sub-Regions Ranked by Size of Growth Rate	P_2O_5 Demand Increase 2005–2025	Annual Growth Rate
	('000 mt)	(%)		('000 mt)	(%)
33. China	3,607	1.5	14. Nigeria	63	5.5
22. India	2,579	2.2	16. Central & Western Sub-Saharan Africa	188	5.3
10. Brazil	1,575	2.5	18. Eastern Sub-Saharan Africa	189	5.0
1. USA	1,019	1.0	30. Vietnam	81	4.9
21. Other West Asia/North Africa	516	2.1	17. Southern Sub-Saharan Africa	202	4.8
5. Other Developed	447	1.3	15. Northern Sub-Saharan Africa	128	3.3
13. Other Latin America	436	2.3	11. Argentina	340	3.2
23. Pakistan	408	2.4	10. Brazil	1,575	2.5
4. Australia	371	1.4	23. Pakistan	408	2.4
11. Argentina	340	3.2	13. Other Latin America	436	2.3
20. Turkey	290	1.8	29. Philippines	263	2.3
29. Philippines	263	2.3	32. Other Southeast Asia	16	2.3
6. Eastern Europe	208	1.3	22. India	2,579	2.2
17. Southern Sub-Saharan Africa	202	4.8	31. Myanmar	72	2.2
18. Eastern Sub-Saharan Africa	189	5.0	36. Rest of the World	30	2.1
16. Central & Western Sub-Saharan Africa	188	5.3	9. Mexico	157	2.1
9. Mexico	157	2.1	21. Other West Asia/North Africa	516	2.1
26. Indonesia	135	1.3	12. Colombia	71	2.0
15. Northern Sub-Saharan Africa	128	3.3	28. Malaysia	83	2.0
8. Rest Former USSR	128	1.0	20. Turkey	290	1.8
2. Europe (EU 15)	124	0.2	19. Egypt	60	1.7
25. Other South Asia	116	1.6	25. Other South Asia	116	1.6
27. Thailand	92	1.5	24. Bangladesh	48	1.6
28. Malaysia	83	2.0	35. Other East Asia	8	1.5
30. Vietnam	81	4.9	27. Thailand	92	1.5
31. Myanmar	72	2.2	33. China	3,607	1.5
12. Colombia	71	2.0	7. Central Asia	62	1.5
14. Nigeria	63	5.5	4. Australia	371	1.4
7. Central Asia	62	1.5	6. Eastern Europe	208	1.3
19. Egypt	60	1.7	26. Indonesia	135	1.3
24. Bangladesh	48	1.6	5. Other Developed	447	1.3
34. South Korea	45	0.9	1. USA	1,019	1.0
36. Rest of the World	30	2.1	8. Rest Former USSR	128	1.0
32. Other Southeast Asia	16	2.3	34. South Korea	45	0.9
35. Other East Asia	8	1.5	2. Europe (EU 15)	124	0.2

region is projected to contribute 18 percent, or about 2.6 million tons, P_2O_5 to such expansion. Shares of the WANA, the Former USSR sub-regions and the SSA region on the projected 2005-2025 global expansion in demand for P fertilizers are substantially smaller and account for only 6 percent, 1 percent and 5 percent, respectively.

c. In terms of estimated 2005-2025 P fertilizer demand growth rates, the SSA and Latin America regions are expected to experience the highest growth rates, 4.63 percent and 2.53 percent, respectively. Demand in Developing Countries is projected to grow at a rate of 2 percent, more than twice as fast as in Developed Countries (0.86 percent).

Table 5.5. Projected 2005–2025 Demand Growth for Fertilizer P by Country Groups and Regions

Country Groups and Regions Ranked by Size of Demand Increase	P_2O_5 Demand Increase 2005–2025	Share in Global Increase	Annual Exponential Growth Rate	Country Groups and Regions Ranked by Size of Growth Rate	P_2O_5 Demand Increase 2005–2025	Annual Exponential Growth Rate
	('000 mt)	(%)	(%)		('000 mt)	(%)
Developing Countries	11,798	83	2.00	Sub-Saharan Africa	770	4.63
All Asia	7,553	53	1.78	Latin America	2,579	2.53
East Asia	3,660	26	1.49	South Asia	3,107	2.25
South Asia	3,107	21	2.25	Developing Countries	11,798	2.00
Latin America	2,579	18	2.53	West Asia/North Africa	866	1.97
Developed Countries	2,359	17	0.86	Southeast Asia	786	1.89
West Asia/North Africa	866	6	1.97	All Asia	7,553	1.78
Southeast Asia	786	6	1.89	East Asia	3,660	1.49
Sub-Saharan Africa	770	5	4.63	Former USSR	190	1.11
Former USSR	190	1	1.11	Developed Countries	2,359	0.86

4. In order to evaluate countries and sub-regions in terms of their relative importance as markets of P fertilizers, the model's 36 countries and sub-regions ranked by their three-year (2012, 2017 and 2022) average share in global demand are presented in Table 5.6. This ranked list of countries and sub-regions is used to classify into *large-size, medium-size* and *small-size markets* for P fertilizers. Results presented on this table are discussed in the following paragraphs.
   a. ***Large-Size Markets for P Fertilizers*** – Four countries, China, India, the USA and Brazil, and one sub-region, Europe (EU 15), are projected to remain as the largest markets for P fertilizers through 2025. These four countries and sub-region are classified here as *large-size markets* and together they are projected to account for about 68 percent of the global market for P fertilizers. However, the global demand shares of these four countries and sub-region are not projected to follow the same 2005-2025 trends. China's share in the global market for P fertilizers is expected to remain at about 27-28 percent, whereas India's and the USA shares are projected to remain at about 13-14 percent and 10-11 percent, respectively, and those of Europe (EU 15) and Brazil at 7-8 percent. Variations in trends of P fertilizer demand among countries and sub-regions are explained mainly by variations in trends of crop areas harvested, crop yields and crop and livestock patterns of production among countries and sub-regions. Historical trends and projections built into the scenario variables of the IMPACT model influence such variations.
   b. ***Medium- and Small-Size Markets*** – *Medium-size markets* are those countries and sub-regions having global P fertilizer demand shares lower than 8 percent but no less than 1 percent. *Small-size markets* are those having market shares of less than 1 percent. Additional observations are made about the relative importance of these markets on the global demand for P fertilizers. Namely, that 12 countries and sub-regions with *medium-size markets* are projected to account for 24.2 percent of the global demand for P fertilizers through 2022. Nineteen countries and sub-regions with *small-size markets* will account for only 7.6 percent and 8.4 percent of the global demand in 2012 and 2022, respectively. However, it should be noted that most of the individual countries included as part of sub-regions (Other WANA, Other Latin America, Eastern Europe and Rest Former USSR) are, in fact, *small-size markets* with demand shares of less than 1 percent of the global market for P fertilizers. Then, if such a fact is accounted for, the actual share of all individual countries with *medium-size markets* is only 15 percent (rather than 24.2 percent) while the share of *small-size market countries* increases from about 9 percent to 17 percent of the world demand. These projections show that, on average, through 2022, about 68 percent, 15 percent and 17 percent

Table 5.6. Countries and Sub-Regions Ranked by Their Average Shares in the Global Demand for P_2O_5 Fertilizer in 2012, 2017 and 2022

Countries and Sub-Regions	Demand Shares 2012	Demand Shares 2017	Demand Shares 2022	Average Demand Shares	Cumulative Demand Shares
	(%)	(%)	(%)	(%)	(%)
China	28.1	28.0	27.6	27.9	27.9
India	13.1	13.5	13.9	13.5	41.4
USA	11.5	11.1	10.8	11.1	52.5
Europe (EU 15)	8.5	7.9	7.4	7.9	60.4
Brazil	7.0	7.3	7.6	7.3	67.8
Total Large-Size Markets	68.2	67.8	67.3	67.8	
Other Developed	4.0	3.9	3.9	3.9	71.7
Australia	3.2	3.2	3.1	3.2	74.9
Other West Asia/North Africa	2.8	2.8	2.9	2.9	77.7
Other Latin America	2.1	2.2	2.3	2.2	79.9
Pakistan	1.9	2.0	2.1	2.0	81.9
Turkey	1.8	1.9	1.9	1.9	83.7
Eastern Europe	1.8	1.8	1.8	1.8	85.5
Rest Former USSR	1.5	1.5	1.4	1.5	87.0
Vietnam	1.3	1.3	1.4	1.3	88.3
Argentina	1.2	1.3	1.4	1.3	89.6
Japan	1.3	1.2	1.1	1.2	90.8
Thailand	1.2	1.2	1.2	1.2	92.0
Total Medium-Size Markets	24.1	24.2	24.3	24.2	
Mexico	0.8	0.9	0.9	0.9	92.9
Indonesia	0.8	0.8	0.8	0.8	93.7
Malaysia	0.7	0.7	0.7	0.7	94.4
South Korea	0.6	0.5	0.5	0.5	94.9
Southern SSA	0.4	0.5	0.6	0.5	95.4
Central Asia	0.5	0.5	0.5	0.5	95.9
Philippines	0.5	0.5	0.5	0.5	96.4
Eastern SSA	0.4	0.5	0.5	0.5	96.9
Northern SSA	0.4	0.5	0.5	0.5	97.4
Central & Western SSA	0.4	0.4	0.5	0.4	97.8
Egypt	0.4	0.4	0.4	0.4	98.2
Colombia	0.4	0.4	0.4	0.4	98.6
Other South Asia	0.4	0.4	0.4	0.4	99.0
Bangladesh	0.3	0.3	0.3	0.3	99.3
Myanmar	0.2	0.2	0.2	0.2	99.6
Rest of the World	0.2	0.2	0.2	0.2	99.7
Nigeria	0.1	0.1	0.2	0.1	99.9
Other Southeast Asia	0.1	0.1	0.1	0.1	99.9
Other East Asia	0.1	0.1	0.1	0.1	100.0
Total Small-Size Markets	7.6	8.0	8.4	8.0	

of the world demand for P fertilizers will take place in countries with *large-, medium-* and *small-size markets*, respectively. *Small-size markets* are often a serious constraint to the production and supply of fertilizers in many developing countries. However, because the production of P fertilizers depends essentially on the availability of sufficient quantities of phosphate rock, production for exports can take place even in countries with very small domestic markets for P fertilizers.

Trends in Production and Supply – Production/supply shares of the 36 countries and sub-regions on the global P fertilizer production/supply in 2012, 2017 and 2022 derived from estimates of the dynamically adjusted levels of fertilizer P production and supply generated by FertTrade for each of the 36 countries and sub-regions are presented in Table 5.7. The methodology used by the model to produce these supply estimates is described above and takes into consideration the availability of phosphate rock resources and raw materials and the historical record and trends in P-fertilizer production capacity building and supply of the countries and sub-regions.

Observations and conclusions drawn on the basis of the model's dynamically adjusted supply projections presented in Table 5.7 are discussed in the following paragraphs.

Large-Size Producers and Suppliers – Supply shares of the 36 countries/sub-regions on the world P fertilizer supply in 2012, 2017 and 2022 are used to rank and list them by the size of their three-year (2012, 2017 and 2022) average share. Countries and sub-regions are further classified into three groups of P fertilizer suppliers (producers); *large-size suppliers* with global shares greater than 6 percent, *medium-size suppliers* with global shares lower than 6 percent but higher than 1.5 percent, and *small-size suppliers* with positive shares in the global supply lower than 1.5 percent are presented in Table 5.7. Three countries – China, India and the USA – and two sub-regions, Other WANA (including Morocco) and Rest Former USSR (including Belarus, Russia and Ukraine), are classified as *large-size suppliers* of P fertilizers. Together, they are projected to account for about 74 percent of the world production and supply of P fertilizers through 2022. World supply shares of these countries and sub-regions are not projected to follow the same 2012-2022 trends. The USA share is projected to decline substantially from about 16 percent in 2012 to 10.7 percent in 2022, while shares of China, India and the Rest Former USSR sub-region will remain around 22-23 percent, 6.3 percent and 9-10 percent, respectively. The global share of the Other WANA sub-region will increase significantly from 19.3 percent in 2012 to 27.3 percent in 2022.

Medium-Size Producers and Suppliers – This group comprises four sub-regions – Other Developed countries (including Canada and South Africa), Southern SSA (including Angola, Mozambique and Zimbabwe), Eastern Europe and Central Asia – and two individual countries, Brazil and Egypt. These four sub-regions and two individual countries together are projected to account for about 17.5 percent of the global P fertilizer production and supply through 2022. Unless unforeseen expansion of production capacity takes place, the supply share of these four sub-regions and two countries together is projected not to change significantly through 2022.

Small-Size Producers and Suppliers – This group includes four sub-regions and 10 individual countries. The sub-regions are Europe (EU 15), Other Latin America, Eastern SSA and Central and Western SSA. The 10 individual countries that are classified as *small-size suppliers* of P fertilizers include Australia, Bangladesh, Indonesia, Japan, Mexico, Philippines, South Korea, Thailand, Turkey and Vietnam. The group of sub-regions and countries, which are small-size producers and suppliers of P fertilizers, are projected to account for about 8 percent of the global supply of P fertilizers in 2015 and 2025. However, most of the countries that are part of the Central Asia and Southern SSA and classified as *medium-size suppliers* are, in fact, *small-size producers and suppliers*. Then, by taking this fact into account, only about 12 percent (rather than 18 percent) of the global supply will actually be produced by countries that are *medium-size producers/suppliers*, about 14 percent (rather than 8 percent) by *small-size producers/suppliers* and 74 percent by countries that may be considered as *large-size producers/suppliers.*

It is important to note that most of the required expansion in production capacity and supply of P fertilizers between 2012 and 2022 (about 7.4 million tons of P_2O_5) is projected to take place in the Other WANA sub-region (5.7 million tons P_2O_5). This sub-region will have an increasingly more dominant role in the global supply of P fertilizers as will China and India with increases of 1.1 and 0.6 million tons of P_2O_5.

Table 5.7. Countries and Sub-Regions Ranked by Their Average Shares in the Projected Global Supply of Fertilizer P_2O_5 in 2012, 2017 and 2022

Countries and Sub-Regions	2012 Supply	2012 Supply Shares	2017 Supply	2017 Supply Shares	2022 Supply	2022 Supply Shares	Average Supply Shares	Cumulative Supply Shares
	('000 mt P_2O_5)	(%)	('000 mt P_2O_5)	(%)	('000 mt P_2O_5)	(%)	(%)	(%)
China	10,762	22.7	11,828	23.8	11,828	21.8	22.8	22.8
Other West Asia/North Africa	9,173	19.3	10,161	20.5	14,827	27.3	22.4	45.1
USA	7,565	15.9	7,031	14.2	5,819	10.7	13.6	58.7
Rest Former USSR	4,711	9.9	4,730	9.5	4,773	8.8	9.4	68.1
India	2,894	6.1	3,099	6.2	3,563	6.6	6.3	74.4
Total Large-Size Suppliers	35,104	73.9	36,848	74.3	40,809	75.1	74.4	
Other Developed	1,849	3.9	1,842	3.7	1,825	3.4	3.7	78.1
Southern SSA	1,734	3.6	1,853	3.7	2,125	3.9	3.8	81.9
Eastern Europe	1,595	3.4	1,618	3.3	1,671	3.1	3.2	85.1
Central Asia	1,323	2.8	1,322	2.7	1,320	2.4	2.6	87.7
Brazil	1,203	2.5	1,229	2.5	1,288	2.4	2.5	90.2
Egypt	678	1.4	834	1.7	1,189	2.2	1.8	91.9
Total Medium-Size Suppliers	8,382	17.6	8,698	17.5	9,417	17.3	17.5	
Central & Western SSA	576	1.2	575	1.2	574	1.1	1.1	1.1
Australia	570	1.2	607	1.2	690	1.3	1.2	2.4
Europe (EU 15)	433	0.9	379	0.8	255	0.5	0.7	3.1
Turkey	421	0.9	418	0.8	410	0.8	0.8	3.9
Japan	393	0.8	393	0.8	393	0.7	0.8	4.7
Philippines	375	0.8	375	0.8	374	0.7	0.7	5.4
South Korea	373	0.8	373	0.8	373	0.7	0.7	6.2
Mexico	250	0.5	248	0.5	245	0.5	0.5	6.7
Vietnam	209	0.4	265	0.5	393	0.7	0.6	7.2
Thailand	191	0.4	190	0.4	189	0.3	0.4	7.6
Indonesia	149	0.3	149	0.3	148	0.3	0.3	7.9
Other Latin America	39	0.1	37	0.1	32	0.1	0.1	8.0
Bangladesh	20	0.0	20	0.0	19	0.0	0.0	99.9
Eastern SSA	18	0.0	18	0.0	17	0.0	0.0	100.0
Total Small-Size Suppliers	4,017	8.5	4,047	8.2	4,113	7.6	8.1	
No Producing Countries/ Sub-Regions:								
Argentina	0	0.0	0	0.0	0	0.0	0.0	100.0
Colombia	0	0.0	0	0.0	0	0.0	0.0	100.0
Nigeria	0	0.0	0	0.0	0	0.0	0.0	100.0
Northern SSA	0	0.0	0	0.0	0	0.0	0.0	100.0
Pakistan	0	0.0	0	0.0	0	0.0	0.0	100.0
Other South Asia	0	0.0	0	0.0	0	0.0	0.0	100.0
Malaysia	0	0.0	0	0.0	0	0.0	0.0	100.0
Myanmar	0	0.0	0	0.0	0	0.0	0.0	100.0
Other Southeast Asia	0	0.0	0	0.0	0	0.0	0.0	100.0
Other East Asia	0	0.0	0	0.0	0	0.0	0.0	100.0
Rest of the World	0	0.0	0	0.0	0	0.0	0.0	100.0
World	47,503	100.0	49,593	100.0	54,340	100.0	100.0	

Supply-Demand Projections, Balances and Trade – Projections for 2012, 2017 and 2022 presented in Table 5.3 for the 36 countries and sub-regions specified in the model are summarized from the 2012-2022 time series array of country and sub-regional estimates of fertilizer P demand. These are dynamically adjusted supply and supply-demand balances (surpluses and deficits) generated by the FertTrade model. These projections show that growth in demand is projected to outpace domestic production and supply in many countries and sub-regions in various degrees. Projections of P fertilizer demand-supply imbalances of the most important trading countries and sub-regions illustrated in Figure 5.5 show that deficits will be substantial in Brazil, China, Europe (EU 15) and India. These deficit countries and sub-regions will become increasingly dependent on imports of P fertilizers from surplus countries and sub-regions such as the Other WANA and the Rest Former USSR.

Projected P fertilizer supply-demand balances or net surpluses of countries and sub-regions for 2012, 2017 and 2022 are used in Table 5.8 to classify countries and sub-regions into three groups:

1. *Exporters Through 2022* – Comprising all countries and sub-regions projected to remain as exporters of P fertilizers through 2022.
2. *Exporters Becoming Importers* – Include the Other Developed countries group, which as a group is projected to remain a P fertilizer exporter through 2012 but will become a net importer by 2017.
3. *Importers Through 2022* – Comprising all countries and sub-regions that are projected to have negative supply-demand balances and thus remain as net importers through 2022.

As indicated by projections presented in Table 5.8 and illustrated in Figure 5.5, the USA and four sub-regions (Other WANA, Rest Former USSR, Southern SSA and Central Asia) are projected to be the most important exporters of P fertilizer through 2022. The Other WANA sub-region is projected to have exportable surpluses of more than 7.9 million tons P_2O_5 by 2012, while those for the Rest Former USSR will be about 4.0 million tons P_2O_5. The USA exportable surpluses will decline markedly from 2.5 million tons P_2O_5 in 2012 to 1.7 and 0.2 million tons P_2O_5 in 2017 and 2022, respectively. If planned expansion in production capacity is realized, fertilizer P surpluses of the Southern SSA region will increase from 1.5 million tons P_2O_5 in 2012 to 1.6 and 1.8 million tons P_2O_5 in 2017 and 2022, respectively.

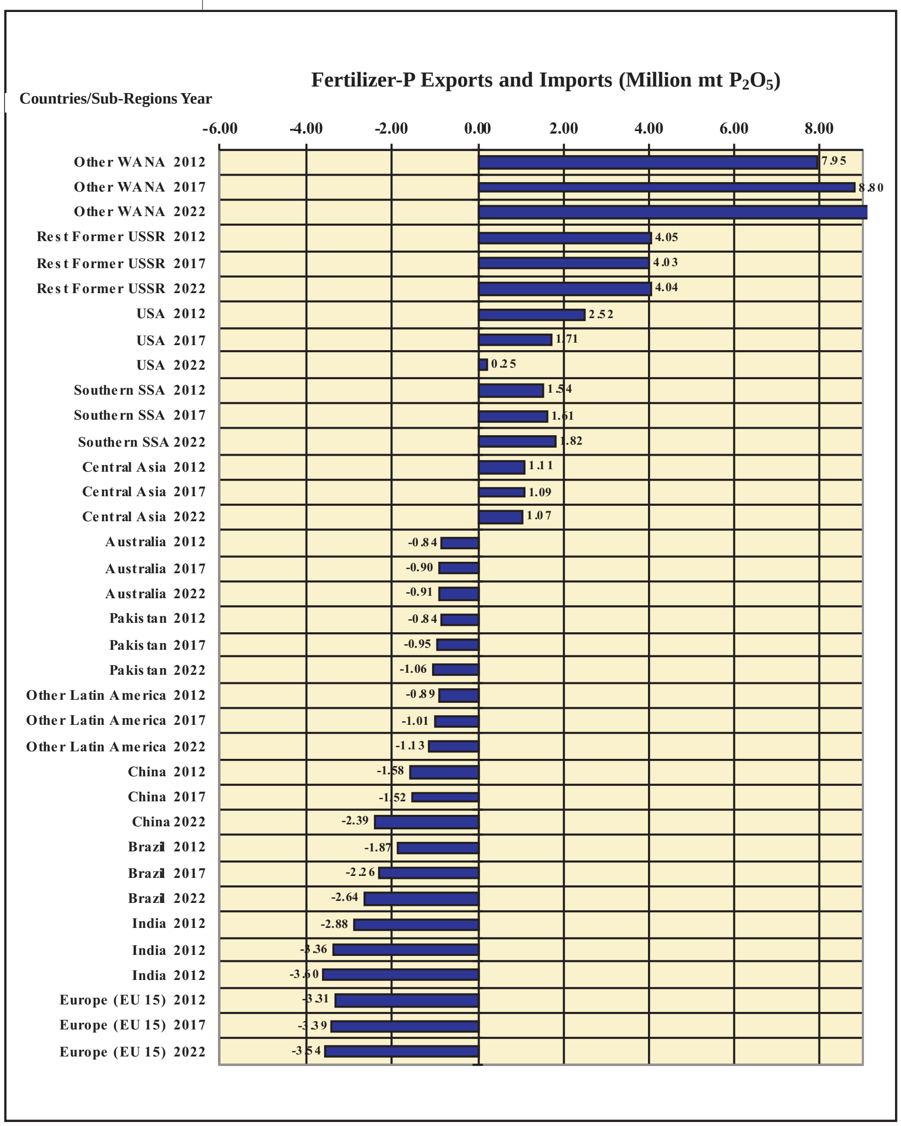


Figure 5.5. Projected Supply-Demand Balances of Fertilizer P in Most Important Trading Countries and Sub-Regions

Table 5.8. Projected Supply-Demand Balances and Fertilizer P_2O_5 Volumes of Trade Among Key Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	Supply-Demand Balances				Volume of Trade (Imports)			
	2012	2017	2022	Annual Linear Trend	2012	2017	2022	Annual Linear Trend
	('000 mt of Fertilizer P_2O_5)							
Exporters Through 2022								
Other West Asia/North Africa	7,950	8,801	13,326	537.6				
Rest Former USSR	4,048	4,033	4,043	-0.4				
USA	2,515	1,713	247	-226.8				
Southern SSA	1,543	1,611	1,819	27.6				
Central Asia	1,108	1,090	1,071	-3.6				
Eastern Europe	799	767	764	-3.5				
Egypt	497	637	976	47.9				
Central & Western SSA	416	366	304	-11.1				
Philippines	167	144	121	-4.5				
South Korea	127	115	103	-2.4				
Exporters Becoming Importers								
Other Developed	88	-39	-170	-25.8		39	170	25.8
Importers Through 2022								
Europe (EU 15)	-3,307	-3,395	-3,542	-23.6	3,307	3,395	3,542	23.6
India	-2,882	-3,365	-3,597	-71.6	2,882	3,365	3,597	71.6
Brazil	-1,870	-2,263	-2,644	-77.4	1,870	2,263	2,644	77.4
China	-1,583	-1,525	-2,392	-80.9	1,583	1,525	2,392	80.9
Other Latin America	-889	-1,007	-1,131	-24.2	889	1,007	1,131	24.2
Pakistan	-838	-947	-1,058	-22.0	838	947	1,058	22.0
Australia	-837	-899	-909	-7.2	837	899	909	7.2
Argentina	-510	-600	-699	-18.9	510	600	699	18.9
Turkey	-389	-470	-556	-16.6	389	470	556	16.6
Vietnam	-358	-373	-318	4.1	358	373	318	-4.1
Thailand	-335	-371	-408	-7.3	335	371	408	7.3
Malaysia	-310	-334	-358	-4.9	310	334	358	4.9
Indonesia	-219	-250	-281	-6.2	219	250	281	6.2
Japan	-191	-191	-191	0.1	191	191	191	-0.1
Northern SSA	-190	-223	-261	-7.1	190	223	261	7.1
Colombia	-175	-194	-213	-3.8	175	194	213	3.8
Other South Asia	-162	-181	-201	-3.9	162	181	201	3.9
Eastern SSA	-154	-203	-264	-11.0	154	203	264	11.0
Bangladesh	-133	-146	-159	-2.6	133	146	159	2.6
Mexico	-120	-164	-210	-8.9	120	164	210	8.9
Myanmar	-75	-96	-122	-4.7	75	96	122	4.7
Rest of the World	-69	-77	-85	-1.6	69	77	85	1.6
Nigeria	-50	-67	-87	-3.6	50	67	87	3.6
Other Southeast Asia	-35	-39	-44	-0.9	35	39	44	0.9
Other East Asia	-27	-29	-32	-0.5	27	29	32	0.5
World	3,548	1,833	2,844	-70.4	15,709	17,446	19,932	70.4

The Central Asia sub-region is projected to have annual surpluses of about 1.0 million tons P_2O_5 during 2012–2022.

The Other WANA sub-region and the Rest Former USSR together are projected to account for 62 percent, 67 percent and 76 percent of the world's exportable surplus of fertilizer P in 2012, 2017 and 2022, respectively. The Other WANA sub-region will increase its share of the world's exportable surplus from about 41 percent in 2012 to 58 percent in 2022. These projections clearly show that by 2022, the Other WANA sub-region will have a major role in supplying the international market for P fertilizers. Whereas, Europe (EU 15), India, Brazil and China are projected to remain the main importers of P fertilizers accounting for 60-61 percent of the world total international demand for exportable surpluses of these fertilizers. These sub-regions and countries are projected to be the dominant players in the international market for P fertilizers through 2022.

The results presented here highlight the increasing importance and essential role that international trade will have in meeting the growing demand for P fertilizers in a considerable majority of the world's countries. Trade of P fertilizers will be particularly important for developing countries where about 83 percent of the global 2005-2025 increase in P fertilizer demand is projected to occur and that depend essentially on imports to meet domestic demands. Most developing countries in SSA, Southeast Asia and Latin America will continue to have negative supply-demand balances and depend on imports of P fertilizers to meet growing domestic demand. Regarding trends in exports and imports, it is useful to note the following:

- Exports of P fertilizers by the USA are projected to decline between 2012 and 2022 at an average rate of 226,800 tons per year from about 2.5 to 0.25 million tons P_2O_5. During that decade, the exportable surplus of the Other WANA sub-region is projected to increase at an average rate of 537,600 tons P_2O_5 per year. Given the availability of phosphate rock resources in North Africa, future expansion in production capacity to meet projected growth in demand should take place mostly in this sub-region. Thus, this sub-region, in particular North African countries with phosphate rock resources, will have an increasingly more dominant role as a global producer and exporter of P fertilizers. The timely expansion of world production capacity for P fertilizers is crucial to prevent projected shortages in the late 2010s.
- Major importing countries such as Brazil, China and India are projected to experience the highest average linear trends of imports expansion of about 77.4, 80.9 and 71.6 thousand tons/year P_2O_5, respectively, between 2012 and 2022. Volumes of imports by Europe (EU 15) will remain relatively stable at about 3.3-3.5 million tons/year P_2O_5. Linear import trends calculated for all other sub-regions and countries classified as "importers through 2022" (Table 5.8) show that they will experience moderate changes in volumes of imports through 2022 (i.e., average linear trends that range from nil in Japan to 24,200 tons/year P_2O_5 in the Other Latin America sub-region).

VI. Trends in the Market for Potash (K) Fertilizers

Estimates produced by the FertTrade model are used here to project and evaluate through 2022-2025 the quantities of K fertilizers (fertilizer K) that will be demanded, produced and traded (imported or exported) by each of the mutually exclusive units representing individual countries and groups of countries (sub-regions) specified in the model. K fertilizers are measured in quantities of K_2O. World, regional and country/sub-regional projections are used to conduct assessments at three levels of aggregation.

A. World Demand and Supply Projections for K Fertilizers

Projections of the world's demand for, and supply of fertilizer K generated by the FertTrade model through 2023 are shown in Figure 6.1. Projected adjustments in supply that will be required to meet increasing demand are portrayed in Figure 6.2. These projections show that current and planned increases in the world's production capacity and potential supply of K fertilizers through 2011 are more than sufficient to satisfactorily meet the projected growth in the global demand for K fertilizers through 2023. Dynamically adjusted supply projections generated by FertTrade show that in order to eliminate substantial potential global surpluses in production capacity and supply with respect to demand, about 5 million tons K_2O per year of planned world production capacity may not be realized or will have to be closed down by 2011. About 4.2 million tons K_2O/year of additional capacity will be closed down by 2013. Then, expansion in production capacity will not be required until 2021 when a production capacity expansion of about 1.7 million tons K_2O per year will be required.

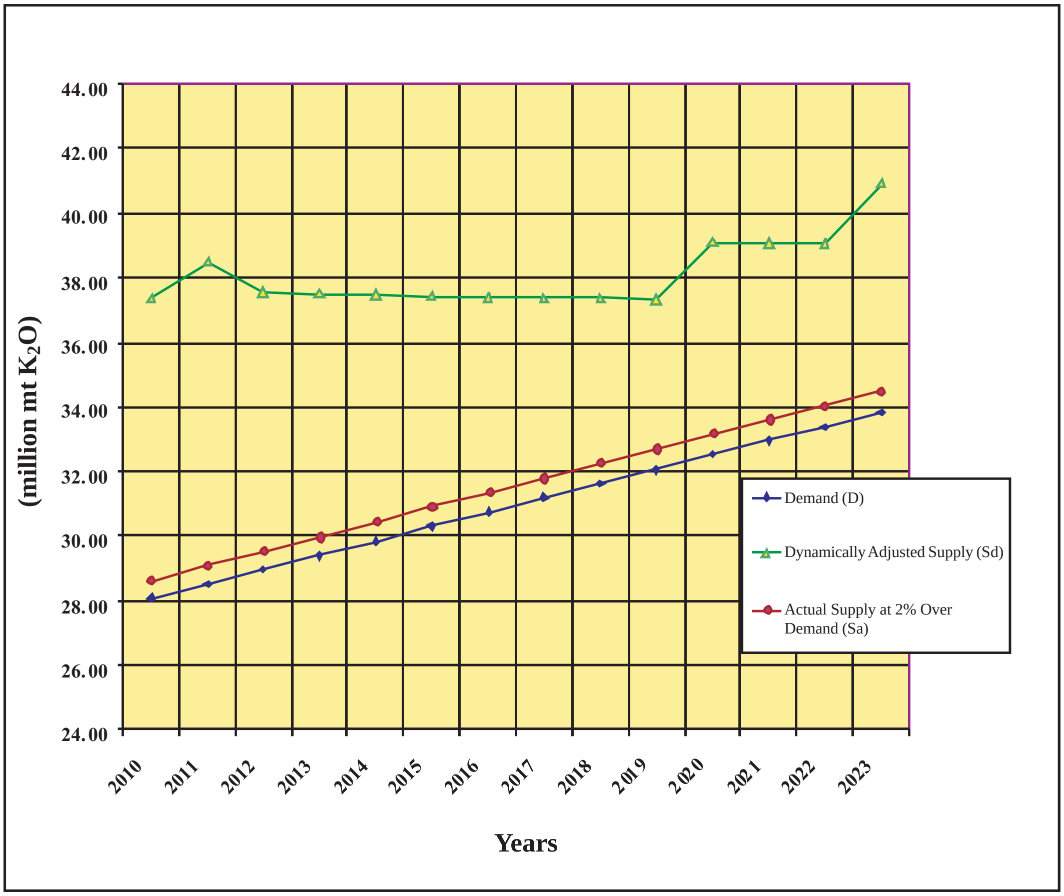


Figure 6.1. World Demand and Supply Projections of Fertilizer K

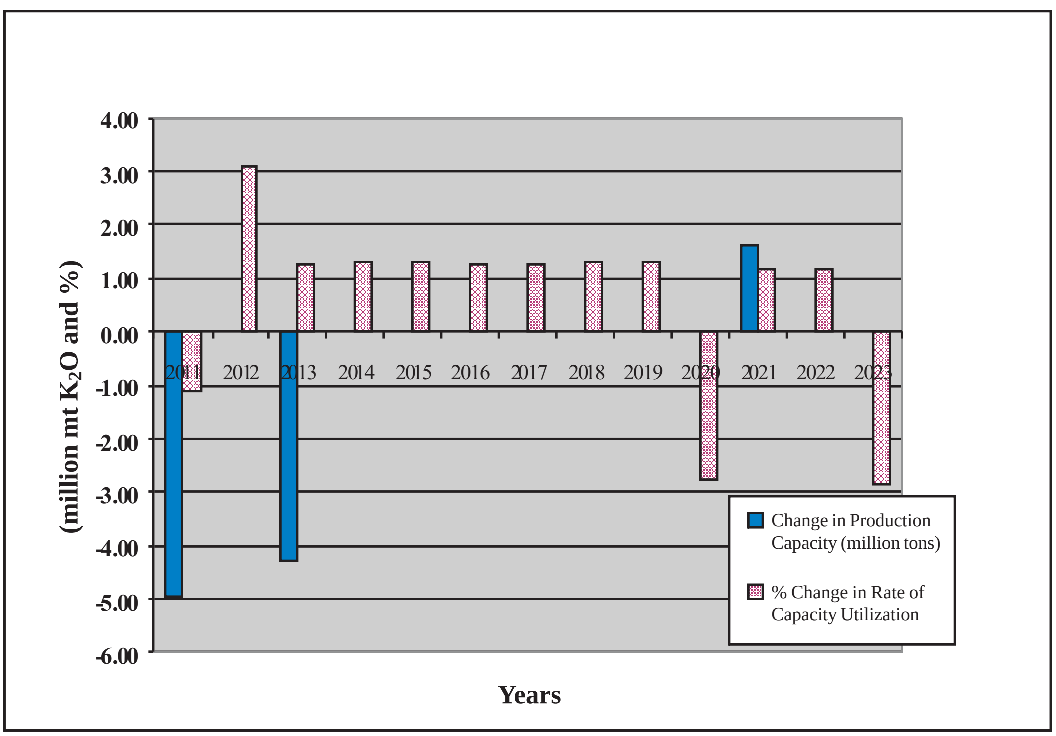


Figure 6.2 Adjustments in K_2O World Supply to Meet Projected Demand

Projections of growth in the world demand for K fertilizers show that it will increase from about 25.8 million tons of K_2O in 2005 to 28.9 million tons in 2012 and 33.4 million tons in 2022. That is an increase of about 16 percent over the 2012-2022 decade.

B. Regional Analysis of Demand, Supply and Trade of K Fertilizers

Demand and supply projections and associated supply-demand balances of K fertilizers for 2012, 2017 and 2022 estimated by the FertTrade model are presented in Table 6.1 for the Developed Countries group and the six geographic regions included in the model. These results are illustrated in Figures 6.3 and 6.4 and are used in this section to conduct the regional analysis and assessment. Several observations and conclusions drawn from these projections are presented and discussed in the following paragraphs.

First, demand and supply projections indicate that the Developed Countries group is and will remain the most important group of global-producing suppliers of K fertilizer. The Developed Countries Group, East Asia and Latin America are projected to continue to be the most

Table 6.1. Regional Fertilizer K_2O Demand and Supply Projections for 2012, 2017 and 2022

Year	Country Groups and Regions	Projected Demand	Projected Supply	Supply-Demand Balance	Volume of Trade	Imports as Percent of Demand
		('000 mt of N)				(%)
2012	West Asia/North Africa	357	1,606	1,249		
	Developed Countries	13,880	29,702	15,822		
	East Asia	4,841	1,329	-3,512	3,512	72.5
	South Asia	2,371	0	-2,371	2,371	100.0
	Southeast Asia	1,975	23	-1,952	1,952	98.9
	Latin America	4,974	1,135	-3,840	3,840	77.2
	Sub-Saharan Africa	488	0	-488	488	100.0
	Rest of the World	69	0	-69	69	100.0
	World	28,953	33,794		12,230	42.2
	World Excess Supply Capacity			4,841		
2017	West Asia/North Africa	394	1,606	1,212		
	Developed Countries	14,436	28,218	13,782		
	East Asia	5,227	1,299	-3,928	3,928	75.1
	South Asia	2,647	0	-2,647	2,647	100.0
	Southeast Asia	2,148	1,085	-1,063	2,126	99.0
	Latin America	5,632	1,131	-4,501	4,501	79.9
	Sub-Saharan Africa	627	296	-332	627	100.0
	Rest of the World	77	0	-77	77	100.0
	World	31,187	33,655		13,906	44.6
	World Excess Supply Capacity			2,467		
2022	West Asia/North Africa	433	1,603	1,170		
	Developed Countries	14,958	29,347	14,388		
	East Asia	5,560	1,622	-3,938	3,938	
	South Asia	2,928	0	-2,928	2,928	100.0
	Southeast Asia	2,323	1,094	-1,229	2,292	98.7
	Latin America	6,320	1,170	-5,150	5,150	81.5
	Sub-Saharan Africa	799	296	-504	799	100.0
	Rest of the World	85	0	-85	85	100.0
	World	33,407	35,151		15,194	45.5
	World Excess Supply Capacity			1,744		

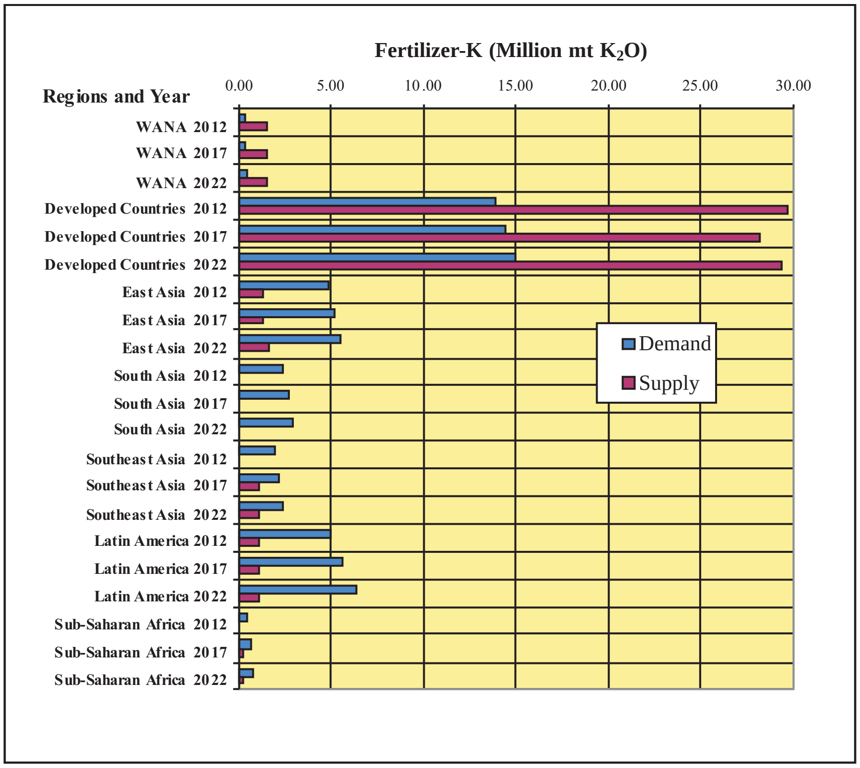


Figure 6.3. Regional Supply and Demand Projections for Fertilizer K

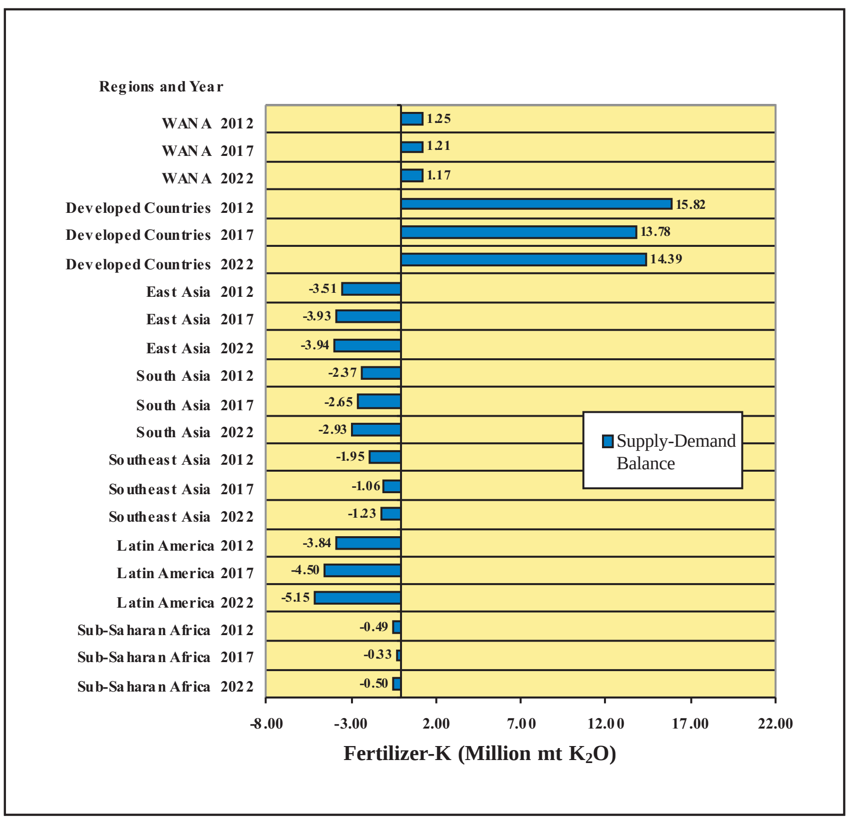


Figure 6.4. Projected Supply-Demand Balances of Fertilizer K by Regions

important consumers of fertilizer P through 2022. Because of growth in consumption with almost no expansion in production and supply; deficits in East Asia, Latin America and South Asia will increase through 2022. In the Southeast Asia region, deficits will decrease as a result of projected expansion of production capacity and supply of about 1 million tons K_2O/year in Thailand by 2013-14. The Developed Countries group is projected to continue to be the most important and dominant region producing and supplying fertilizer K to all other world regions.

Second, estimates indicate that the Developed Countries group and the WANA region are and will remain the regions with the most potential surpluses of K fertilizers. The Developed Countries group, which includes Canada and the Russian Federation, are projected to account for about 87 percent of the global potential production and supply of K fertilizers through 2012 and for about 84 percent in 2017 and 2022, if projected expansion in production capacity and supply takes place in Thailand in 2013-14. The Developed Countries group together with the WANA region will continue to account for about 92 percent of the world's production and supply through 2012 and for about 88 percent in 2017 and 2022. All other regions together account for the other 8 percent to 12 percent of potential production/supply and are projected to remain deficit regions and net importers of K fertilizers.

Third, as shown in Figure 6.4, Latin America, East Asia and South Asia are projected to be the regions with the largest expected levels of excess demand for K fertilizers (i.e., the most important fertilizer K deficit regions). Regarding the flow/trade of K fertilizers among regions, the WANA region and the Developed Countries group are and will remain as the dominant exporting regions with 88 percent to 92 percent of the world's production/supply, while East Asia, Latin America and South Asia, with less than 8 percent of the world's production/supply, will continue to be the most important importing regions. Because the production of K fertilizers depends on the availability of suitable mineral resources of K, projected trends in production/supply and inter-regional trade of K fertilizers should continue well beyond 2022.

Fourth, trends of regional supply-demand balances for K fertilizers illustrated in Figure 6.4 also show significant differences among regions. It is clear that the Developed Countries group and the WANA region will continue as the main exporting regions through 2022 and beyond. However, the relative importance of the Developed Countries group's exports will remain high while that of the WANA region will decline to some extent through 2022. The SSA region as a whole is projected to continue to import K fertilizers at annual rates of about 490,000, 333,000 and 500,000 tons K_2O in 2012, 2017 and 2022, respectively. Southeast Asia is projected to decrease imports somewhat from 1.95 million tons K_2O in 2012 to 1.06 and 1.23 million tons K_2O in 2017 and 2022.

Fifth, as shown in Table 6.1, the volume of inter-regional trade in K fertilizers between exporting and importing regions – inflows and outflows of K_2O fertilizer – is projected to increase from 10.7 million tons K_2O in 2005 to 12.2 and 15.2 million tons K_2O in 2012 and 2022. Such inter-regional "trade" obviously will take place through commercial trade between K fertilizer surplus countries in a region and K fertilizer deficit countries in another.

Projections presented in Table 6.2 and illustrated in Figures 6.2 and 6.3 are further used to highlight the following additional observations.

1. The Developed Countries group as a regional unit is the largest consumer and producer of K fertilizers, accounting for 48 percent and 45 percent of the projected global demand and for 88 percent and 84 percent of the projected global production/supply in 2012 and 2022, respectively.
2. The WANA region is projected to account for only 1 percent of the global demand of K fertilizers but for 4.8 percent and 4.6 percent of the global production and supply in 2012 and 2022, respectively.
3. Because of the high concentration of K fertilizer production capacity in one region (the Developed Countries group), assessments on production/supply, demand and trade at the country and sub-regional level are particularly important to assess patterns of trade of K fertilizers among key countries and sub-regions.

C. Sub-Regional Analysis of K Fertilizers Demand, Supply and Trade

Estimates produced by the FertTrade model on the projected country/sub-regional demand and supply situation for K fertilizers in 2012, 2017 and 2022 summarized in Table 6.3 are used in the following subsections to discuss trends in the demand, supply and supply-demand balances and trade of fertilizer K in key countries and sub-regions through 2025.

Table 6.2. Global Shares of Projected Regional Fertilizer K_2O Demand and Supply in 2012, 2017 and 2022

Year	Regions	Projected K_2O Demand			Projected Dynamically Adjusted K_2O Supply		
		Quantity	Share	Cumulative Share	Quantity	Share	Cumulative Share
		('000 mt)	(%)	(%)	('000 mt)	(%)	(%)
2012	Developed Countries	13,880	47.9	47.9	29,702	87.9	87.9
	West Asia/North Africa	357	1.2	1.2	1,606	4.8	92.6
	East Asia	4,841	16.7	18.0	1,329	3.9	96.6
	Latin America	4,974	17.2	35.1	1,135	3.4	99.9
	Southeast Asia	1,975	6.8	42.0	23	0.1	100.0
	South Asia	2,371	8.2	50.1	0	0.0	100.0
	Sub-Saharan Africa	488	1.7	51.8	0	0.0	100.0
	Rest of the World	69	0.2	52.1	0	0.0	100.0
	World	28,953	100		33,794	100	
	World Excess Supply Capacity					14.3	
2017	Developed Countries	14,436	46.3	46.3	28,218	83.8	83.8
	West Asia/North Africa	394	1.3	1.3	1,606	4.8	88.6
	East Asia	5,227	16.8	18.0	1,299	3.9	92.5
	Latin America	5,632	18.1	36.1	1,131	3.4	95.8
	Southeast Asia	2,148	6.9	43.0	1,085	3.2	99.1
	Sub-Saharan Africa	627	2.0	45.0	296	0.9	100.0
	South Asia	2,647	8.5	53.5	0	0.0	100.0
	Rest of the World	77	0.3	53.7	0	0.0	100.0
	World	31,187	100.0		33,655	100.0	
	World Excess Supply Capacity					7.3	
2022	Developed Countries	14,958	44.8	44.8	29,347	83.5	83.5
	East Asia	5,560	16.6	61.4	1,622	4.6	88.1
	West Asia/North Africa	433	1.3	1.3	1,603	4.6	92.7
	Latin America	6,320	18.9	20.2	1,170	3.3	96.0
	Southeast Asia	2,323	7.0	27.2	1,094	3.1	99.1
	Sub-Saharan Africa	799	2.4	29.6	296	0.8	100.0
	South Asia	2,928	8.8	38.3	0	0.0	100.0
	Rest of the World	85	0.3	38.6	0	0.0	100.0
	World	33,407	100.0		35,151	100.0	
	World Excess Supply Capacity					5.0	

Demand Projections and Trends through 2025 – Demand growth estimates of K fertilizers through 2025 derived from the FertTrade model's demand projections by countries and sub-regions are presented in Table 6.4 and further summarized by major country groups and regions in Table 6.5. The projected 2005-2025 amounts of increased fertilizer K demand in thousands of metric tons of K_2O and corresponding exponential annual growth rates presented in these tables are used to draw the following observations and conclusions.

1. Brazil, China, India and the USA are projected to experience the largest 2005-2025 increases in terms of quantity demand for K fertilizers. In the 20-year period, K fertilizer demands in Brazil, China, the USA and India are projected to increase by about 1.9, 1.3, 1.2 and 0.90 million tons of K_2O, respectively. Annual growth rates of fertilizer K demand are very similar to those previously discussed for fertilizer N and fertilizer P because N:P:K ratios of the derived quantity demanded of fertilizer nutrients are determined mainly by the proportional distribution of crop production in each country/sub-region, which do not vary significantly across years. Hence, growth rates of fertilizer K demand in Brazil (2.54 percent) and India (2.24 percent) are projected to be larger than those in China (1.5 percent) and the USA (1 percent).

Table 6.3. Projected Fertilizer K_2O Demand, Supply and Balances by Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	2012			2017			2022		
	Demand	Supply	Supply-Demand Balances	Demand	Supply	Supply-Demand Balances	Demand	Supply	Supply-Demand Balances
	('000 mt of K_2O)								
USA	5,799	8	-5,792	6,108	9	-6,099	6,400	9	-6,391
Europe (EU 15)	4,398	4,488	90	4,438	4,481	43	4,466	4,544	78
Japan	416	0	-416	416	0	-416	415	0	-415
Australia	329	0	-329	352	0	-352	374	0	-374
Other Developed	948	15,030	14,082	1,012	13,567	12,554	1,074	14,476	13,402
Eastern Europe	856	0	-856	916	0	-916	976	0	-976
Central Asia	131	0	-131	141	20	-121	151	20	-131
Rest Former USSR	1,001	10,176	9,174	1,053	10,161	9,108	1,102	10,318	9,216
Mexico	274	0	-274	305	0	-305	336	0	-336
Brazil	3,676	317	-3,359	4,176	315	-3,862	4,703	343	-4,359
Argentina	52	0	-52	61	0	-61	71	0	-71
Colombia	240	5	-234	265	5	-260	291	5	-286
Other Latin America	733	812	79	825	811	-13	919	821	-98
Nigeria	92	0	-92	121	0	-121	158	0	-158
Northern SSA	35	0	-35	41	0	-41	48	0	-48
Central & Western SSA	150	0	-150	196	296	99	254	296	42
Southern SSA	164	0	-164	209	0	-209	264	0	-264
Eastern SSA	47	0	-47	60	0	-60	76	0	-76
Egypt	39	0	-39	43	0	-43	46	0	-46
Turkey	91	0	-91	99	0	-99	108	0	-108
Other West Asia/North Africa	227	1,606	1,379	252	1,606	1,354	278	1,603	1,324
India	2,026	0	-2,026	2,267	0	-2,267	2,511	0	-2,511
Pakistan	31	0	-31	35	0	-35	39	0	-39
Bangladesh	152	0	-152	164	0	-164	177	0	-177
Other South Asia	162	0	-162	181	0	-181	201	0	-201
Indonesia	317	0	-317	343	0	-343	370	0	-370
Thailand	341	0	-341	364	1,063	699	387	1,063	676
Malaysia	871	0	-871	940	0	-940	1,009	0	-1,009
Philippines	158	0	-158	174	0	-174	191	0	-191
Vietnam	237	0	-237	267	0	-267	298	0	-298
Myanmar	15	0	-15	20	0	-20	25	0	-25
Other Southeast Asia	35	23	-12	39	22	-18	44	31	-13
China	4,551	1,329	-3,222	4,922	1,299	-3,623	5,242	1,622	-3,620
South Korea	289	0	-289	303	0	-303	317	0	-317
Other East Asia	1	0	-1	1	0	-1	1	0	-1
Rest of the World	69	0	-69	77	0	-77	85	0	-85
World	28,953	33,794	4,841	31,187	33,655	2,467	33,407	35,151	1,744

Differences in demand growth among N, P and K fertilizers are significant in terms of projected quantities demanded but not in terms of rates of growth.

2. Nigeria, Myanmar and the four sub-regions of SSA are projected to experience the highest rates of growth in the demand for P fertilizer. These high rates of growth are mainly due to current low levels of fertilizer use in these countries and sub-regions and the existence of a significant potential for expansion in the adoption and use of fertilizers. As shown in Table 6.4, these countries and sub-regions are projected to have annual rates of growth of 3.3 percent to 5.5 percent through 2025. Improvements in crop yields and agricultural productivity in general and expansion of crop areas should be the main drivers of growth in demand for fertilizer in these countries and sub-regions.

Table 6.4. Projected 2005–2025 Demand Growth for Fertilizer K in Key Countries and Sub-Regions

Countries and Sub-Regions Ranked by Size of Demand Increase	Demand Increase 2005–2025	Annual Growth Rate	Countries and Sub-Regions Ranked by Size of Rate of Growth	Demand Increase 2005–2025	Growth Rate
	K_2O ('000 mt)	(%)		K_2O ('000 mt)	(%)
10. Brazil	1,884	2.54	14. Nigeria	114	5.53
33. China	1,330	1.50	16. Central & Western Sub -SA	177	5.27
1. USA	1,170	1.04	18. Eastern Sub-Saharan Africa	51	4.98
22. India	905	2.24	31. Myanmar	17	4.87
13. Other Latin America	344	2.34	17. Southern Sub-Saharan Africa	174	4.85
28. Malaysia	259	1.51	15. Northern Sub-Saharan Africa	24	3.27
5. Other Developed	241	1.30	11. Argentina	34	3.23
6. Eastern Europe	224	1.34	10. Brazil	1,884	2.54
8. Rest Former USSR	193	0.99	23. Pakistan	15	2.43
16. Central & Western Sub -SA	177	5.27	13. Other Latin America	344	2.34
17. Southern Sub-Saharan Africa	174	4.85	30. Vietnam	110	2.32
2. Europe (EU 15)	146	0.17	32. Other Southeast Asia	16	2.27
9. Mexico	116	2.13	22. India	905	2.24
14. Nigeria	114	5.53	25. Other South Asia	72	2.21
30. Vietnam	110	2.32	36. Rest of the World	30	2.15
26. Indonesia	100	1.60	9. Mexico	116	2.13
12. Colombia	97	2.04	21. Other West Asia/North Africa	96	2.12
21. Other West Asia/North Africa	96	2.12	12. Colombia	97	2.04
27. Thailand	87	1.31	29. Philippines	63	2.00
4. Australia	87	1.35	20. Turkey	32	1.81
25. Other South Asia	72	2.21	19. Egypt	13	1.68
29. Philippines	63	2.00	26. Indonesia	100	1.60
34. South Korea	53	0.93	24. Bangladesh	47	1.59
18. Eastern Sub-Saharan Africa	51	4.98	35. Other East Asia	0	1.54
24. Bangladesh	47	1.59	28. Malaysia	259	1.51
7. Central Asia	38	1.48	33. China	1,330	1.50
11. Argentina	34	3.23	7. Central Asia	38	1.48
20. Turkey	32	1.81	4. Australia	87	1.35
36. Rest of the World	30	2.15	6. Eastern Europe	224	1.34
15. Northern Sub-Saharan Africa	24	3.27	27. Thailand	87	1.31
31. Myanmar	17	4.87	5. Other Developed	241	1.30
32. Other Southeast Asia	16	2.27	1. USA	1,170	1.04
23. Pakistan	15	2.43	8. Rest Former USSR	193	0.99
19. Egypt	13	1.68	34. South Korea	53	0.93
35. Other East Asia	0	1.54	2. Europe (EU 15)	146	0.17
3. Japan	0	0.00	3. Japan	0	0.00

3. Increases in demand for K fertilizers between 2005-2025 measured in terms of quantities of K_2O and growth rates calculated for two mutually exclusive groups of countries, one comprising the developing countries and another the developed countries, and for eight other selected regional and sub-regional groups of countries are summarized in Table 6.5. The following observations are made on the basis of these results:

   a. About 75 percent or 6.3 million tons K_2O of the world 2005-2025 increase in K fertilizer demand will take place in the developing countries. Corresponding projected increase in the developed countries will be substantially smaller, about 2.1 million tons K_2O of K fertilizers or 25 percent of the projected world increase in demand.

Table 6.5. Projected 2005–2025 Demand Growth for Fertilizer K by Country Groups and Regions

Country Groups and Regions Ranked by Size of Increase	Demand Increase 2005–2025	Share in Global Increase	Exponential Growth Rate	Country Groups and Regions Ranked by Size of Growth Rate	Demand Increase 2005–2025	Exponential Growth Rate
	K_2O ('000 mt)	(%)	(%)		K_2O ('000 mt)	(%)
Developing Countries	6,259	74.9	2.0	Sub-Saharan Africa	540	4.6
All Asia	3,073	36.8	1.8	Latin America	2,476	2.5
South Asia	1,039	12.4	2.2	South Asia	1,039	2.2
East Asia	1,383	16.5	1.5	Developing Countries	6,259	2.0
Developed Countries	2,098	25.1	0.9	West Asia/North Africa	141	2.0
Latin America	2,476	29.6	2.5	Southeast Asia	651	1.9
Southeast Asia	651	7.8	1.9	All Asia	3,073	1.8
West Asia/North Africa	141	1.7	2.0	East Asia	1383	1.5
Sub-Saharan Africa	540	6.5	4.6	Former USSR	231	1.1
Former USSR	231	2.8	1.1	Developed Countries	2,098	0.9

b. The sub-regions of East Asia, South Asia and Southeast Asia account for 16.5 percent, 12.4 percent and 7.8 percent, respectively, of the projected 2005-2025 increase in the global demand for K fertilizer. Thus, the All Asia region is expected to contribute 37 percent or about 3.1 million tons K_2O to the projected 2005-2025 world expansion in demand for K fertilizer. The Latin America region is projected to contribute 29.6 percent or about 2.5 million tons K_2O to this expansion. Shares of the SSA region and the Former USSR and WANA sub-regions on the projected 2005-2025 global expansion in demand for K fertilizers are smaller and account for only 6.5 percent, 2.8 percent and 1.7 percent, respectively.

c. Estimated 2005-2025 fertilizer K demand growth rates show that the SSA and Latin America regions will have the highest rates of growth, 4.6 percent and 2.5 percent, respectively. Demand in Developing Countries is projected to grow at a rate of 2 percent, more than twice as fast as in Developed Countries.

4. In order to evaluate countries and sub-regions in terms of their relative importance as markets of K fertilizers, the model's 36 countries and sub-regions ranked by their three-year (2012, 2017 and 2022) average share in global demand are presented on Table 6.6. This ranked list of countries and sub-regions is further used to classify them into *large-size*, *medium-size* and *small-size markets* for K fertilizers. Results presented in this table are discussed in the following paragraphs.

a. Large-Size Markets for K Fertilizers – Four countries, the USA, China, Brazil and India, and one sub-region, Europe (EU 15), are projected to remain as the largest markets for K fertilizers through 2025. They are each classified here as having a global market share of at least 7 percent. Together these *large-size markets* are projected to account for about 70 percent of the global market for K fertilizers. However, global demand shares of each of these three countries and sub-region are not projected to follow the same 2012-2022 trends. The shares in the global market for K fertilizers in the USA and Europe (EU 15) are expected to decline from about 20 percent to 19 percent and from 15 percent to 13 percent, respectively, during 2012-2022. China's share will remain essentially unchanged at about 15.7 percent while Brazil's and India's shares are projected to increase from 12.7 percent and 7 percent in 2012 to 14.1 percent and 7.5 percent in 2022, respectively. Variations in trends of K fertilizer demand among countries and sub-regions are due mainly to variations in trends of crop areas harvested, crop yields and crop and livestock patterns of production among countries and sub-regions. Historical trends and projections built into the scenario variables of the IMPACT model influence such variations.

b. Medium- and Small-Size Markets – By further identifying as *medium-size markets* those countries

Table 6.6. Countries and Sub-Regions Ranked by Their Average Shares in the Global Demand for K Fertilizer in 2012, 2017 and 2022

Countries and Sub-Regions	Demand Shares 2012	Demand Shares 2017	Demand Shares 2022	Average Demand Shares	Cumulative Demand Shares
	(%)				
USA	20.0	19.6	19.2	19.6	19.6
China	15.7	15.8	15.7	15.7	35.3
Europe (EU 15)	15.2	14.2	13.4	14.2	49.5
Brazil	12.7	13.4	14.1	13.4	62.9
India	7.0	7.3	7.5	7.3	70.2
Total Large-Size Markets	70.6	70.3	69.8	70.2	
Rest Former USSR	3.5	3.4	3.3	3.4	73.6
Other Developed	3.3	3.2	3.2	3.2	76.8
Malaysia	3.0	3.0	3.0	3.0	79.8
Eastern Europe	3.0	2.9	2.9	2.9	82.8
Other Latin America	2.5	2.6	2.8	2.6	85.4
Japan	1.4	1.3	1.2	1.3	86.8
Thailand	1.2	1.2	1.2	1.2	87.9
Australia	1.1	1.1	1.1	1.1	89.1
Indonesia	1.1	1.1	1.1	1.1	90.2
Mexico	0.9	1.0	1.0	1.0	91.1
South Korea	1.0	1.0	0.9	1.0	92.1
Total Medium-Size Markets	22.0	21.9	21.8	21.9	
Vietnam	0.8	0.9	0.9	0.9	93.0
Colombia	0.8	0.9	0.9	0.9	93.8
Other West Asia/North Africa	0.8	0.8	0.8	0.8	94.6
Southern SSA	0.6	0.7	0.8	0.7	95.3
Central & Western SSA	0.5	0.6	0.8	0.6	95.9
Other South Asia	0.6	0.6	0.6	0.6	96.5
Philippines	0.5	0.6	0.6	0.6	97.1
Bangladesh	0.5	0.5	0.5	0.5	97.6
Central Asia	0.5	0.5	0.5	0.5	98.1
Nigeria	0.3	0.4	0.5	0.4	98.5
Turkey	0.3	0.3	0.3	0.3	98.8
Rest of the World	0.2	0.2	0.3	0.2	99.0
Argentina	0.2	0.2	0.2	0.2	99.2
Eastern SSA	0.2	0.2	0.2	0.2	99.4
Egypt	0.1	0.1	0.1	0.1	99.6
Northern SSA	0.1	0.1	0.1	0.1	99.7
Other Southeast Asia	0.1	0.1	0.1	0.1	99.8
Pakistan	0.1	0.1	0.1	0.1	99.9
Myanmar	0.1	0.1	0.1	0.1	100.0
Other East Asia	0.0	0.0	0.0	0.0	100.0
Total Small-Size Markets	7.3	7.8	8.4	7.9	

and sub-regions having global K fertilizer demand shares lower than 7 percent but no less than 1 percent and as *small-size markets* those having market shares of less than 1 percent, additional observations are made about the relative importance of these markets on the global demand for K fertilizers. Seven individual countries and four sub-regions with *medium-size markets* are projected to account together for about 22 percent of the global demand for K fertilizers through 2022, while 10 countries and 10 sub-regions with *small-size markets* will account together for only 7.3 percent and 8.4 percent of the global demand in 2012 and 2022, respectively. However, these estimates should be adjusted further to account for the fact that most of the individual countries included as part of sub-regions, such as Other WANA, Other Latin America, Eastern Europe and Rest Former USSR, are in fact *small-size markets* with demand shares of less than 1 percent of the global market for K fertilizers. Then, the actual share of all individual countries with *medium-size markets* will be only about 17 percent (rather than 22 percent), while the market share of *small-size market countries* will be 13 percent (rather than 8 percent) of the global demand. These adjusted projections show that, on average through 2025, about 70 percent, 17 percent and 13 percent of the global demand for P fertilizers will come from countries with large-, medium- and small-size markets, respectively. *Small-size markets* are often a serious constraint to the production and supply – efficient distribution and marketing – of fertilizers in many developing countries. However, because the production of K fertilizers depends essentially on the availability of suitable mineral sources of K, production for exports could take place even in countries with very small domestic markets for K fertilizers.

Trends in Production and Supply – Shares of the 36 countries and sub-regions on the global K fertilizer production/supply in 2012, 2017 and 2022 derived from estimates of the dynamically adjusted levels of fertilizer K production and supply generated by FertTrade for each of the 36 countries and sub-regions in the model are presented in Table 6.7. The methodology used by the model to produce these supply estimates is described above and takes into consideration the availability of phosphate rock resources and raw materials and the countries and sub-regions historical record and trends in K fertilizer production capacity building and supply.

Observations and conclusions drawn on the basis of the model's dynamically adjusted supply projections presented in Table 6.7 are discussed in following paragraphs.

Large-Size Producers and Suppliers – Shares of the 36 countries/sub-regions on the world K fertilizer supply in 2012, 2017 and 2022 are used to rank and list them by the size of their three-year (2012, 2017 and 2022) average share. Countries and sub-regions further classified into three groups of K fertilizer suppliers (producers) are presented in Table 6.7: *large-size suppliers* with global shares greater than or equal 10 percent; *medium-size suppliers* with global shares lower than 10 percent but higher or equal to 1 percent; and *small-size suppliers* with positive shares in the global supply lower than 0.9 percent. Three sub-regions, the Other Developed countries group (including Canada), Rest Former USSR (including Russia, Ukraine and Belarus) and Europe (EU 15), are classified as *large-size suppliers* of K fertilizers and, together, are projected to account for about 88 percent of the global production and supply of K fertilizers through 2012 and for 84 percent in 2017 and 2022. Global supply shares of these countries and sub-regions are projected to change somewhat between 2012 and 2022, due in part to a projected increase in the global share of Thailand and China in the production of K fertilizer. The share of the Other Developed countries group is projected to change from 43 percent in 2005 to 44.5 percent in 2012 and 40.3 percent and 41.2 percent in 2017 and 2022, respectively. Shares of the Rest Former USSR and Europe (EU 15) sub-regions will decrease from 32 percent and 14.4 percent in 2005 to 29.4 percent and 12.9 percent, respectively, in 2022.

Medium-Size Producers and Suppliers – This group comprises two sub-regions, Other WANA (including Jordan) and Other Latin America (including Chile), and three individual countries, China, Thailand and Brazil. Shares of the two sub-regions and three individual countries together on the global production capacity and supply of K fertilizers are projected to increase from 10 percent in 2005 to 12 percent in 2012 and 15.5 percent in 2022. The share of China is projected to increase from 1.8 percent in 2005 to 3.9 percent and 4.6 percent in 2017 and 2022, respectively; Thailand's share is projected to become 3.2 percent and 3.0 percent in 2017 and 2022, respectively.

Small-Size Producers and Suppliers – This group includes countries and sub-regions with very small shares in the global production of K fertilizers. The other Southeast Asia and Central Asia sub-regions and the USA and Colombia as individual countries are included in this group. These two sub-regions and countries together account for a very small share (0.1-0.2 percent) of the global supply for K fertilizer.

The results presented above show that the global potential production and supply of K fertilizers is and will continue to be concentrated in a few of the sub-regions and countries that are key sources of supply to many countries without suitable resources to produce K fertilizers. Hence, as further shown below, trade is

Table 6.7. Countries and Sub-Regions Ranked by Their Average Shares in the Projected Global Supply of Fertilizer K_2O in 2012, 2017 and 2022

Countries and Sub-Regions	2012 Supply	2012 Supply Shares	2017 Supply	2017 Supply Shares	2022 Supply	2022 Supply Shares	Average Supply Shares	Cumulative Shares
	('000 mt K_2O)	(%)	('000 mt K_2O)	(%)	('000 mt K_2O)	(%)	(%)	(%)
Other Developed	15,030	44.5	13,567	40.3	14,476	41.2	42.0	42.0
Rest Former USSR	10,176	30.1	10,161	30.2	10,318	29.4	29.9	71.9
Europe (EU 15)	4,488	13.3	4,481	13.3	4,544	12.9	13.2	85.0
Total Large-Size Suppliers	29,694	87.9	28,209	83.8	29,337	83.5	85.0	
Other West Asia/North Africa	1,606	4.8	1,606	4.8	1,603	4.6	4.7	89.7
China	1,329	3.9	1,299	3.9	1,622	4.6	4.1	93.9
Other Latin America	812	2.4	811	2.4	821	2	2.4	96.2
Thailand	0	0.0	1,063	3.2	1,063	3.0	2.1	98.3
Brazil	317	0.9	315	0.9	343	1.0	1.0	99.3
Central & Western SSA	0	0.0	296	0.9	296	0.8	0.6	99.8
Total Medium-Size Suppliers	4,065	12.0	5,094	15.1	5,452	15.5	14.2	
Other Southeast Asia	23	0.1	22	0.1	31	0.1	0.1	99.9
Central Asia	0	0.0	20	0.1	20	0.1	0.0	99.96
USA	8	0.0	9	0.0	9	0.0	0.0	100.0
Colombia	5	0.0	5	0.0	5	0	0	
Total Small-Size Suppliers	30	0.1	51	0.2	60	0.2	0.1	
No Producing Country/Sub-Region								
Japan	0	0.0	0	0.0	0	0.0	0.0	
Australia	0	0.0	0	0.0	0	0.0	0.0	
Eastern Europe	0	0.0	0	0.0	0	0.0	0.0	
Mexico	0	0.0	0	0.0	0	0.0	0.0	
Argentina	0	0.0	0	0.0	0	0.0	0.0	
Nigeria	0	0.0	0	0.0	0	0.0	0.0	
Northern SSA	0	0.0	0	0.0	0	0.0	0.0	
Southern SSA	0	0.0	0	0.0	0	0.0	0.0	
Eastern SSA	0	0.0	0	0.0	0	0.0	0.0	
Egypt	0	0.0	0	0.0	0	0.0	0.0	
Turkey	0	0.0	0	0.0	0	0.0	0.0	
India	0	0.0	0	0.0	0	0.0	0.0	
Pakistan	0	0.0	0	0.0	0	0.0	0.0	
Bangladesh	0	0.0	0	0.0	0	0.0	0.0	
Other South Asia	0	0.0	0	0.0	0	0.0	0.0	
Indonesia	0	0.0	0	0.0	0	0.0	0.0	
Malaysia	0	0.0	0	0.0	0	0.0	0.0	
Philippines	0	0.0	0	0.0	0	0.0	0.0	
Vietnam	0	0.0	0	0.0	0	0.0	0.0	
Myanmar	0	0.0	0	0.0	0	0.0	0.0	
South Korea	0	0.0	0	0.0	0	0.0	0.0	
Other East Asia	0	0.0	0	0.0	0	0.0	0.0	
Rest of the World	0	0.0	0	0.0	0	0.0	0.0	
South Korea	0	0.0	0	0.0	0	0.0	0.0	
Other East Asia	0	0.0	0	0.0	0	0.0	0.0	
Rest of the World	0	0.0	0	0.0	0	0.0	0.0	

essential to meet the growing demand for K fertilizers in a substantial majority of the world's countries.

Supply-Demand Balances and Trade – Projected K fertilizers supply-demand balances and volumes of trade among key countries and sub-regions in 2012, 2017 and 2022 are used in Table 6.8 to classify them into four groups:

1. *Exporters Through 2022* – Comprising all countries and sub-regions projected to remain as exporters of K fertilizers through 2022. Namely, the Other Developed countries group (including Canada and Israel) and the Rest Former USSR (including the Russia Federation and Belarus), Europe (EU 15) and Other WANA sub-regions.
2. *Exporters Becoming Importers* – Including the Other Latin America sub-region, which is projected to have surpluses through 2012 becoming a deficit sub-region by 2017 and remaining as such through 2022.
3. *Importers Becoming Exporters* – To include one country, Thailand, and one sub-region, Central and Western SSA, which are projected as net importers of K fertilizers through 2012 to become exporters by 2014-2017.
4. *Importers Through 2022* – Comprising all countries and sub-regions that are projected to have negative supply-demand balances and thus remain as net importers through 2022 and beyond.

As indicated by projections presented in Table 6.8 and illustrated on Figure 6.4, two sub-regions, the Other Developed countries group (including Canada and Israel) and the Rest Former USSR (including the Russia Federation and Belarus), are projected to remain as the dominant exporting sub-regions through 2022 and beyond. The Other Developed countries group is projected to have exportable surpluses of more than 12 million tons K_2O per year through 2022 and the Rest Former USSR sub-region exportable surpluses of more than 9 million tons K_2O per year through 2022. The Other WANA sub-region (including Jordan), is projected to have exportable surpluses of about 1.3 million tons K_2O through 2022 while surpluses of the Europe (EU 15) sub-region through 2022 will be substantially smaller – 40,000–90,000 tons K_2O per year.

The USA, Brazil, China and India are and will remain through 2022 as the main importers of K fertilizers; each importing more than 2 million tons K_2O per year through 2022. These four countries are projected to account for about 73 percent to 75 percent of the world's imports through 2022, while a substantial majority of the world's countries and sub-regions will account for the residual 27 percent to 25 percent of the world's imports. These estimates highlight the importance and crucial role of K fertilizer trade to meet the demands for these fertilizers in a significant majority of the world's countries. Trade of K fertilizers will be particularly important for the developing countries, which depend on imports to meet domestic demands, where about 75 percent of the global 2005-2025 increase in K fertilizer demand is projected to occur. Nearly all developing countries in SSA, Southeast Asia and Latin America have negative supply-demand balances and will continue to depend on imports of K fertilizers. Regarding trends in exports and imports, it is useful to note the following:

- Exportable surpluses of K fertilizers by the Other Developed countries group and the Rest Former USSR sub-region are together projected to be from 23.1 million tons K_2O in 2012 and 21.6 and 22.6 million tons K_2O in 2015 and 2025, respectively. Planned expansion of global production capacity and supply of K fertilizers will be more than sufficient to meet projected increases in the global demand for K fertilizers through 2020. However, about 1.7 million tons K_2O expansion in global production capacity will be required by 2021. Given the world's known availability of suitable mineral K resources, any expansion in production capacity that may be required in the future is likely to take place in the two sub-regions that currently have a dominant role as producers and exporters of K fertilizers (i.e., the Other Developed countries group and the Rest Former USSR sub-region).
- Importing countries, such as the USA, Brazil, China and India are projected to experience increases in imports through 2022 in amounts that represent average annual linear trends of expansion in imports, of about 60, 100 and 40 and 49 thousand tons K_2O, respectively.
- Linear 2012–2022 import trends calculated for all other sub-regions and countries classified as "importers through 2022" in Table 6.8 show that all of them will experience moderate increases in volumes of imports through 2025. These increases represent positive average linear trends that range from nil in Japan and in the Central Asia, Other Southeast Asia and Other East Asia sub-regions to 14,000 tons K_2O per year in Malaysia.
- About 68 percent of the projected total world demand for K fertilizers will be met by imports through 2022.

Table 6.8. Projected Supply-Demand Balances and Fertilizer K_2O Volumes of Trade Among Key Countries and Sub-Regions in 2012, 2017 and 2022

Countries and Sub-Regions	Supply-Demand Balances 2012	2017	2022	Annual Linear Trend	Volume of Trade (Imports) 2012	2017	2022	Annual Linear Trend
	('000 mt of K_2O)							
Exporters Through 2022								
Other Developed	14,082	12,554	13,402	-68.0				
Rest Former USSR	9,174	9,108	9,216	4.1				
Other West Asia/North Africa	1,379	1,354	1,324	-5.5				
Europe (EU 15)	90	43	78	-1.2				
Exporters Becoming Importers								
Other Latin America	79	-13	-98	-17.7		13	98	
Importers Becoming Exporters								
Thailand	-341	699	676	101.7	341			102
Central & Western SSA	-150	99	42	19.3	150			19
Importers Through 2022								
USA	-5,792	-6,099	-6,391	-59.9	5,792	6,099	6,391	60
Brazil	-3,359	-3,862	-4,359	-100.1	3,359	3,862	4,359	100
China	-3,222	-3,623	-3,620	-39.8	3,222	3,623	3,620	40
India	-2,026	-2,267	-2,511	-48.5	2,026	2,267	2,511	49
Malaysia	-871	-940	-1,009	-13.7	871	940	1,009	14
Eastern Europe	-856	-916	-976	-12.0	856	916	976	12
Japan	-416	-416	-415	0.1	416	416	415	0
Australia	-329	-352	-374	-4.5	329	352	374	4
Indonesia	-317	-343	-370	-5.3	317	343	370	5
South Korea	-289	-303	-317	-2.8	289	303	317	3
Mexico	-274	-305	-336	-6.3	274	305	336	6
Vietnam	-237	-267	-298	-6.0	237	267	298	6
Colombia	-234	-260	-286	-5.2	234	260	286	5
Southern SSA	-164	-209	-264	-10.0	164	209	264	10
Other South Asia	-162	-181	-201	-3.9	162	181	201	4
Philippines	-158	-174	-191	-3.4	158	174	191	3
Bangladesh	-152	-164	-177	-2.5	152	164	177	3
Central Asia	-131	-121	-131	0.0	131	121	131	0
Nigeria	-92	-121	-158	-6.6	92	121	158	7
Turkey	-91	-99	-108	-1.7	91	99	108	2
Rest of the World	-69	-77	-85	-1.6	69	77	85	2
Argentina	-52	-61	-71	-1.9	52	61	71	2
Eastern SSA	-47	-60	-76	-2.9	47	60	76	3
Egypt	-39	-43	-46	-0.7	39	43	46	1
Northern SSA	-35	-41	-48	-1.3	35	41	48	1
Pakistan	-31	-35	-39	-0.8	31	35	39	1
Myanmar	-15	-20	-25	-1.0	15	20	25	1
Other Southeast Asia	-12	-18	-13	0.0	12	18	13	0
Other East Asia	-1	-1	-1	0.0	1	1	1	0
World	4,841	2,467	1,744	-309.7	19,963	21,392	22,995	310

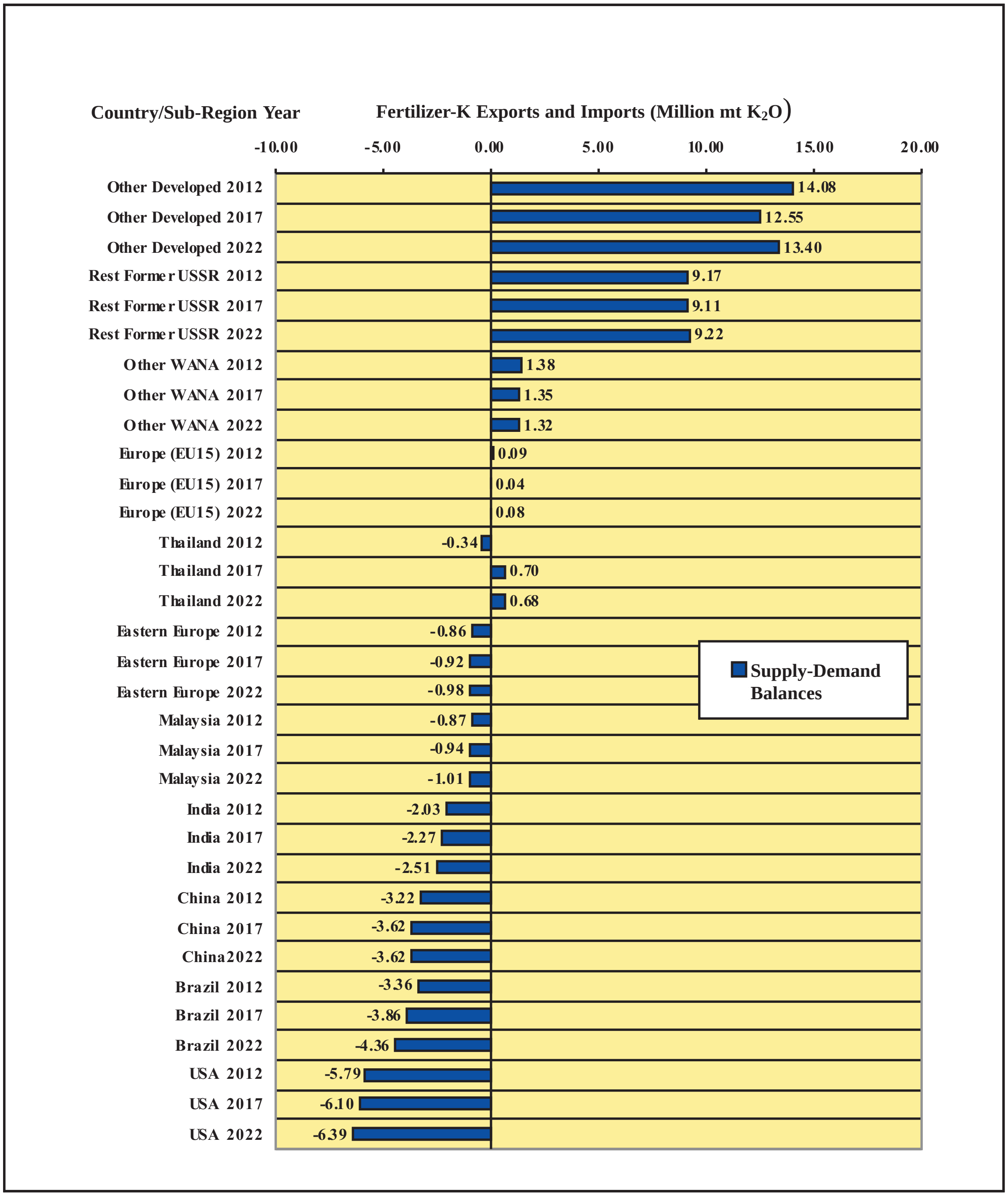


Figure 6.4. Projected Supply-Demand Balances of Fertilizer K in the Major Trading Countries and Sub-Regions

VII. Model Capabilities and Limitations

At its current state of development, the FertTrade model has uniquely useful capabilities as a tool for analysis and evaluation of the issues and evolving circumstances that affect fertilizer sectors and agricultural production and development globally, regionally and nationally. However, it is important to recognize that the capabilities and applications of the model can be significantly expanded through additional work in model development and refinement. For instance, by expanding its capability to derive estimates of animal waste production and pollution associated with livestock and crop production, as well as fertilizer production and use, impacts on the environment (land, water and air) could be estimated and assessed. Then, the FertTrade model could also be used to evaluate scenarios of changing circumstances in terms of their potential impact on the environment. Environmental impact assessments are becoming increasingly important for decision-making on policies and investments. The model's current capabilities and limitations are discussed in this chapter. Some of the limitations, which could be overcome through additional work in model development, are also discussed.

A. Current Model Capabilities

In its current state of development, FertTrade has a number of important and useful capabilities, including conducting analyses of scenarios that can be specifically designed to evaluate impacts of changes in policies, technologies and circumstances affecting agriculture and fertilizer sectors on the production, demand and trade of fertilizer N, P and K. Current model capabilities include the assessment of scenarios portraying changes in the values of many key variables important to evaluate impacts of policy interventions, technical change and investment strategies such as the following:

1. To assess the need and timing for investing in facilities to produce, import/export, store, transport and handle fertilizers in key countries and sub-regions in response to changing circumstances affecting fertilizer markets.
2. To estimate the impact of changes in population and income growth in key countries and sub-regions on the production, demand and trade of N, P and K fertilizers.
3. To evaluate the consequences of expected changes in preferences for food consumption on the production, demand and trade of N, P and K fertilizers.
4. To assess the impact of expected changes in the demand for bio-fuels on crop production and fertilizer demand, production and trade.
5. To evaluate the consequences of expected changes in areas harvested with various crops and crop yields (productivity) in key countries and sub-regions on fertilizer demand, production and trade.
6. To conduct ex-ante assessments of the potential impact of technical change and innovations in the production and use of more efficient fertilizer products on the demand, consumption and use of fertilizers and on crop productivity.

It should be noted that one of the current capabilities of the model is to project through 2025 the annual consumption of N, P and K fertilizer by the major key crops and groups of crops in each of the model's key countries and sub-regions. The projected baseline scenario estimates of annual N, P and K fertilizer consumption by major crops are not presented in this paper but are part of the results currently produced by the model. These estimates could be the focus of studies to evaluate, for instance, the consequences of changes in areas harvested with various crops as a result of the increased demand for bio-fuels or changes in consumers' preferences for food commodities.

B. Current Model Limitations

Some of the limitations of the model are imposed by its linkage to the food commodities market outcomes produced by the IMPACT model. Because of this linkage, the highest level of resolution (zoom-in) at which estimates of N, P and K fertilizer demand and production are obtained is the 20 major countries (including China, comprising Taiwan and Hong Kong) and the 16 multi-country sub-regions specified in the IMPACT model. This limitation restricts the capability of the model to properly estimate and evaluate N, P and K fertilizer demand, production and trade in the individual countries that are part of the 16 multi-country sub-regions. Despite this limitation, analyses and evaluations can still be conducted by using the model's aggregated estimates for the sub-regions in conjunction with available information on the agriculture and fertilizer sectors in the individual countries within the sub-regions.

Quantities of N, P and K fertilizers traded among the 20 key countries and 16 sub-regions specified in the model are estimated by the amounts of excess demand in deficit-importing countries/sub-regions and excess supply in surplus-exporting countries/sub-regions with excess production capacity. This approach does not account for some of the trade that occurs among the model's key countries and sub-regions. This includes: (a) fertilizer imports made by surplus countries to meet seasonal demands or for other commercial purposes; and (b) the exports of fertilizers made by a country deficient in a given fertilizer nutrient to meet the demand in another country for a specific type of fertilizer product containing such nutrient. Although some quantities of fertilizers will continue to be traded for such purposes, the volume of net trade occurring in this way is a very small fraction of the total volume of fertilizer trade. Hence, this limitation does not and should not hamper significantly the analytical capability of the FertTrade model.

Additional limitations of the model are related to the assumptions adopted in the methodology to derive estimates of the demand for fertilizer N, P and K in each of the model's key countries and sub-regions. In this regard, the model's demand estimates are affected and restricted by the following assumptions and considerations:

1. It is assumed that fertilizer demand quantities are not significantly affected by changes in prices of fertilizers and agricultural commodities over time. This means that we are implicitly assuming that the real prices of fertilizers (i.e., the fertilizer/commodity price ratios) will not change significantly over time and therefore will not influence significantly the projected quantity demanded of fertilizer nutrients in each country/sub-region. This implicit assumption is in part supported by trends in world market price data showing that real prices of fertilizers have either declined somewhat or remained relatively stable over periods of 20-30 years. Changes in the quantity of fertilizer demanded are determined in the model by shifts of the demand curve such as changes in population, incomes and technology over time rather than by movements along the demand curve due to sudden changes in prices. This assumption and model limitation should not affect the reliability of the model to estimate long-term trends in fertilizer demand estimates. However, the model is currently limited in evaluating the short-term impact of sudden drastic changes in fertilizer prices on the demand and consumption of fertilizers.
2. Average crop-specific N:P:K demand ratios are assumed to remain stable over time. They are determined mainly by the technical nutrient uptake requirements of each crop. Because of this methodology, the model currently does not account for changes that may take place in crop-specific N:P:K ratios in response to policies or price changes that promote the use of one fertilizer nutrient over another. This limitation should not affect significantly the assessment of long-term trends in fertilizer markets. However, it is a limitation that can be overcome through additional work on the model.
3. Coefficients reflecting levels of fertilizer adoption and rates of use specific for each of the model's key countries and sub-regions are calculated and used in the estimation of fertilizer demand quantities. These coefficients are calculated using data on rates of fertilizer adoption and use on various crops in current years in the key countries and sub-regions. However, it is recognized that because of limitations in the availability of proper data in many countries, some of these coefficients could be improved with better information. These coefficients should be refined as part of the continuous maintenance and upgrading of the model.
4. Country-specific coefficients reflecting rates of change over time in the coefficients of fertilizer adoption and rates of use discussed above are identified on the basis of recent historical trends and expectations. These coefficients also could be further refined and upgraded and can be used as variables for scenario design.

C. Potential Expanded Capabilities

Additional work in model development, testing and evaluation can be conducted to overcome some of the model's limitations discussed above and improve its capabilities and reliability. Some of the possible areas of expansion where methodological challenges must be confronted and proper methods and procedures developed to expand and enhance the analytical capabilities of the model are briefly discussed here.

1. ***Resource Base Impact Assessment*** – To assess the consequences of policy measures and changing circumstances affecting agricultural and fertilizer sectors on the resource base – air, land and water – and the environment. This involves the development of methods and procedures to derive estimates of pollution flows associated with agricultural production and fertilizer use and production. It requires methods to estimate the flows of major pollutants into air, land and water by linking the model's outputs on food commodities' production and fertilizer use and production with the creation and fate (the path) of such pollutants.

2. ***Trends in Markets for Fertilizer Products*** – To derive estimates of the demand, production and trade of main fertilizer products (in addition to nutrients) on the basis of the model's estimates for the demand, production and trade of N, P and K fertilizer nutrients.
3. ***Impact of Fertilizer and Commodity Price Changes*** – To develop methods and procedures to evaluate short- and long-term effects of fertilizer and food commodity price changes on the demand for fertilizer N, P and K and their consumption, supply and trade.
4. ***Inclusion of Water in the Model*** – Methods and procedures could be designed to derive estimates of water demand and consumption associated with the production of food commodities and fertilizer use including the impact of improved irrigation/fertilizer-use technology. In an increasing number of countries and regions, water rather than land is becoming the most limiting resource for agricultural production. Therefore, it is important now, and will be even more so in the future, to evaluate changes in (and impacts on) water use efficiency and the productivity of water (crop yield per unit of water). The model's capabilities will be significantly enhanced by the explicit inclusion in the model of fertilizer nutrient-water interactions.

Improvements in the analytical capabilities of the model will be useful to evaluate emerging issues and concerns associated with the need for increased agricultural production to meet growing demands for food and bio-fuels while conserving the resource base and protecting the environment. Added capabilities can significantly enhance the value of the model as a tool for policy evaluation and decision-making on key policy measures and investments concerning agriculture and fertilizer sector development taking into account impacts on the environment. This would be particularly useful for decision-making in developing countries with fragile environments and inherently poor resource bases. Although proposed improvements in model development may be challenging and time-consuming endeavors that are often difficult to implement, circumstances associated with prevailing trends in trade, globalization and climate change greatly facilitate the justification of investments in such efforts. The increased interdependence of national country economies to these global evolving circumstances will, in the future, boost the need for assessments to be conducted from global, regional and sub-regional perspectives. Therefore, the need and benefits of analytical tools to conduct these types of analyses and assessments shall be significantly increased in the future.

VIII. "What If" Scenarios and Policy Development

The FertTrade model at its current level of development is a useful tool for decision-making concerning the design of key policies and technology development efforts to enhance the performance of fertilizer and agriculture sectors globally, regionally and nationally. The model can be used to evaluate "what if" scenarios of changes induced by policies or technology innovations that affect fertilizer and agriculture sectors. Such changes can be assessed in terms of their expected impacts on agriculture production, productivity and efficiency, and the demand for and trade of fertilizers.

In this chapter, a "what if" scenario illustrates the use of the model as a tool to assess the expected impact of improving the efficiency of fertilizer N applied through technical innovation. The purpose is to facilitate decision-making for investing in research and development. In this instance, the FertTrade model evaluates *ex-ante* the potential feasibility of investing in research and development work and technology transfer activities that will achieve pre-established goals of increased technical efficiency in the use of fertilizer N applied to the production of cereals (rice, maize, wheat and other grains) in developing countries.

The assessment involves using the model's outcomes of a "what if" scenario portraying an increased fertilizer N use efficiency in cereal production from 40 percent to 60 percent to estimate the main economic and environmental impacts that will take place as a result of a successful effort in technology development and transfer. The evaluation focuses on the developing countries and is based on estimates of impacts on: (a) the consumption of fertilizer N; (b) the losses of fertilizer N to the environment; (c) the total expenditures in fertilizers by farmers; and (d) the potential economic feasibility for society as a whole to invest in such a technology. In the following section, estimates of impacts associated with the adoption of the improved fertilizer N technology for cereal production in developing countries are presented and discussed.

A. Assessing the Impact of Increased Fertilizer N Efficiency in Developing Countries

The efficiency of fertilizer N applied to crops is in general quite low. This is particularly evident in developing countries where only about one-third (30 percent to 40 percent) of the fertilizer N applied is used by the crop and two-thirds is lost to the environment. Improvement in fertilizer N use efficiency by crops can provide important benefits to farmers, consumers and the environment by: (a) increasing, or at least maintaining, crop yields while decreasing the rate and cost to farmers of fertilizer N applied; (b) increasing the production of crop outputs for consumers; and (c) reducing the losses of fertilizer N to the environment (air, land and water). IFDC, in collaboration with national and international organizations, has and is still conducting research and technology transfer to increase the efficiency of fertilizer N applied to crops (in particular to paddy rice production in Bangladesh and Southeast Asia). Although important progress has been made in some areas of this region through the deep placement of urea briquettes in conjunction with better crop management practices, substantial additional efforts in research and technology transfer are needed to significantly increase the efficiency of fertilizer N applied to crops in developing countries.

The FertTrade model is used here to illustrate its value as a tool for evaluating *ex-ante* the consequences, impacts and benefits of investing in a concerted research and development and technology transfer effort to achieve the goal of increasing the efficiency of fertilizer N applied to cereal production in developing countries, from about 40 percent to 60 percent after the improved technology is adopted by farmers. This evaluation is based on estimates derived from the model's outcomes produced by the simulation of a scenario that explicitly accounts for the impacts of the improved efficiency of fertilizer N applied to all cereals, namely wheat, rice, maize and other grains. It is assumed that fertilizer N use efficiency in other crops will not change significantly in conjunction with the improvement achieved for cereals.

Context for Assessment of Impact – Two variables are important in describing the context in which the strategy of increased fertilizer N efficiency is evaluated; namely, the consumption of fertilizer N in developing and developed countries and the current apparent levels of fertilizer N efficiency that prevail in these two groups of countries.

The consumption of fertilizer N in developing countries is projected to increase through 2025 at an annual rate of growth of about 2 percent, about twice as fast as the 0.9-1 percent projected rate of growth in the developed countries. As shown in Table 8.1, the developing countries' consumption of fertilizer N is projected to increase between 2010 and 2024 from about 69.1 to 89.6 million tons, respectively, that is, from 67.1 percent to 70.2 percent of the world's consumption. In the developed countries, the consumption of fertilizer N is projected to increase from 33.9 million tons in 2010 to about 38.0 million tons in 2024. Such projections indicate a decline in the developed countries share of the world's consumption from 32.9 percent in 2010 to 29.8 percent. Thus, fertilizer N consumption in developing countries will increase in importance in terms of both the amount consumed and their share in the world's market for fertilizer N.

Because of advantages in crop management practices and mechanization, the efficiency of fertilizer N applied to crops is on the average higher in developed than in developing countries. The limited but increasing use of controlled release N fertilizers on selected crops by a few developed countries, and the more widespread use of fertilizer sources of N in conjunction with drip irrigation are contributing to the higher efficiency of fertilizer N applied in the developed countries. Additional factors contributing to the lower efficiency of fertilizer N applied in some developing countries are subsidies for N fertilizers that exist in those countries (for example, Bangladesh, China and India). Subsidies for fertilizer N are often conducive to the overuse of fertilizer N, which results in increased loss of N to the environment and unbalanced N:P:K ratios of fertilization.

The benefits of a successful strategy to improve the efficiency of fertilizer N applied are expected to be substantially higher in the developing countries where the levels of current and projected fertilizer N consumption are more than twice as high as in the developed countries and the current efficiency of fertilizer N applied is significantly lower. The proposed strategy focuses on developing and transferring an improved fertilizer use technology, which may involve a modified fertilizer product and method of application that successfully increases the efficiency of the fertilizer N applied to cereal crops. Focusing on cereals takes into consideration that they are important core sources of food (and feed) needed to meet the rapid growing demand of increasing populations and higher incomes in the developing world.

Impact on Consumption of Fertilizer N – Impacts of the improved fertilizer technology on the 2010-2025

Table 8.1. Projected Consumption of Nitrogen (Fertilizer N) in Developing and Developed Countries

Year	Developing Countries		Developed Countries		World
	('000 ton)	World's Share	('000 ton)	World's Share	('000 ton)
2010	69,137	67.1%	33,932	32.9%	103,069
2011	70,568	67.3%	34,236	32.7%	104,804
2012	72,027	67.6%	34,541	32.4%	106,568
2013	73,513	67.8%	34,846	32.2%	108,360
2014	75,029	68.1%	35,152	31.9%	110,181
2015	76,573	68.3%	35,458	31.7%	112,031
2016	78,019	68.6%	35,747	31.4%	113,766
2017	79,484	68.8%	36,036	31.2%	115,520
2018	80,970	69.0%	36,326	31.0%	117,295
2019	82,479	69.3%	36,614	30.7%	119,093
2020	84,012	69.5%	36,903	30.5%	120,915
2021	85,393	69.7%	37,178	30.3%	122,570
2022	86,791	69.9%	37,452	30.1%	124,242
2023	88,208	70.0%	37,725	30.0%	125,933
2024	89,646	70.2%	37,996	29.8%	127,642

projected demand and consumption of fertilizer N in developed and developing countries are presented in Table 8.2. Adoption of the improved technology would reduce the world's projected consumption of fertilizer N in the production of cereals by about: (a) 13.3 million tons in 2010, 5.8 and 7.5 million tons in the developed and developing countries, respectively; and (b) 15.7 million tons in 2025, 6.5 and 9.3 million tons in the developed and developing countries, respectively. The impact of the improved technology in reducing fertilizer N consumption would be about 30 percent greater in the developing countries than in the group of developed countries. This is because consumption of fertilizer N in the developing countries is projected to be more than double the consumption projected for developed countries. About 42 percent and 58 percent of the projected impact of the improved technology in reducing the world's consumption of fertilizer N would take place in the developed and developing countries, respectively. Projections produced by the model show that, by increasing the efficiency of fertilizer N applied to cereals, the improved fertilizer technology will decrease the annual world demand and consumption of fertilizer N by 13.3 million tons in 2010 and 15.7 million tons in 2025.

Impact on Losses of Fertilizer N to the Environment – Estimates of the impacts that the development and transfer of the improved fertilizer technology to cereal farmers in developing countries would have on the losses of fertilizer N to the environment are presented in Table 8.3. These estimates are derived from the projected levels of fertilizer N consumption in developing countries produced by the FertTrade model for scenarios depicting, in one instance, the use of the current technology (60 percent N lost) and, in another, the improved, more efficient (40 percent N lost) fertilizer N technology in cereal production. Such estimates show the following:

1. Under current low levels of fertilizer N use efficiency, losses of fertilizer N to the environment are substantial and increasing in proportion to the growth in consumption of fertilizer N by farmers. If the current prevailing efficiency of N applied to crops in the developing countries was to continue at a low average of about 40 percent; then, the 60 percent of the applied fertilizer N, which will be lost to the environment is projected to increase from an annual rate of about 41.5 million tons in 2010 to 54.7 million tons in 2025, a significant increase in the annual rate of losses of about 13.2 million tons over 15 years.
2. The development and transfer of a fertilizer technology that increases the average efficiency of fertilizer N applied to cereals from 40 percent to 60 percent (i.e., decreases fertilizer N losses in cereal production from 60 percent to 40 percent), will reduce substantially the amounts of fertilizer N lost to the environment, in particular in the developing countries where

Table 8.2. Impact of Improved Technology on Fertilizer N Consumption in Developed and Developing Countries

Year	Developed Countries				Developing Countries				World			
	Current Fertilizer Technology	Improved Fertilizer Technology [a]			Current Fertilizer Technology	Improved Fertilizer Technology [a]			Current Fertilizer Technology	Improved Fertilizer Technology [a]		
	Consumption Fertilizer N	Consumption Fertilizer N	Decrease in Consumption Fertilizer N in Cereals		Consumption Fertilizer N	Consumption Fertilizer N	Decrease in Consumption Fertilizer N in Cereals		Consumption Fertilizer N	Consumption Fertilizer N	Decrease in Consumption Fertilizer N in Cereals	
	('000 mt)	('000 mt)	('000 mt)	(% of World)	('000 mt)	('000 mt)	('000 mt)	(% of World)	('000 mt)	('000 mt)	('000 mt)	(%)
2010	33,932	28,176	5,756	43.3%	69,137	61,605	7,532	56.7%	103,069	89,781	13,288	12.9%
2011	34,236	28,429	5,807	43.1%	70,568	62,914	7,654	56.9%	104,804	91,343	13,461	12.8%
2012	34,541	28,682	5,859	43.0%	72,027	64,250	7,776	57.0%	106,568	92,933	13,635	12.8%
2013	34,846	28,936	5,910	42.8%	73,513	65,613	7,901	57.2%	108,360	94,549	13,811	12.7%
2014	35,152	29,190	5,962	42.6%	75,029	67,002	8,026	57.4%	110,181	96,193	13,988	12.7%
2015	35,458	29,445	6,013	42.4%	76,573	68,419	8,154	57.6%	112,031	97,864	14,167	12.6%
2016	35,747	29,686	6,061	42.3%	78,019	69,749	8,270	57.7%	113,766	99,435	14,331	12.6%
2017	36,036	29,927	6,109	42.1%	79,484	71,097	8,386	57.9%	115,520	101,025	14,495	12.5%
2018	36,326	30,169	6,157	42.0%	80,970	72,467	8,502	58.0%	117,295	102,636	14,659	12.5%
2019	36,614	30,410	6,204	41.9%	82,479	73,860	8,619	58.1%	119,093	104,270	14,823	12.4%
2020	36,903	30,651	6,252	41.7%	84,012	75,276	8,736	58.3%	120,915	105,927	14,988	12.4%
2021	37,178	30,882	6,296	41.6%	85,393	76,549	8,843	58.4%	122,570	107,431	15,139	12.4%
2022	37,452	31,113	6,339	41.5%	86,791	77,841	8,950	58.5%	124,242	108,953	15,289	12.3%
2023	37,725	31,342	6,382	41.3%	88,208	79,151	9,057	58.7%	125,933	110,493	15,440	12.3%
2024	37,996	31,571	6,425	41.2%	89,646	80,481	9,165	58.8%	127,642	112,052	15,590	12.2%
2025	38,266	31,799	6,468	41.1%	91,105	81,832	9,273	58.9%	129,371	113,631	15,741	12.2%

a. Technology to increase efficiency of N applied to cereals – wheat, rice, maize and other grains – from 40 percent to 60 percent.

Table 8.3. Impact of Improved Technology on Fertilizer N Consumption and the Losses of N to the Environment in Developing Countries

Year	Current Technology			Improved Technology [a]					
	Projected Consumption Fertilizer N	Fertilizer N Lost to the Environment	Fertilizer N Used by Crops	Projected Consumption Fertilizer N	Fertilizer N Lost to the Environment	Fertilizer N Used by Crops	Decrease in Consumption of Fertilizer N	Decrease in Fertilizer N Lost to the Environment	
	('000 mt of N)								(%)
2010	69,137	41,482	27,655	61,605	33,950	27,655	7,532	7,532.36	18.2%
2011	70,568	42,341	28,227	62,914	34,687	28,227	7,654	7,653.60	18.1%
2012	72,027	43,216	28,811	64,250	35,440	28,811	7,776	7,776.31	18.0%
2013	73,513	44,108	29,405	65,613	36,208	29,405	7,901	7,900.52	17.9%
2014	75,029	45,017	30,011	67,002	36,991	30,011	8,026	8,026.28	17.8%
2015	76,573	45,944	30,629	68,419	37,790	30,629	8,154	8,153.50	17.7%
2016	78,019	46,811	31,208	69,749	38,541	31,208	8,270	8,270.24	17.7%
2017	79,484	47,690	31,793	71,097	39,304	31,793	8,386	8,386.21	17.6%
2018	80,970	48,582	32,388	72,467	40,079	32,388	8,502	8,502.28	17.5%
2019	82,479	49,487	32,992	73,860	40,868	32,992	8,619	8,618.96	17.4%
2020	84,012	50,407	33,605	75,276	41,671	33,605	8,736	8,736.37	17.3%
2021	85,393	51,236	34,157	76,549	42,392	34,157	8,843	8,843.29	17.3%
2022	86,791	52,074	34,716	77,841	43,124	34,716	8,950	8,950.15	17.2%
2023	88,208	52,925	35,283	79,151	43,868	35,283	9,057	9,057.31	17.1%
2024	89,646	53,788	35,859	80,481	44,623	35,859	9,165	9,164.95	17.0%
2025	91,105	54,663	36,442	81,832	45,390	36,442	9,273	9,273.15	17.0%

a. Technology to increase efficiency of N applied to cereals – wheat, rice, maize and other grains – from 40 percent to 60 percent.

higher levels of consumption and losses of fertilizer N occur. A 40 percent to 60 percent improvement in fertilizer N efficiency is estimated to decrease the projected amounts of fertilizer N lost to the environment in developing countries by approximately 7.5 million tons (from 41.5 to 34.0 million tons) in 2010 and 9.3 million tons (from 54.7 to 45.4 million tons) in 2025. It is interesting to note that the annual projected decrease of fertilizer N lost to the environment caused by the improved technology is approximately equal to 60 percent of the USA's annual consumption of fertilizer N.

3. A 40 percent to 60 percent increased efficiency of fertilizer N applied to cereal crops in developing countries will decrease the overall losses of fertilizer N in developing countries by 18.2 percent and 17.0 percent in 2010 and 2025, respectively (i.e., from 41.5 to 34.0 million tons in 2010 and from 54.7 to 45.4 million tons in 2025).

B. Economic Impact of Increased Fertilizer N Efficiency in Developing Countries

Assumptions for Assessment of Economic Benefits – In addition to the model's outcomes, information about prices (per-unit cost) of fertilizer N when using current and improved technologies is required to estimate changes in benefits and costs that would be associated with the adoption of the improved technology and to conduct this assessment. Raising fertilizer N efficiency from 40 percent to 60 percent through improved technology implies a 50 percent increase in efficiency of applied fertilizer N. Assumptions are made by taking into consideration that: (a) the benefits of fertilizer N applied associated with the increased efficiency provide margins of saving that represent "*funding allowances*" to partially cover additional costs (price) for purchasing and applying the improved fertilizer N technology; and (b) these saving margins or "*funding allowances*" increase in direct proportion to the rate of increased fertilizer N efficiency and serve to establish limits on the amount of funds that could be used for investments in technology development and transfer, and on the fertilizer N price (cost) increase that the improved technology could support.

The parameters and assumptions adopted for scenario simulation and to derive the estimates necessary for conducting the assessment of economic benefits are described on Table 8.4. A urea price of $500/mt is used to price the current fertilizer N technology at $1,086.96/mt of N. The added cost of the improved fertilizer N is assumed to be $300/ton of N so that the cost (price) of the improved fertilizer N will be $1,386.96/ton of N applied. The added cost of $300/ton of N is assumed to cover research and development costs and operational added costs for producing, transferring and applying a ton of improved fertilizer N.

The break-even per-unit added cost of improved fertilizer N represents the amount of additional cost per ton of improved fertilizer N that will make the total expenditures (cost) in fertilizer N equal using either technology. This implies that the break-even price of improved fertilizer N will increase in the same proportion as the quantity of fertilizer N applied decreases (50 percent). The following observations are made about the assumptions described above:

1. The added cost of $300/ton of N for developing and transferring the technology accounts for only 55 percent of the saving margin, which is equivalent to a break-even added cost of $543.48/ton of N. Hence, there is still a margin of saving that allows higher added costs than are assumed here.
2. It is implicitly assumed that lower fertilizer N rates with the improved technology occur as a result of the increased efficiency of N applied and that average cereal yields increases of zero percent to 15 percent are obtained at the lower optimum rates of fertilizer N applied. Experimental data have shown that response curves of cereal yields to N applied using more efficient improved fertilizer N technology, such as deep placement of urea supergranules, are steeper than those to N applied using the less efficient current fertilizer N technology. Such results indicate that crop yields are often 20 percent to 25 percent higher at lower rates of fertilizer N when the efficiency of fertilizer N applied is increased. Thus, in this assessment, returns to investments in research and development and technology transfer of an improved, more efficient N technology are evaluated at four conservative levels of cereal yield increases – zero percent, 5 percent, 10 percent and 15 percent.

Impact on Farmers' Expenditures in Fertilizers – Impact estimates of the improved, more efficient fertilizer N technology on the developing countries in terms of aggregated levels of fertilizer N consumption, the total cost of (farmers' total expenditures in) the quantity of fertilizer N applied and the farmers' benefits in the form of savings in fertilizer expenditures are shown on Table 8.5. These estimates indicate the following:

Table 8.4. Parameters Used in Scenario Simulation and Economic Analysis

	Parameters	Derived Estimates	Notation	Calculation of Derived Estimates
Current all-crop average efficiency of fertilizer N applied	40%		E0	
Current percent lost of fertilizer N applied (%)		60%	NL0	1-E0
Efficiency of fertilizer N applied using improved technology (%)	60%		E1	
Percent lost of fertilizer N applied using improved technology (%)		40%	NL1	1-E1
Average increased efficiency of N applied (%)		50.0%	ChE	(E1/E0)-1
Price of urea ($/mt urea)	500.00		Pu	
Price of urea N ($/mt of urea N)		1,086.96	PNu	Pu/0.46
Total added cost of improved N fertilizer ($/mt of N)	300.00		ChPN	
Break-even added cost of improved N fertilizer ($/mt of N)		543.48	BEChPN	PNu*(ChE)
Break-even cost of improved N fertilizer ($/mt of N)		1,630.43	BEPN	PNu + BEchPN
Total added cost of improved N fertilizer as percent of break-even added cost (%)		55%		(ChPN/BEChPN)*100
Price of improved N fertilizer ($/mt of N)		1,386.96	PN1	PNu + ChPN

Table 8.5. Projected Impacts of Using Improved Fertilizer N Technology for Cereal Production in Developing Countries

Year	Impact on Projected Consumption of Fertilizer N		Impact on Projected Consumption of Fertilizer N in Cereals		Impact on N Consumption, Losses to the Environment and Farmers' Expenditures in N Fertilizers.				
	Using Current Technology	Using Improved Technology in Cereals	Using Current Technology	Using Improved Technology in Cereals	Decrease in Fertilizer N Consumption and the N Lost to the Environment	Farmers' Expenditures in Fertilizer N Applied to Cereals Using Urea	Farmers' Expenditures in Fertilizer N Applied to Cereals Using Improved Technology	Total Savings of Farmers in Fertilizer Expenditures	Value of Urea N Lost to the Environment Under Current Technology
	('000 ton N)					(million $)			
	TQN_u	TQN_I	QN_u	QN_I	$QN_u - QN_I$	$FEN_u = QN_u * (PN_u)$	$FEN_I = QN_I * (PN_I)$	$FEN_u - FEN_I$	$PN_u * (TQN_u - TQN_I)$
2010	69,137	61,605	22,597	15,065	7,532	24,562	20,894	3,668	8,187
2011	70,568	62,914	22,961	15,307	7,654	24,957	21,230	3,727	8,319
2012	72,027	64,250	23,329	15,553	7,776	25,358	21,571	3,787	8,453
2013	73,513	65,613	23,702	15,801	7,901	25,763	21,915	3,847	8,588
2014	75,029	67,002	24,079	16,053	8,026	26,173	22,264	3,908	8,724
2015	76,573	68,419	24,461	16,307	8,154	26,588	22,617	3,970	8,863
2016	78,019	69,749	24,811	16,540	8,270	26,968	22,941	4,027	8,989
2017	79,484	71,097	25,159	16,772	8,386	27,346	23,263	4,084	9,115
2018	80,970	72,467	25,507	17,005	8,502	27,725	23,585	4,140	9,242
2019	82,479	73,860	25,857	17,238	8,619	28,105	23,908	4,197	9,368
2020	84,012	75,276	26,209	17,473	8,736	28,488	24,234	4,254	9,496
2021	85,393	76,549	26,530	17,687	8,843	28,837	24,531	4,306	9,612
2022	86,791	77,841	26,850	17,900	8,950	29,185	24,827	4,358	9,728
2023	88,208	79,151	27,172	18,115	9,057	29,535	25,124	4,411	9,845
2024	89,646	80,481	27,495	18,330	9,165	29,886	25,423	4,463	9,962
2025	91,105	81,832	27,819	18,546	9,273	30,239	25,723	4,516	10,080

1. A substantial decrease in fertilizer N applied to cereals as a result of replacing the use of urea N with the improved fertilizer N technology accounts for the overall decline in fertilizer N consumption. Such decreases are equal to reductions in the quantities of fertilizer N lost to the environment, which are projected to amount to 7.5 million tons in 2010 and increasing to 9.3 million tons in 2025.
2. Farmers' savings in fertilizer N expenditures as a result of the increased efficiency of fertilizer N applied are explained in detail in Appendix 3. Estimates of saving are presented in Table 8.5 and show that despite a $300 increase in the cost per ton of improved fertilizer N technology applied, total net saving of farmers' expenditures in N fertilizers in developing countries would increase from about $3.7 billion in 2010 to $4.5 billion in 2025. Farmers' total expenditures in fertilizer N for cereal production in developing countries would decrease from $24.6 billion to $20.9 billion in 2010 and from $30.2 billion to $25.7 billion in 2025. This saving will significantly increase the incomes of millions of cereal farmers in developing countries.
3. In addition to the farmers' savings in fertilizer expenditures (costs), the improved fertilizer N technology will prevent the loss of substantial amounts of urea N to the environment (i.e., about 7.5 million tons in 2010 and 9.3 million tons in 2025). The value of the urea N saved as a result of using the improved fertilizer N technology for cereal production in developing countries (calculated at a price of $500/mt of urea) is projected to be $8.2 billion and $10.1 billion in 2010 and 2025, respectively. These valuations, however, do not account for the benefit that the prevention of N losses to the environment will provide. Such losses occur as an externality caused by the current management and use of N fertilizers, which result in the low efficiency of uptake by crops of the applied N. Such losses are detrimental in general to the environment, frequently reducing and degrading the conservation and value of the resource base.

C. Ex-Ante Assessment of Feasibility to Invest in Technology Development and Transfer

Added Benefits of Technology to Cover for Developing and Transferring Costs – Benefits associated with replacing urea N with improved, more efficient fertilizer N technology in the production of cereals provide savings margins and funding to pay for the development and transfer costs of the technology. If the costs (prices) of using a unit of urea N and improved fertilizer N were the same, then replacing urea N with improved fertilizer N would result in savings equal to the value of the urea lost to the environment when urea rather than the improved, more efficient technology is used. However, prices and costs of using an improved fertilizer N technology will be greater than those of urea N. Additional costs are associated with investing in research and development and technology transfer efforts required to be successful in the development and widespread adoption of the improved technology. Hence, in the extreme case that cereal yields were not increased (no impact on crop yields), the saving of adopting the improved technology should be less than the value of the urea lost to the environment when urea rather than the improved, more efficient technology is used.

In that extreme case, the calculated breakeven added cost and corresponding price of the improved technology are $543.48 and $1,630.44/ton of fertilizer N, respectively. At such added cost and price, the value of the entire amount of the urea N that would be saved from being lost to the environment would be used up to pay for the additional cost of developing and transferring the improved fertilizer N technology to cereal farmers. At the high price of $1,630.44/ton for the improved technology fertilizer N, there would not be direct benefits to farmers, only benefits to the environment due to reduced N pollution of land, air and water. Therefore, the added cost (or increased price) of the improved fertilizer N technology must be significantly lower than $543.48/ton of N to provide sufficient incentives for farmers to adopt the improved technology.

In Table 8.6, cost (price) increases of $300 and the break-even $543.48/ton of N are used to calculate the projected 2010-2025 streams of funds that would be generated by such increases for possible use in research and development and technology transfer efforts. This will encourage the development and widespread adoption of the improved technology for cereal production in developing countries. These estimates show that a fertilizer N price increase of $300/ton will provide more than $4.5 billion per year in funds for investing in research and development and technology transfer, in addition to the significant benefits that the technology would bring to farmers, consumers and the environment. Fertilizer N price increases greater than $300/ton but lower than $543.48 (e.g., $400/ton of N), will provide more than $6.0 billion per year in funds for investing in

Table 8.6. Streams of Funds That Could be Used to Justify Investments in the Development and Transfer of the Improved Fertilizer N Technology to Cereal Farmers in Developing Countries

Year	Funds to Justify Expenditures in R&D and the Transfer of Improved Technology to Farmers	
	If Total Added Cost of Improved Technology is $300/mt of N	If Total Added Cost of Improved Technology is at Breakeven Level – $543/mt of N
	(million $)	(million $)
2010	4,519	8,187
2011	4,592	8,319
2012	4,666	8,453
2013	4,740	8,588
2014	4,816	8,724
2015	4,892	8,863
2016	4,962	8,989
2017	5,032	9,115
2018	5,101	9,242
2019	5,171	9,368
2020	5,242	9,496
2021	5,306	9,612
2022	5,370	9,728
2023	5,434	9,845
2024	5,499	9,962

research and development and technology transfer, but will reduce proportionally the benefits to farmers.

The billions of dollars in saving that the improved technology can generate by replacing the use of urea N with the widespread adoption of more efficient N fertilizer technology in cereal production are a clear indication of the magnitude of investments that society as a whole could afford to achieve such goals. In this context, the funds to cover research and development and technology transfer costs calculated on the basis of a total added cost of $300/ton of fertilizer N indicate that society as a whole could afford to invest $4.5 billion to $5.0 billion globally in this effort on an annual basis for many years. The potential feasibility of such effort is examined below.

Economic Feasibility of Investing in More Efficient N Fertilizer Technology – Estimates presented in Table 8.6 are further used in Table 8.7 to assess the potential economic feasibility of investing in the improved fertilizer N technology. This takes into consideration the years that may be required to develop, evaluate and then successfully transfer the improved technology to farmers. Results of a scenario evaluated to conduct such assessment are presented in Table 8.7. The scenario is designed considering estimates shown in Table 8.6 suggesting that five years will be required for research and development work followed by eight additional years to transfer the technology to cereal farmers in the developing countries. The streams of costs and benefits presented in Table 8.7 are based on the following additional expectations:

1. An amount of $4.0 billion will be invested annually during six years (2009-2014) to conduct research and development work needed to be successful in developing fertilizer N products/use technologies that increase fertilizer N use efficiency in cereal production to 60 percent from a current average of 40 percent of the N applied.

Table 8.7. Assessing the Potential Feasibility of Investing in the Development and Transferring of the Improved Fertilizer N Technology in Developing Countries

Year	Value of Urea N Lost to the Environment Under Current Technology	Funds That Could be Used to Cover R&D and Transfer Costs of Improved Technology at Rate of $300/mt of N	Stream of Investment Costs to Develop and Transfer Improved Technology	Rate of Adoption of Improved Technology in Cereals in Developing Countries	Projected Streams of Net Benefits of Improved Technology			
					If No Yields Increase	If Yields Increase 5%	If Yields Increase 10%	If Yields Increase 15%
	(million $)	(million $)	(million $)	(%)	(million $)			
2009			4,000	0.0%	0	-4,000	-4,000	-4,000
2010			4,000	0.0%	0	-4,000	-4,000	-4,000
2011			4,000	0.0%	0	-4,000	-4,000	-4,000
2012			4,000	0.0%	0	-4,000	-4,000	-4,000
2013			4,000	0.0%	0	-4,000	-4,000	-4,000
2014	8,724	4,816	4,000	10.0%	872	-2,014	-901	213
2015	8,863	4,892	3,600	20.8%	1,847	605	2,963	5,322
2016	8,989	4,962	2,850	32.6%	2,935	3,832	7,579	11,326
2017	9,115	5,032	1,919	45.5%	4,148	7,525	12,822	18,118
2018	9,242	5,101	1,046	59.5%	5,501	11,480	18,505	25,530
2019	9,368	5,171	423	74.8%	7,010	15,540	24,493	33,446
2020	9,496	5,242	120	90.0%	8,546	19,343	30,260	41,177
2021	9,612	5,306	120	90.0%	8,651	19,583	30,635	41,686
2022	9,728	5,370	120	90.0%	8,756	19,822	31,009	42,196
2023	9,845	5,434	120	90.0%	8,860	20,063	31,385	42,708
2024	9,962	5,499	120	90.0%	8,966	20,304	31,762	43,221
2025	10,080	5,564	120	90.0%	9,072	20,546	32,141	43,735
2026	10,080		120	90.0%	9,072	20,546	32,141	43,735
2027	10,080		120	90.0%	9,072	20,546	32,141	43,735
2028	10,080		120	90.0%	9,072	20,546	32,141	43,735
2029	10,080		120	90.0%	9,072	20,546	32,141	43,735
2030	10,080		120	90.0%	9,072	20,546	32,141	43,735
Internal rate of return (IRR):					13.3%	24.2%	31.1%	36.3%

2. Investments in technology transfer are initiated in the sixth year (2014) to actively replace the use of urea N with improved fertilizer N in cereal production in developing countries. An investment of $4.0 billion would occur in the first year of technology transfer efforts to rapidly achieve a 10 percent compounded annual rate of adoption of the improved technology in developing countries. Annual investments in technology transfer are gradually reduced in the following years as the improved technology is more widely used and better known by farmers. Annual amounts invested in technology transfer are reduced during subsequent years in inverse proportion to the total rate of adoption up to the point when the improved fertilizer N technology accounts for 90 percent of the fertilizer N used on cereals in developing countries by 2020. Thereafter, annual expenditures in technology transfer are maintained at $120 million to make the 90 percent total rate of adoption of the improved technology sustainable and permanent.
3. Estimates of the improved technology benefits presented in Table 8.7 are determined by: (a) the value of the urea N that is saved by gradually replacing it with the more efficient fertilizer N technology in cereal production in developing countries; and (b) the value of the projected increase in cereal production in developing countries associated with yield increases of zero percent, 5 percent, 10 percent and 15 percent, respectively. Projections of cereal

production in developing countries generated by the model and world prices of cereals are used to calculate the projected streams of net benefits. These estimates should be considered in the lower tier of the total benefits because: (a) the economic value of environmental benefits associated with the prevention of urea N losses to the environment, although important, is not accounted for; and (b) annual benefits during 2026-2030 are assumed to be equal to those of 2025, implying no growth in N consumption during this period.

Results of the cost-benefit analysis used to assess the potential feasibility of investing in the improved fertilizer N technology presented in Table 8.7 indicate the following:

1. Even if only the direct benefits on cereal production in the developing countries are accounted for, and there was no (zero percent) impact on crop yields, an internal rate of return of 13.3 percent would be obtained by successful research and technology transfer investments of about $34 billion scheduled to occur mainly over 10 years.
2. Streams of net benefits associated with the more realistic expectations of cereal yield increases of 5 percent, 10 percent and 15 percent result in significantly higher internal rates of return on investment of 24 percent, 31 percent and 36 percent. Although investment amounts in this effort are substantial, it is clear that returns to investments will be substantial and significantly higher than required to justify such investments if the N use efficiency goals of the improved fertilizer N technology are reached and the projected levels of adoption by cereal farmers are achieved in the proposed time horizon of 10-12 years. The uncertainty of successful achievement associated with investments in research and development efforts to improve technology is always a challenge to researchers and policymakers. However, in this case, the magnitude of potential benefits to farmers, the environment and society as a whole should greatly compensate for the risks that are usually attached to investments in research and development projects.

Benefits to the Environment and Resource Base – Estimates of some of the potential benefits of the improved fertilizer N technology to the environment are summarized in Table 8.8. Benefits to the environment result from the amount of urea N, which the improved, more-efficient fertilizer N technology prevents from being lost to the air, land and ground water. In Table 8.8, quantitative estimates of the reduction in fertilizer N consumption (i.e., estimates of quantities of urea N lost to the environment) are used to derive rough estimates about: (a) losses of N as emissions of N_2O-NOX gases; and (b) the associated decline in consumption of oil (petroleum) for the production of urea.

Estimates presented in Table 8.8 show the following:

1. Losses of N as emissions of N_2O-NO_X gases occurring at an average estimated rate of 1 percent of the fertilizer N applied would be decreased by about 75,300 tons in 2010 and 92,700 tons in 2025 with the adoption of the improved technology for cereal production in the developing countries. In terms of environmental impact, the emission of a unit of N_2O-NO_X gases is equivalent to 310 units of CO_2 emissions. Thus, estimates of impact of N_2O-NO_X gas emissions are 310 times greater when expressed in terms of CO_2 equivalents. Then, impact on the environment, which the improved fertilizer N technology would have by reducing N_2O-NO_X gas emissions, is equivalent to reductions of millions of tons of CO_2 gas emissions – about 23.4 and 28.7 million tons in 2010 and 2025, respectively.
2. The consumption of energy in the production of urea would decline by the equivalent of about 16.4 million barrels of petroleum in 2010 and 20.2 million barrels in 2025.

D. Other Uses of Model and "What If" Scenarios

Despite its current limitations, a variety of "what if" scenarios can be designed and evaluated to address a broad scope of policy issues and concerns as well as the impact of a number of changing circumstances (variables and drivers) affecting the demand for and supply of food commodities and fertilizers. For example, it is possible to design and evaluate policy measures and investment strategies that can be implemented to achieve a rapid increase in cereal yields through the accelerated adoption of improved seeds and higher fertilizer rates in the subregions of SSA. To conduct such an evaluation, a properly designed scenario would be first simulated by the model to forecast estimates of impact on cereal production and fertilizer demand and consumption over several years. Then, these estimates in conjunction with price/cost data can be used to assess the benefits of the policy measures and investment strategies. Impacts can be assessed in terms of increases in fertilizer use, crop yields and production, the growth of the countries economies, as well as the challenges that policymakers

Table 8.8. Estimates of Some Benefits to the Environment

Year	Decrease in Fertilizer N Consumption and the N Lost to the Environment	Decreased Losses of N as Emissions of N_2O-NOX Gases	Decreased Impact on Global Warming in Terms of CO_2 Equivalents	Decreased Consumption of Petroleum in Urea Production
	('000 tons N)	('000 tons N)	('000 tons CO_2)	('000 barrels)
2010	7,532	75.3	23,350	16,375
2011	7,654	76.5	23,726	16,638
2012	7,776	77.8	24,107	16,905
2013	7,901	79.0	24,492	17,175
2014	8,026	80.3	24,881	17,448
2015	8,154	81.5	25,276	17,725
2016	8,270	82.7	25,638	17,979
2017	8,386	83.9	25,997	18,231
2018	8,502	85.0	26,357	18,483
2019	8,619	86.2	26,719	18,737
2020	8,736	87.4	27,083	18,992
2021	8,843	88.4	27,414	19,225
2022	8,950	89.5	27,745	19,457
2023	9,057	90.6	28,078	19,690
2024	9,165	91.6	28,411	19,924
2025	9,273	92.7	28,747	20,159
Coefficients used in calculations:				
Losses of N as emissions of N_2O-NOX gases			1%	
Consumption of petroleum (barrels/mt of urea)			1	

will have to confront in meeting additional demands for investments in physical and institutional infrastructure that accelerated growth and development of the agricultural and agribusiness sectors will bring about.

The FertTrade model can also be useful to measure impacts of emerging and changing circumstances in food production and fertilizer supply and demand by evaluating scenarios that clearly reflect those changes. Expected changes in variables such as the countries' populations, incomes, crop areas, crop/livestock production yields, fertilizer production and supply, fertilizer use rates and fertilizer nutrient use efficiency can be included in the specification and design of scenarios to be evaluated. Impact assessments can be conducted on changes in a broad range of variables and circumstances. The model can be used to assess impacts of changes in just one or in several variables simultaneously. This can be accomplished by evaluating outcomes of scenarios that involve changes of just one variable in one case and simultaneous changes in several variables in another.

Finally, it is important to remark that improvements in the analytical capabilities of the model will significantly enhance the value of the model as a tool for policy evaluation and decision-making on key policy measures and investments concerning agriculture and fertilizer sector development that should take into account impacts on the environment. Assessments of environmental impact would be particularly useful for decision-making in developing countries with fragile environments and inherently poor resources. Although such improvements in model development are usually very challenging and time-consuming endeavors, prevailing trends in trade, economic globalization and climate change would greatly improve the benefits of a FertTrade model with enhanced capabilities. Moreover, the increased interdependence of national economies to global changes and evolving circumstances will, in the future, boost the value of analytical tools to conduct assessments from global, regional and sub-regional perspectives.

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Appendix 1.

Agricultural Commodities in the IMPACT Model and Subsequently in FertTrade

Commodity		Description
Cm1	Beef	Beef and veal (meat of bovine animals, fresh, chilled or frozen, with bone in) and buffalo meat (fresh, chilled or frozen, with bone in or boneless).
Cm2	Pork	Pig meat (meat, with the bone in, of domestic or wild pigs, whether fresh, chilled or frozen).
Cm3	Sheep and Goat	Meat of sheep and lamb, whether fresh, chilled or frozen, with bone in or boneless, and meat of goats and kids, whether fresh, chilled or frozen, with bone in or boneless.
Cm4	Poultry	Chicken meat (fresh, chilled or frozen. May include all types of poultry meat like duck, goose and turkey if national statistics do not report separate data.)
Cm5	Eggs	Weight in shell.
Cm6	Dairy Animals	Cow, sheep, goat, buffalo and camel milk (production data refer to raw milk containing all its constituents. Trade data normally cover milk from any animal and refer to milk that is not concentrated, pasteurized, sterilized or otherwise preserved, homogenized or peptonized.)
Cm13	Wheat	
Cm14	Rice	Rice milled equivalent (white rice milled from locally grown paddy. Includes semi-milled, whole-milled and parboiled rice.)
Cm15	Maize	
Cm16	Other Grains	Barley (varieties include with husk and without. Used as a livestock feed, for malt and for preparing foods.), millet (used locally, both as a food and as a livestock feed.), oats (used primarily in breakfast foods. Makes excellent fodder for horses.), rye (mainly used in making bread, whisky and beer. When fed to livestock, it is generally mixed with other grains.) and sorghum (a cereal that has both food and feed uses.)
Cm17	Potatoes	
Cm18	Sweet Potatoes and Yams	Sweet potatoes (used mainly for human food. Trade data cover fresh and dried tubers, whether or not sliced or in the form or pellets) and yams (a starchy staple foodstuff, normally eaten as a vegetable, boiled, baked or fried).
Cm19	Cassava and Other Roots and Tubers	Cassava and other tubers, roots or rhizomes. (Cassava is the staple food in many tropical countries. It is not traded internationally in its fresh state because tubers deteriorate very rapidly.)
Cm20	Soybean	
Cm21	Meals	Copra cake, cottonseed cake, groundnut cake, other oilseed cakes, palm kernel cake, rape and mustard seed cake, sesame seed cake, soybean cake, sunflower seed cake, fish meal, meat and blood meal (residue from oil extraction, mainly used for feed).
Cm22	Oils	Vegetable oils and products, animal fats and products (obtained by pressure or solvent extraction. Used mainly for food).
Cm23	Vegetables	Olives, onions, tomatoes and miscellaneous vegetables.
Cm24	Sub-Tropical Fruits	Bananas, cantaloupes and other melons, citrus fruits, dates, grapefruit, lemons, limes, oranges, pineapples, plantains, watermelons, miscellaneous tropical fruits.
Cm25	Temperate Fruits	Apples, grapes and miscellaneous temperate fruits.
Cm26	Sugarcane	
Cm27	Sugar Beets	
Cm28	Sweeteners	
z1	All Meat (non-poultry)	Cm1-Cm3
z2	All Cereals	Cm13-Cm-16
z3	All Roots and Tubers	Cm17-Cm19
z5	All Meat (w/ poultry)	Cm1-Cm4

Appendix 2.

Values of Selected Variables in Baseline Scenario

Country/Regions	Scenario Variables									
	Beef Herd Number Growth (percent/year)					Pork Number Growth (percent/year)				
	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025
USA	0.765	0.554	0.413	0.131	-0.009	0.728	0.673	0.637	0.563	0.501
Europe (EU 15)	-0.150	-0.050	-0.050	-0.050	-0.050	0.210	0.005	-0.080	-0.160	-0.160
Japan	0.199	0.140	0.140	0.140	0.140	0.210	0.195	0.195	0.195	0.195
Australia	0.791	0.436	0.289	0.150	0.150	0.915	0.491	0.316	0.150	0.150
Other Developed	0.761	0.256	0.084	-0.090	-0.135	0.714	0.407	0.314	0.219	0.179
Eastern Europe	0.421	0.130	0.019	0.017	0.015	0.422	0.305	0.210	0.208	0.206
Central Asia	0.788	0.707	0.694	0.694	0.694	0.332	0.332	0.373	0.332	0.305
Rest Former USSR	-0.012	-0.093	-0.106	-0.106	-0.106	0.232	0.232	0.273	0.232	0.205
Mexico	2.095	2.041	1.767	1.712	1.659	1.362	1.330	1.170	1.138	1.107
Brazil	2.068	1.807	1.677	1.155	0.801	2.150	2.017	1.950	1.683	1.481
Argentina	1.703	1.446	1.060	0.838	0.661	2.038	1.910	1.718	1.607	1.507
Colombia	1.484	1.459	1.249	1.207	1.171	1.045	1.023	0.841	0.805	0.770
Other Latin America	2.073	2.036	1.727	1.665	1.606	1.419	1.388	1.130	1.079	1.030
Nigeria	2.272	2.104	1.936	1.903	1.869	2.196	2.035	1.873	1.841	1.809
Northern Sub-Saharan Africa	2.826	2.475	2.241	1.948	1.693	2.906	2.435	2.121	1.728	1.414
Central & Western Sub-Saharan Africa	2.262	2.262	2.262	2.262	2.262	2.727	2.538	2.387	2.134	1.911
Southern Sub-Saharan Africa	2.274	2.033	2.033	1.793	1.580	2.159	1.897	1.897	1.635	1.404
Eastern Sub-Saharan Africa	2.331	2.296	1.980	1.805	1.641	2.174	2.138	1.819	1.641	1.477
Egypt	0.979	0.814	0.636	0.636	0.636	0.370	0.312	0.250	0.250	0.250
Turkey	1.422	1.090	0.728	0.728	0.728	1.692	1.511	1.298	1.175	1.065
Other West Asia/North Africa	2.211	1.751	1.251	1.251	1.251	1.587	1.419	1.220	1.106	1.003
India	1.913	1.404	1.082	0.882	0.729	1.830	1.501	1.294	1.164	1.083
Pakistan	3.098	2.385	1.870	1.493	1.199	0.358	0.302	0.262	0.232	0.210
Bangladesh	2.195	2.109	2.022	1.874	1.772	0.312	0.271	0.231	0.161	0.152
Other South Asia	1.992	1.912	1.823	1.823	1.823	0.308	0.255	0.197	0.197	0.197
Indonesia	3.063	2.766	2.075	1.423	0.958	2.496	2.216	1.564	0.949	0.611
Thailand	2.765	2.367	2.188	1.937	1.716	2.503	2.480	2.370	2.161	2.074
Malaysia	2.078	1.962	1.699	1.660	1.623	2.942	2.384	1.686	1.267	0.962
Philippines	2.555	2.431	2.193	2.100	2.011	2.939	2.749	2.318	2.255	2.193
Vietnam	2.530	2.254	2.254	1.978	1.738	2.657	2.195	2.195	1.734	1.388
Myanmar	2.560	2.278	2.278	1.996	1.751	2.264	1.842	1.842	1.419	1.102
Other Southeast Asia	2.333	2.096	2.096	1.860	1.652	2.088	1.780	1.780	1.473	1.242
China	3.042	2.861	2.634	2.182	1.804	2.157	1.783	1.515	1.087	0.647
South Korea	1.975	1.857	1.681	1.539	1.411	1.819	1.795	1.759	1.730	1.701
Other East Asia	1.419	1.419	0.785	0.785	0.785	1.660	1.660	1.455	1.455	1.455
Rest of the World	0.312	0.231	0.204	0.177	0.164	0.295	0.223	0.199	0.174	0.162

(continued)

Appendix 2.

Values of Selected Variables in Baseline Scenario (continued)

Country/Regions	Scenario Variables									
	Wheat Area Growth (percent/year)					Maize Area Growth (percent/year)				
	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025
USA	0.492	0.131	-0.050	-0.050	-0.050	0.207	0.200	0.100	0.100	0.100
Europe (EU 15)	-0.053	-0.079	-0.090	-0.100	-0.100	-0.236	-0.249	-0.255	-0.260	-0.266
Japan	-0.181	-0.169	-0.169	-0.169	-0.169	-0.210	-0.186	-0.186	-0.186	-0.186
Australia	0.518	0.203	0.073	-0.050	-0.050	0.738	0.357	0.200	0.050	0.050
Other Developed	0.067	0.002	-0.024	-0.050	-0.050	0.473	0.183	0.064	-0.050	-0.050
Eastern Europe	0.034	-0.018	-0.038	-0.038	-0.039	0.225	0.117	0.076	0.075	0.074
Central Asia	0.400	0.313	0.299	0.299	0.299	0.209	0.058	0.034	0.034	0.034
Rest Former USSR	0.100	0.013	-0.001	-0.001	-0.001	0.309	0.158	0.134	0.134	0.134
Mexico	0.056	0.016	-0.010	-0.050	-0.050	0.482	0.320	0.212	0.050	0.050
Brazil	0.615	0.526	0.473	0.385	0.360	0.500	0.450	0.420	0.370	0.335
Argentina	1.737	1.251	0.960	0.474	0.336	0.712	0.692	0.679	0.658	0.639
Colombia	1.419	0.929	0.635	0.146	0.006	0.549	0.382	0.283	0.117	0.069
Other Latin America	1.541	1.011	0.693	0.162	0.011	1.109	0.756	0.544	0.191	0.090
Nigeria	0.775	0.969	1.663	1.256	1.203	0.872	0.617	0.361	0.310	0.264
Northern Sub-Saharan Africa	1.474	1.296	1.143	0.951	0.801	0.926	0.761	0.651	0.513	0.410
Central & Western Sub -Saharan Africa	2.343	1.864	1.864	1.386	1.027	1.377	1.072	1.072	0.766	0.537
Southern Sub-Saharan Africa	1.873	1.873	1.616	1.616	1.616	1.033	1.033	0.876	0.876	0.876
Eastern Sub-Saharan Africa	2.510	1.830	1.570	1.570	1.570	1.297	0.895	0.654	0.654	0.654
Egypt	0.714	0.684	0.652	0.652	0.652	0.279	0.193	0.100	0.100	0.100
Turkey	0.353	0.274	0.188	0.188	0.188	-0.121	-0.207	-0.300	-0.300	-0.300
Other West Asia/North Africa	0.478	0.418	0.353	0.353	0.353	0.161	0.054	-0.063	-0.063	-0.063
India	0.237	0.177	0.119	0.085	0.058	0.032	0.025	0.019	0.015	0.012
Pakistan	0.195	0.129	0.081	0.047	0.021	0.210	0.167	0.136	0.113	0.096
Bangladesh	0.035	0.014	-0.008	-0.044	-0.049	0.175	0.144	0.112	0.059	0.051
Other South Asia	0.065	0.027	-0.016	-0.016	-0.016	0.208	0.155	0.097	0.097	0.097
Indonesia	0.205	0.205	0.078	0.014	-0.018	-0.008	-0.008	-0.054	-0.077	-0.088
Thailand	0.067	0.002	-0.025	-0.050	-0.050	0.050	0.050	0.050	0.050	0.050
Malaysia	-0.025	-0.050	-0.050	-0.050	-0.050	0.073	0.050	0.050	0.050	0.050
Philippines	0.103	0.027	-0.050	-0.050	-0.050	0.274	0.212	0.150	0.150	0.150
Vietnam	0.800	0.630	0.630	0.460	0.333	0.353	0.292	0.292	0.232	0.186
Myanmar	0.630	0.494	0.494	0.358	0.256	0.443	0.364	0.364	0.286	0.227
Other Southeast Asia	0.800	0.630	0.630	0.460	0.333	0.506	0.415	0.415	0.323	0.255
China	-0.099	-0.100	-0.100	-0.100	-0.100	0.631	0.545	0.518	0.518	0.518
South Korea	-0.016	-0.050	-0.050	-0.050	-0.050	0.106	0.050	0.050	0.050	0.050
Other East Asia	0.161	0.161	0.055	0.055	0.055	0.378	0.378	0.214	0.214	0.214
Rest of the World	-0.254	-0.254	-0.254	-0.254	-0.254	-0.137	-0.137	-0.137	-0.137	-0.137

(continued)

Appendix 2.

Values of Selected Variables in Baseline Scenario (continued)

Country/Regions	Scenario Variables									
	Beef Herd Yield Growth (percent/year)					Pork Yield Growth (percent/year)				
	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025
USA	0.454	0.432	0.441	0.472	0.456	0.338	0.371	0.387	0.416	0.397
Europe (EU 15)	0.184	0.195	0.199	0.220	0.193	0.231	0.254	0.265	0.286	0.257
Japan	0.167	0.175	0.180	0.197	0.166	0.145	0.190	0.212	0.246	0.232
Australia	0.547	0.547	0.541	0.562	0.533	0.360	0.385	0.393	0.415	0.388
Other Developed	0.508	0.522	0.523	0.548	0.525	0.172	0.183	0.187	0.198	0.159
Eastern Europe	0.480	0.528	0.550	0.591	0.585	0.090	0.108	0.118	0.137	0.109
Central Asia	0.461	0.469	0.472	0.499	0.477	0.352	0.413	0.445	0.487	0.483
Rest Former USSR	0.261	0.269	0.272	0.299	0.277	0.252	0.313	0.345	0.387	0.383
Mexico	0.555	0.594	0.599	0.626	0.605	0.822	1.010	1.093	1.188	1.143
Brazil	0.488	0.540	0.566	0.603	0.593	0.371	0.521	0.597	0.696	0.654
Argentina	0.309	0.356	0.369	0.399	0.381	0.505	0.627	0.663	0.735	0.713
Colombia	0.500	0.481	0.445	0.387	0.290	0.826	0.930	0.982	1.079	1.033
Other Latin America	0.582	0.632	0.657	0.708	0.644	1.083	1.213	1.278	1.398	1.379
Nigeria	1.033	1.197	1.264	1.337	1.294	0.922	0.965	0.969	1.018	0.969
Northern Sub-Saharan Africa	0.990	1.014	1.014	1.007	0.881	1.036	1.215	1.336	1.469	1.416
Central & Western Sub -Saharan Africa	1.165	1.330	1.439	1.534	1.515	0.992	1.084	1.161	1.246	1.186
Southern Sub-Saharan Africa	0.906	1.048	1.149	1.238	1.212	0.845	0.979	1.083	1.184	1.143
Eastern Sub-Saharan Africa	0.869	1.113	1.258	1.378	1.365	0.891	0.981	1.062	1.156	1.108
Egypt	0.871	0.991	1.035	1.073	1.063	0.909	1.179	1.307	1.392	1.333
Turkey	0.932	0.931	0.920	0.943	0.915	0.378	0.455	0.503	0.545	0.490
Other West Asia/North Africa	0.932	0.931	0.920	0.943	0.915	0.378	0.455	0.503	0.545	0.490
India	1.345	1.410	1.441	1.499	1.453	1.233	1.422	1.516	1.628	1.551
Pakistan	0.813	0.748	0.712	0.704	0.647	0.980	1.158	1.292	1.426	1.375
Bangladesh	0.736	0.836	0.899	1.009	0.992	0.945	1.122	1.230	1.392	1.375
Other South Asia	0.725	0.860	0.949	1.043	1.007	0.941	1.023	1.088	1.176	1.071
Indonesia	0.506	0.738	0.846	0.963	0.949	1.041	1.174	1.235	1.315	1.201
Thailand	0.804	0.900	0.912	0.961	0.872	1.487	1.536	1.555	1.730	1.659
Malaysia	0.908	1.074	1.147	1.239	1.199	0.148	0.164	0.164	0.170	0.146
Philippines	0.975	1.005	0.970	0.981	0.943	0.473	0.572	0.621	0.678	0.640
Vietnam	0.688	0.752	0.811	0.869	0.852	0.817	0.893	0.958	1.020	0.986
Myanmar	0.590	0.645	0.695	0.819	0.786	0.833	0.929	1.011	1.088	1.070
Other Southeast Asia	0.688	0.752	0.811	0.869	0.831	0.778	0.867	0.943	1.015	0.992
China	1.261	1.269	1.246	1.234	1.223	0.513	0.528	0.518	0.513	0.508
South Korea	0.911	0.967	0.994	1.059	1.028	0.353	0.363	0.368	0.389	0.361
Other East Asia	0.844	0.986	1.032	1.103	1.080	0.493	0.542	0.554	0.585	0.569
Rest of the World	0.992	1.164	1.270	1.413	1.373	0.992	1.164	1.270	1.413	1.373

(continued)

Appendix 2.

Values of Selected Variables in Baseline Scenario (continued)

Country/Regions	Scenario Variables									
	Wheat Yield Growth (percent/year)					Maize Yield Growth (percent/year)				
	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025	2001–2005	2006–2010	2011–2016	2016–2020	2021–2025
USA	0.941	1.069	1.125	1.086	1.048	0.820	0.805	0.794	0.777	0.759
Europe (EU 15)	0.276	0.280	0.280	0.259	0.239	0.465	0.465	0.434	0.417	0.401
Japan	0.711	0.774	0.805	0.778	0.751	1.574	1.420	1.285	1.217	1.153
Australia	0.883	0.801	0.800	0.750	0.701	1.205	1.075	0.962	0.894	0.830
Other Developed	1.198	1.170	1.153	1.070	0.991	1.135	1.122	1.065	1.034	1.004
Eastern Europe	0.902	0.965	0.995	0.954	0.914	0.986	1.223	1.282	1.312	1.283
Central Asia	0.910	1.181	1.152	1.082	1.015	1.587	1.673	1.645	1.631	1.618
Rest Former USSR	0.510	0.781	0.752	0.682	0.615	1.387	1.473	1.445	1.431	1.418
Mexico	0.773	0.861	0.900	0.848	0.797	1.544	1.531	1.455	1.394	1.336
Brazil	1.827	1.831	1.829	1.747	1.669	1.899	1.903	1.848	1.817	1.787
Argentina	1.448	1.522	1.547	1.463	1.382	1.719	1.709	1.649	1.617	1.586
Colombia	1.383	1.263	1.210	1.113	1.022	1.813	1.878	1.845	1.806	1.781
Other Latin America	1.648	1.519	1.461	1.356	1.257	1.496	1.549	1.522	1.505	1.449
Nigeria	1.079	2.520	2.618	2.343	1.994	1.513	1.501	1.421	1.388	1.355
Northern Sub-Saharan Africa	1.466	1.381	1.367	1.313	1.261	1.310	1.395	1.409	1.366	1.274
Central & Western Sub -Saharan Africa	1.598	1.407	1.346	1.219	1.101	1.845	1.934	1.954	1.861	1.772
Southern Sub-Saharan Africa	0.586	0.533	0.518	0.481	0.445	0.822	2.092	1.429	1.391	1.354
Eastern Sub-Saharan Africa	1.530	1.917	2.225	2.272	2.120	1.368	1.591	1.638	1.567	1.498
Egypt	1.029	0.837	0.754	0.695	0.590	1.218	1.184	1.105	1.036	0.970
Turkey	1.047	1.032	1.020	0.917	0.819	0.193	0.163	0.115	0.192	0.123
Other West Asia/North Africa	1.573	1.557	1.544	1.435	1.331	1.188	1.166	1.132	1.108	1.084
India	1.266	1.278	1.276	1.201	1.129	0.954	0.904	0.813	0.764	0.716
Pakistan	1.508	1.507	1.542	1.488	1.435	1.777	1.871	1.875	1.868	1.811
Bangladesh	1.178	1.592	1.824	1.901	1.882	1.303	1.306	1.266	1.279	1.241
Other South Asia	1.560	1.663	1.758	1.729	1.600	1.154	1.195	1.194	1.193	1.142
Indonesia	1.004	1.096	1.122	1.076	1.031	1.276	1.252	1.181	1.131	1.085
Thailand	1.024	1.082	1.069	1.005	0.944	2.067	2.146	2.038	1.984	1.931
Malaysia	0.953	1.030	1.035	0.988	0.943	1.291	1.289	1.200	1.155	1.112
Philippines	0.922	1.027	1.067	1.038	1.009	2.406	2.339	2.192	2.118	2.046
Vietnam	0.361	0.755	0.985	1.038	0.993	1.374	1.495	1.536	1.539	1.493
Myanmar	0.361	0.755	0.985	1.038	0.993	1.026	1.118	1.150	1.152	1.105
Other Southeast Asia	0.361	0.755	0.985	1.038	0.993	1.312	1.429	1.468	1.471	1.424
China	0.977	1.004	0.987	0.936	0.886	1.750	1.724	1.619	1.401	1.218
South Korea	1.003	1.083	1.123	1.089	1.056	1.382	1.485	1.469	1.461	1.453
Other East Asia	1.506	1.871	2.012	1.998	1.985	0.774	1.096	1.111	1.119	1.111
Rest of the World	0.771	0.872	0.957	0.950	0.943	0.632	0.785	0.848	0.879	0.862

Appendix 3.

Estimating the Impact of Improving Fertilizer N Efficiency

Estimating Changes in Fertilizer N Consumption

The quantity of fertilizer N applied (NA) can be decomposed into the N that is uptake and used by crops (NU) and the N lost to the environment:

$$NA = NU + NL \qquad (1)$$

Then, the fertilizer N use efficiency of technology t, say, E_t, is:

$E_t = NU_t / NA_t$ and

For technologies t = 0 and t = 1 we have

$NU_0 = NA_0 (E_0)$ and $NU_1 = NA_1 (E_1)$;

Then, to make $NU_0 = NU_1$

$NA_0 (E_0) = NA_1 (E_1)$ so that,

The quantity of N applied using technology 1 is

$$NA_1 = NA_0 (E_0/E_1) \qquad (2)$$

But $E_1 > E_0$ if efficiency improves

Then the change in quantity of fertilizer N applied (“N) is:

$$\Delta N_{0,1} = NA_1 - NA_0 \quad \text{and,} \qquad (3)$$

Replacing (2) into (3):

$\Delta N_{0,1} = NA_0 (E_0/E_1) - NA_0$ or

$$\Delta N_{0,1} = NA_0 ((E_0/E_1) - 1) < 0 \qquad (4)$$

Shows the decrease in N applied using the more efficient N fertilizer technology 1.

Estimating Changes in Farmers’ Expenditures in N Fertilizers

Given the changes in quantities of N applied described above, changes of farmers’ expenditures in N fertilizers are calculated as follows:

$$\Delta FEx_{01} = PN_0 (NA_0) - PN_1 (NA_1);$$

where PN_0 and PN_1 are the prices of fertilizer N using technologies 0 and 1, respectively.

Then replacing NA_1 from equation (2) we have

$$\Delta FEx_{01} = PN_0 (NA_0) - PN_1 [NA_0 (E_0/E_1)]$$

$$\Delta FEx_{01} = NA_0 [PN_0 - PN_1 (E_0/E_1)] \qquad (5)$$

Then, if

TQN_u = world consumption of urea N.

TQN_1 = world consumption of improved fertilizer N in cereals.

QN_u = consumption of urea N for cereals production in developing countries.

QN_1 = consumption of improved fertilizer N for cereal production in developing countries.

$\Delta QN = QN_u - QN_1$

Then fertilizer expenditures in urea (FEN_u) and in improved fertilizer N (FEN_i) in cereals in developing countries are:

$$FEN_u = PN_u\ (QN_u)$$

$$FEN_1 = PN_1\ (QN_1)$$

Where PN_u is the price of urea N and PN_1 is the price of improved fertilizer N.

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