World Fertilizer Model—The WorldNPK Model

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Abstract

We introduce a world fertilizers model that is capable of producing fertilizer demand projections by crop, by country, by macronutrients, and by year. For each crop, the most relevant countries in terms of production, consumption, or trade are explicitly modeled. The remaining countries are modeled, for each crop, within a regional aggregate. The nutrient coverage includes nitrogen (N), phosphorous (P), and potassium (K). In this report we present the data and procedures used to set up the model as well as the assumptions made. The fertilizer model interacts with the yield equations of the FAPRI-ISU model (Food and Agricultural Policy Research Institute at Iowa State University), and by means of a set of production elasticities, projects each nutrient's application rate per hectare for each commodity and each country covered by the FAPRI-ISU model. Then, the application rates and the areas projected by FAPRI-ISU are used to obtain projections of fertilizer demand from agriculture on a global scale. With this fertilizer module, policies that directly affect fertilizer markets, such as input taxes or subsidies, quantity use restrictions, and trade restrictions, can now be explicitly formulated and evaluated. The effects of these policies on global agricultural markets and on greenhouse gas emissions can be evaluated with the FAPRI-ISU model and the Greenhouse Gas in Agriculture Simulation Model (GreenAgSiM). Also, any other policy affecting commodity markets such as input and output price shocks, biofuels mandates, and land-use change can now be evaluated with regard to its impacts on the world fertilizer markets.

Keywords: agriculture, fertilizer, nitrogen, phosphorous, policy analysis, potassium, projections.

JEL codes: Q10, Q11, Q18

Introduction

The rising demand for agricultural commodities in order to satisfy demand for food, feed, and fuel has increased interest in the supply side of agricultural commodity markets. Extended periods of growth in developing countries have driven up the demand for food and feed. Also, recent policies that encourage the use of biofuels have resulted in an increased demand for agricultural commodities. These changes in global commodity markets have several environmental consequences that have also been in the center of attention in the international community.

Fertilizers play an important role in the recent changes in global agricultural commodity markets. Fertilizer use is directly connected to the forces driving crop supply through the increase in productivity. The use of fertilizers in agriculture also has direct and indirect consequences for the environment. For these reasons, it is important to understand how fertilizers respond to changes in the global economy and how fertilizers interact with the crops for which they are used.

We have developed a world fertilizer model, the WorldNPK model, that by interacting with a broader model of international commodity markets supplied by the Food and Agricultural Policy Research Institute at Iowa State University—the FAPRI-ISU model—allows us to determine and project the use of fertilizers in agriculture. The WorldNPK model covers three macronutrients individually: nitrogen (N), phosphorous (P), and potassium (K); 15 crops; and the most relevant countries and regions for each commodity in terms of production, consumption, or trade.

The objective of this report is to describe the procedures used to set up the world fertilizer model (WorldNPK), as well as to discuss the assumptions made in the model. We also explain the planned extensions and improvements. The construction of the fertilizer model is divided into two stages.

> *First Stage*. The model projects the quantities of N, P, and K demanded for each crop and for each country/region covered by the FAPRI-ISU model. Demand for each nutrient is obtained by projecting a fertilizer application rate that is crop-specific and country-specific as a function of the relevant variables affecting the farmer's fertilization decision. Then, we use the crop areas projected by FAPRI together with the nutrient application rates to obtain a crop- and country-specific quantity demanded for each N, P, and K.
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> *Second Stage.* The output of the model will be projections of crop- and country-specific nutrient (N, P, and K) quantities demanded as described in the first stage, and projections of world fertilizer prices at the nutrient level, such that they are consistent with a zero excess demand in each nutrient world market. We do this by introducing a nutrient-specific world supply curve and solve for an endogenous fertilizer price of equilibrium that clears the mentioned market.

The WorldNPK Model: A Demand Model

The FAPRI-ISU model covers supply, demand, and international trade of 15 crops worldwide. The crops are wheat, corn, rice, barley, oats, sorghum, rye, soybeans, canola, rapeseed, sunflower seed, oil palm, cotton, sugarcane, and sugar beet. Either individually or within a region, every country in the world is covered in the FAPRI model. In terms of crop production, FAPRI reports projections of harvested areas (AHH) and yields (YHH) for each country/region, among other relevant variables.

The objective of the fertilizer model is to provide projections of quantities of fertilizer demanded that are nutrient/crop/country-specific. Each quantity demanded is obtained as the product of a fertilizer application rate (in kilograms per hectare) and a harvested area (in hectares).[1] Our procedure is as follows. We first generate a fertilizer application rate per nutrient, crop, and country for selected base years (2006/07 and 2007/08). Second, we collect and construct fertilizer prices for each nutrient at the country level. Then, we incorporate these fertilizer rates and prices into the existing FAPRI-ISU model as part of the variable cost of production in each crop yield equation of the model. When the FAPRI model runs, the fertilizer rate reacts to changes in the relevant variables of the fertilizer decision process, conditional on the parameters of the model. It also projects each fertilizer rate for future years according to the dynamics embedded in the model. Finally, we multiply these fertilizer rates by the harvested areas projected by FAPRI, in order to obtain the desired quantities demanded of fertilizer by nutrient, by crop, and by country.

In the rest of the report, we describe (1) how we obtain these fertilizer rates for the base years (i.e., an accounting model of fertilizer demand), and (2) how the interaction is implemented in a way that is not only consistent with the rest of the FAPRI-ISU model but is also consistent with the economics of fertilizer use in agriculture.

The major benefits of developing this world fertilizer model are improving the existing FAPRI model as a consequence of the specific treatment of fertilizers used in agriculture, and responding to the general interest in fertilizer application rates and fertilizer demand projections at the nutrient, country, and crop levels.

The Accounting Model

We obtained an application rate for each nutrient, N, P, and K, that is crop and country specific. We used, in order of importance, the following data sources.

1. “Assessment of Fertilizer Use by Crop at the Global Level 2006/07 – 2007/08,” Patrick Heffer, International Fertilizer Industry Association, April 2009 (hereafter IFA 2009)
2. “Fertilizers Europe data base on nutrient application rate by crop”. Fertilizers Europe 2010
3. “Fertilizer Use by Crop”. FAO 2006 (hereafter FAO 2006)
4. “Fertilizer Use by Crop”. FAO 2002 (hereafter FAO 2002)
5. “Fertilizer Use by Crop for Specific Countries” FAO 2002-2005 (hereafter FAO 2002-2005)
6. “Agricultural Census” Ministry of Agriculture - Government of India 1986, 1991, 1996, and 2001

The IFA 2009 report provides the worldwide fertilizer consumption of the 23 bigger fertilizer consumer countries and the rest of the world (ROW). For each country it provides the demand (by nutrient) for each of the following crops: wheat, corn, rice, other cereals, soybeans, oil palm, other oilseeds, cotton, sugar

[1] Note that throughout the model we use the term fertilizer application rate to refer to the more appropriate term, fertilizer use per harvested hectare.

crops, fruits and vegetables, and other crops. The years covered are the campaigns 2006/07 and 2007/08. We made extensive use of these statistics because they span the world, and to our knowledge this is the most updated report. Appendix A shows this dataset.

The FAO 2006 report provides statistics on fertilizer use by nutrient and for several countries, and in some cases summarizes information provided in the "Fertilizer Use by Crop" for specific countries' reports (FAO 2002-2005). The FAO 2002 study provides area, fertilizer rates, percentage of fertilized area, and fertilizer consumption by nutrients and by crop for 88 countries and for their most important crops. While this report covers most of the countries and crops of interest, data are from 1996 to 2000. Finally, the "Fertilizer Use by Crop" for specific countries contains detailed expositions of the cropping systems, fertilizer industry, and fertilizer use of the corresponding country, but it usually provides data that can be found in the previous reports.

The crop- and country-specific nutrient application rates for the base years were obtained in three steps. Results are shown in Appendix B for each nutrient and for the base year 2007/08.

First, we directly associated each of the 23 higher fertilizer consuming countries from IFA 2009 with the FAPRI countries for the following crops: wheat, corn, rice, soybeans, oil palm, and cotton. When a country in IFA 2009 was not individually reported by FAPRI, it was added to the ROW, for example, Chile or Iran in wheat. Depending on the crop, these 23 countries accounted for about 90% of the world fertilizer demand of that crop.

Second, and for the same crops, we allocated what was reported as ROW by IFA 2009 to each of the remaining countries or regions in the FAPRI model. While this allocation accounts for about 10% of the world fertilizer demand, a significant amount of effort was put into finding the most appropriate fertilizer rate for each country. The allocation was done one crop at a time and required finding the most updated fertilizer application rate, collected from different sources. We first found a fertilizer rate for the highest producing countries of that particular crop; then, the remaining countries were assumed to lie on the same production function, and a fertilizer rate was calculated for each of them, such that those with lower yields were assumed to have a lower rate, and those with higher yields were assumed to have a higher rate.

Third, once we completed these crops, we turned to the nutrient demands of "Other Coarse Grains," "Other Oilseeds," and "Sugar" reported in IFA 2009 that had to be distributed into the remaining crops in the FAPRI-ISU model (barley, sorghum, oats and rye; rapeseed/canola, peanut and sunflower seed, sugar beet, and sugarcane). Note that the categories "Other Coarse Grains" and "Other Oilseeds" in the IFA 2009 report include some crops not covered by FAPRI, such as triticale, millet, mustard, and copra. While FAPRI does not project the harvested areas of these crops, their demand will be taken into account in the barley, sorghum, oats, rye, canola, peanut, rapeseed, and sunflower seed commodities because their rates will be slightly overestimated. In the case of "Other Coarse Grains," we took one country at a time and distributed the fertilizer demand from IFA 2009 into the four cereals (barley, sorghum, oats, and rye) covered by FAPRI. If FAPRI covered only one cereal for a certain country, all the demand was assigned to that crop. If there was more than one cereal, the demand was distributed proportional to the fertilizer rates from the most reliable source (FAO 2006, FAO 2002, or FAO 2002-2005). Similarly, we distributed the fertilizer demand of "Other Oilseeds" from IFA 2009 among rapeseed/canola, peanut, and sunflower seed for the countries covered by FAPRI. We used the same procedure for the IFA 2009 fertilizer demand of “Sugar” that we distributed among sugar beet and sugarcane.

Demonstration of Procedures

We present in this section the cases of China, India, EU-27, and Ukraine to illustrate the procedures used. The first three, shown in Table 1, will help demonstrate the procedure used when IFA reported the crop-specific fertilizer demand for a given country, as these three countries represent more than 50% of the world fertilizer consumption (IFA 2009). Ukraine was chosen to illustrate the methodology used for the cases when FAPRI reports a country that was not individually reported by IFA 2009.

Table 1 shows how fertilizer use by nutrients is reported by IFA. In the cases of wheat, rice, corn, soybeans, and cotton, we took the harvested area from FAPRI and directly obtained the fertilizer application rate for each nutrient.

Table 1. Fertilizer use by crop in 2006/07 in China, India, and EU-27, extracted from the IFA 2009 report

				CEREALS								OILSEEDS											
				Wheat		Rice		Maize		Other CG		Soybean		Oil Palm		Other OS		Cotton		Sugar Crops		Fruits & Veg.		Other Crops	
		Total	% of World	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty
China	N	30,200	31.5%	14.1%	4,258	18.2%	5,496	16.1%	4,862	1.0%	302	1.5%	453	0.0%	6	4.8%	1,450	4.1%	1,238	1.5%	453	30.0%	9,060	8.7%	2,621
	P_2O_5	11,600	30.3%	16.5%	1,914	15.3%	1,775	6.6%	766	1.0%	116	3.3%	383	0.0%	2	5.0%	580	3.9%	452	2.2%	255	34.0%	3,944	12.2%	1,413
	K_2O	5,800	21.4%	4.4%	255	28.0%	1,624	2.2%	128	1.0%	58	1.0%	58	0.1%	6	2.3%	133	1.2%	70	4.8%	278	50.0%	2,900	5.0%	290
	N+P+K	47,600	29.5%	13.5%	6,427	18.7%	8,895	12.1%	5,755	1.0%	476	1.9%	894	0.0%	14	4.5%	2,163	3.7%	1,760	2.1%	987	33.4%	15,904	9.1%	4,325
India	N	13,773	14.4%	21.0%	2,892	30.0%	4,132	2.5%	344	4.5%	620	1.0%	138	0.0%	0	4.5%	620	6.5%	895	5.0%	689	7.0%	964	18.0%	2,479
	P_2O_5	5,543	14.5%	20.0%	1,109	25.0%	1,386	1.5%	83	5.0%	277	2.5%	139	0.0%	0	7.0%	388	8.0%	443	4.5%	249	11.0%	610	15.5%	859
	K_2O	2,335	8.6%	8.0%	187	34.0%	794	1.0%	23	2.5%	58	1.0%	23	0.0%	0	5.0%	117	5.5%	128	10.0%	234	22.0%	514	11.0%	257
	N+P+K	21,651	13.4%	19.3%	4,188	29.2%	6,312	2.1%	451	4.4%	955	1.4%	300	0.0%	0	5.2%	1,125	6.8%	1,467	5.4%	1,172	9.6%	2,088	16.6%	3,595
EU-27	N	10,746	11.2%	26.0%	2,794	0.4%	43	12.0%	1,290	16.0%	1,719	0.1%	11	0.0%	0	9.2%	989	0.5%	54	2.1%	226	7.5%	806	26.2%	2,815
	P_2O_5	3,091	8.1%	19.5%	603	0.5%	15	13.2%	408	15.9%	491	0.3%	9	0.0%	0	8.2%	253	0.7%	22	3.6%	111	13.4%	414	24.7%	763
	K_2O	3,592	13.2%	12.7%	456	0.9%	32	11.9%	427	12.8%	460	0.3%	11	0.0%	0	9.9%	356	0.6%	22	5.9%	212	14.4%	517	30.6%	1,099
	N+P+K	17,429	10.8%	22.1%	3,853	0.5%	91	12.2%	2,125	15.3%	2,671	0.2%	31	0.0%	0	9.2%	1,598	0.6%	97	3.1%	549	10.0%	1,737	26.8%	4,678

Then, according to the IFA 2009 report, “Other Coarse Grains” includes barley, oats, rye, sorghum, triticale, millet, etc. So, for example, we needed to allocate among these crops China’s demand of 302,000 tons of nitrogen and the EU-27’s 1,719,000 tons of nitrogen. We distributed this quantity only among those crops covered by FAPRI (barley, oats, rye, and sorghum) and ignored the other crops not covered because we would not be able to give projections of fertilizer demand. While this will overestimate their crop-specific fertilizer demand, it will be closer at the nutrient’s aggregate level. To make this allocation, we found the N, P, and K rates in China, India, and EU-27 for each of the four crops from the most reliable source and proportionally distributed each total nutrient demand. In China, barley is the only relevant crop among these according to FAPRI, so we directly calculated the N rate as the ratio between the 302,000 tons and the FAPRI harvested area. For the case of Europe, our most reliable source is “Fertilizers Europe” (2010), which reports fertilizer application rates by nutrients for all crops in 2007/08. Given that FAPRI reports harvested areas of barley, oats, and rye in the EU-27, a fertilizer application rate was found for each crop such that it maintains the relationship between rates given by Fertilizers Europe 2010, and when multiplied by the areas from the FAPRI-ISU model it gives a total demand of 1,719,000 tons of N, 491,000 tons of P, and 460,000 of K. The assumption that the proportionality of fertilizer rates between crops remains constant implies that there was no structural change in the cropping system that affected only one of these crops; if there was any, it affected all of them equally.

The same criterion was used to allocate each country's fertilizer demand of "Other Oilseeds" from IFA 2009 into rapeseed, peanuts, and sunflower (others such as mustard and safflower were not considered because they are not projected by FAPRI). For example, the 1,450,000 tons of N in China were distributed among rapeseed, peanuts, and sunflower in a way consistent with the fertilizer application rates from FAO 2002, such that when the FAPRI harvested areas were multiplied by the calculated fertilizer rates, they add up to the 1,450,000 tons of N while maintaining the distance between the rates of each crop from FAO 2002. The same was done for the 580,000 and 133,000 tons of P and K, respectively. For the case of India, the fertilizer demand was distributed among peanuts and rapeseed, also using the rates from FAO 2002, while for EU-27 the fertilizer demand was distributed among rapeseed and sunflower using the rates from Fertilizers Europe 2010.

Then "Sugar Crops," composed only of sugarcane and sugar beet, were distributed according to the methodology described above and using the FAO 2002 report for the rates of China and India. The Fertilizers Europe 2010 report does not give rates for sugarcane, but according to FAPRI most of the area is devoted to sugar beet (99.98%), so the sugarcane fertilization rate from another developed country (Australia) was used to calculate the fertilizer demand attributed to sugarcane, and the rest was allocated to sugar beet (and its corresponding rates were obtained).

Finally, FAPRI does not report harvested areas for the categories of "Fruits and Vegetables" (FV) and "Other Crops" (OC—roots and tubers, pulses, nuts, rubber, coffee, tea, tobacco, ornamentals, turf, pastures, forestry) from IFA 2009. However, they account for about 30% of the world fertilizer demand. In order to project an aggregated world nutrient demand of FV and OC, we assumed that world N, P, and K demand for FV and OC changes at the same rate as the world nutrient demand of all the remaining crops. So, for example, once we calculated the total demand of N for each crop and country reported by FAPRI, we obtained its rate of change with respect to the previous year and applied it to the demand of FV and OC. The same was done for P and K. Note that this demand projection is not country specific.

The last step was to allocate, to all the remaining countries or regions for which FAPRI gives a harvested area and yield projection, the fertilizer demand reported by IFA 2009 as ROW. Also, when for a given crop there were countries reported by IFA 2009 but not reported individually by FAPRI, that nutrient demand was added to the ROW. Given that the FAPRI model's coverage of countries is bigger than that of the IFA 2009 report, this had to be done for several countries or regions.

As an illustrating example, we describe in detail how we obtained each N, P, and K application rate for Ukraine that is not individually reported by IFA 2009 but is individually reported by FAPRI as a producer of several crops (wheat, corn, sugar beet, rapeseed, sunflower, barley, oats, and rye). We could not find fertilizer application rates for Ukraine, other than some fertilizer recommended rates (FAO-FUBC-Ukraine 2005), which are far from the actual rates according to the statistics on the country's fertilizer consumption (IFADATA). According to the FAO-FUBC-Ukraine report, wheat is planted throughout the country but is more concentrated in the eastern region (Forest-Steppe Right Bank and Steppe) on the border to Russia. Similarly, according to USDA-FAS, wheat in Russia "is grown mainly in the fertile *chernozem* (black soil) zone, which includes the Southern district, the southern tier of the Central district, and the southern and central Volga district" of the region on the border with Ukraine. Therefore, we used Russian application rates from the IFA 2009 report as a reference to calculate those of Ukraine.

The methodology applied consisted of assuming that there exists an underlying production function of wheat that is common to Ukraine and Russia, and both countries are positioned at some point along the curve describing the response of wheat yields to applications of fertilizer (one curve for each of the three nutrients). From the FAPRI model we know wheat yields from both countries so we know where they lie on the vertical axis. Given that we do not know the form of the underlying production function (it requires unavailable data to estimate it), we make the simplifying assumption that the production function is increasing and linear; therefore, we apply the percentage difference between both countries' yields to the Russian fertilizer rate from IFA 2009. We could give this production function some curvature describing decreasing or increasing returns to scale, but the curvature imposed would also be an ad hoc assumption, unless we are able to find that curvature for each crop and for each country. Instead of considering the observed yield for 2006/07 and 2007/08, we used a proxy of the expected yield by taking the average of the yields from 2003/04 to 2007/08. This was done to avoid big swings in fertilizer rates due to big changes in yields caused by, for example, extreme weather events. Figure 1 shows why this is the case. Let y_R^1 and N_R^1 be the observed Russian yield and nitrogen rate, respectively, on a given year and let y_U^1 be that of Ukraine in the same year. We know these values from FAPRI and IFA 2009 data. Suppose that y_R^1 is low because of a bad weather event that affected only Russia but not Ukraine. This implies an application rate for Ukraine of N_U^1 according to the procedure described above. Suppose now that in all previous years Russian yields were actually higher, with the average equal to y_R^2. In that case, the application rate for Ukraine consistent with y_R^2 would be N_U^2, which is lower. Because fertilization decisions are mostly made before weather is observed, using the average yield implies that the farmer is looking at an expected production function. Weather shifts the production function up and down (dashed lines), but at planting the farmer is concerned with a production function consistent with expected conditions (solid line). For a similar reason, we used an average of the Ukrainian yields between 2003/04 and 2007/08.

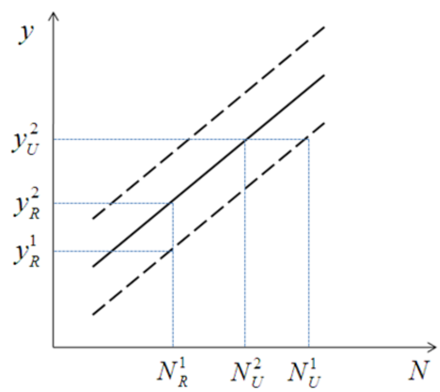

Figure 1. Example of obtaining the nitrogen application rate for a country using the expected production function

The same procedure was used to calculate the fertilizer application rates for corn in Ukraine. Regarding sugar crops and according to FAPRI, Ukraine only plants sugar beet and not sugarcane, so the fertilizer demand was calculated and subtracted from the ROW. The FAO-FUBC-Ukraine report gives one point of the sugar beet production for each nutrient in 2002. By assuming that this production function is linear and has not changed since 2002, each nutrient application rate was obtained for the years 2006/07 and 2007/08. In the case of "Other Oilseeds," FAPRI reports that Ukraine produces rapeseed and sunflower.

The sunflower rate was obtained in a similar manner to that of sugar beet with data also from FAO-FUBC-Ukraine. However no data for Ukraine was found on rapeseed and therefore we used the fertilizer rate from a neighboring country such as Hungary. With these two rates, their fertilizer demand was obtained and subtracted from that of the ROW. Finally we calculated the fertilizer rates for Ukrainian "Other Coarse Grains," which according to FAPRI are barley, oats, and rye. For each of these crops, we assumed that Ukraine has the same linear production function as Russia and calculated each nutrient's application rate in a similar way as what was done in the case of wheat and corn.

When a region instead of a country was reported by FAPRI, each fertilizer application rate was obtained as follows. For a given crop, we took the average yield of the countries in the region (with yields obtained from the USDA-FAS "Production, Supply and Distribution" dataset). Then, in most cases, we used the FAO 2002 report to obtain each country's nutrient application rate and constructed an average of the nutrient rate for the region, where the weights were given by the planted area in each country (with planted areas also obtained from the USDA-FAS "Production, Supply and Distribution" dataset). The FAO 2002 was the preferred source of data because it is the report that spans most of the relevant countries and crops with fertilizer application rates from 1998 to 2000. Then, having found a yield and an application rate for the region, we have a point in the underlying production function for one year (usually between 1998 and 2000). Next, assuming that the production function had not changed, we obtained the fertilizer rate for the region in 2006/07 and 2007/08, using the methodology just described.

We show the 2007/08 fertilizer application rates for N, P, and K for each country and crop covered by FAPRI in Appendix B.

Projection of Fertilizer Application Rates

We seek to find a fertilizer application rate (nutrient/crop/country-specific) whose variation in each year is a function of the relevant variables of the decision process. The FAPRI-ISU model is capable of producing this variation, in particular, through the yield equations.

The FAPRI model has, for each crop and country, its respective yield and area equation and projects the country's crop production as the product of its yield and harvested area. The fertilizer decision affects the total cost of production, which in turn is one of the explanatory variables of the FAPRI yield equation. Therefore, to obtain a fertilizer demand projection that is a function of the relevant variables in the model, we induce interaction between the fertilizer application rate (N, P, and K) and the yield equation in each country, by means of an underlying production function. The procedure is as follows.

The yield equation stated below accounts for three drivers: a time trend, an intensification component, and an extensification component. We are interested in the intensification terms because they account for the cost of production, and it is through these terms that the fertilizer application rates induce their effect.

$$y_{it} = \alpha + \beta Trend_t + \delta\left(\frac{TRev_{it}}{NFCost_{it} + FCost_{it}}\right) + \gamma\left(\frac{TRev_{i10y-ave}}{TCost_{i10y-ave}}\right) + \lambda a_{it} + \kappa(\sum a_{it}) + \epsilon_t$$

where $TCost_{it} = NFCost_{it} + FCost_{it}$ is the total variable cost expressed as the sum of the non-fertilizer cost and the fertilizer cost. The fertilizer cost is the sum of prices times quantities of each nutrient N, P, and K ($FCost_{it} = p_{Nit}N_{it} + p_{Pit}P_{it} + p_{Kit}K_{it}$). Suppose there exists an underlying production function for country *i* that determines the yield at time *t*, y_{it}^1. Holding everything else constant, except the application of nitrogen fertilizer, this production function is described by a curve of the form shown in Figure 2. Therefore such a yield is consistent with a certain per hectare nitrogen application rate, N_{it}^1. If we assume that the consistent nitrogen rate is the one found in the "Accounting Model," we have one point on the production function curve. When the FAPRI-ISU model makes its first iteration (indexed by the superscript), a new value for the yield is found (y_{it}^2), which will be consistent with a different nitrogen application rate (N_{it}^2), consistency that is given by the curvature of the production function at that point. Therefore, we must know the curvature (elasticity of yields with respect to changes in N application rates) of the underlying production function for each country and each crop covered by FAPRI (these are explained in the next section).

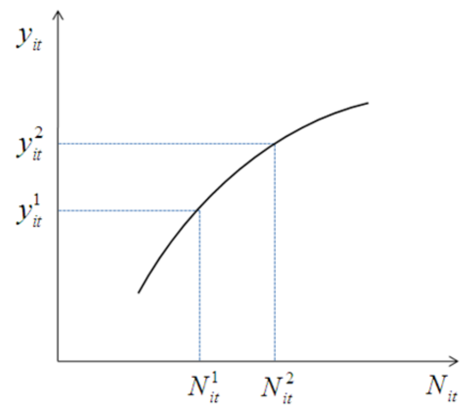

Figure 2. Underlying production function to determine yield response to nitrogen application rate

Before the third iteration, the total cost of production ($FCcost_{it}$) has to be updated with the new nitrogen application rate just found (N_{it}^2); that is, $FCost_{it}^3 = FCost_{it}^2(1 + g.w)$ where g is the change in the nitrogen rate and w is the weight of nitrogen in the fertilizer cost. The value of g is a function of the elasticity of the production function. Then, a yield will be obtained in the third iteration (y_{it}^3), which according to the curvature of the production function determines a new nitrogen application rate of N_{it}^3. This process continues until the market for this crop clears. Also, the process is repeated for each year projected by FAPRI, which allows us to obtain the fertilizer application rate projection.

The obtained nitrogen application rate will then be multiplied by the projected harvested area to obtain the corresponding fertilizer demand projection. The case of phosphorous and potash is the same as that of nitrogen.

Fertilizer Input Prices at the Country Level

The variable cost of production is composed of fertilizer costs plus non-fertilizer costs. Fertilizer costs at the country level are obtained by multiplying the country-specific fertilizer rate of a given crop times a country-specific fertilizer price. In order to obtain fertilizer prices (landed nutrient prices), we took the world fertilizer price for each nutrient (assumed to be the U.S. price), multiplied by the exchange rate, and applied the import tariffs of the country of interest. U.S. fertilizer prices (urea, superphospate triple, and potassium chloride) were obtained from USDA-NASS and projected using the "Cost of Production Model." Exchange rates by country are readily available, and import tariffs were obtained from the World Trade Organization database.

Production Function Elasticities for Each Crop

We seek to find an underlying production function from which to obtain the response of crop yields to the application of fertilizer for each country. The ideal situation would be to estimate a country- and crop-specific production function, so that an elasticity of yields with respect to the application of nutrients can be obtained for each country. This is not possible with the available data because it requires cross-section or time-series data on input use by crop and by country. Therefore, we are forced to produce a less ambitious estimation. In this sense, for each commodity, we take the nutrient application rates from the Accounting Model or from other sources[2] and the crop yield from FAPRI or from USDA-FAS and use these pairs to fit a "world" production function. This will give us a yield response curve for each nutrient and for each crop, and the elasticity will be given by where the country is located in the production function. Results will be conditional on the form of the production function chosen. We also assume that all countries share the same technology functional form for producing a given crop. We explain the procedure used with an example for corn.

The production function with raw country data is plotted in blue in each of the nutrient dimensions, as shown in Figure 3. We fitted a Cobb-Douglas production function to these yield data as a function of the three nutrients ($y = AN^{\alpha}P^{\beta}K^{\gamma}e^{\varepsilon}$). For this functional form, the elasticity with respect to each input is exactly its exponent. The estimation output showing statistically significant estimates of elasticities is shown in Table 2. Figure 3 shows the case of nitrogen, where the raw data used in the estimation is in blue and the fitted Cobb-Douglas production function is in red (graphs for phosphorous and potassium are in Appendix C). The higher elasticity with respect to nitrogen implies that nitrogen rates will be less

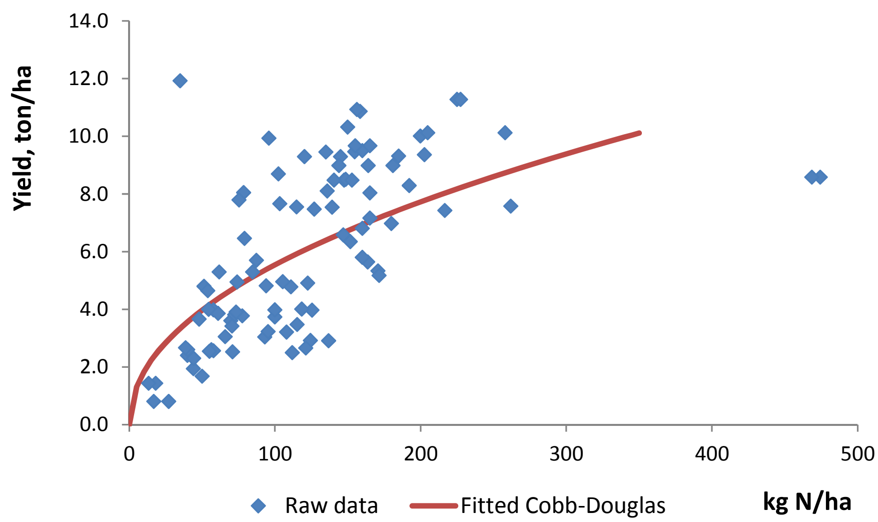

Figure 3. Corn yield response to nitrogen

[2] USDA-ERS, IFA, and Fertilizers Europe.

responsive to corn price changes than those of phosphorous and potassium. This is consistent with the country data of aggregate consumption of nutrients where the latter changes more from year to year. The explanation hinges on the fact that N has to be applied every year (so in that sense is more inelastic) while P and K are stored nutrients so the farmer can "wait" until price conditions are more favorable to purchase them. The lack of other input data at the crop and country level does not allow us to specify the technology as a function of other relevant inputs in the crop production process.

Table 2. Estimated elasticities for corn (Equation: $\ln(y) = \ln(A) + \alpha \ln(N) + \beta \ln(P) + \gamma \ln(K)$)

Variable	$\ln(A)$	$\ln(N_{corn})$	$\ln(P_{corn})$	$\ln(K_{corn})$
Coefficient	-1.396	0.480	0.174	0.067
Standard error	0.294	0.092	0.094	0.038
t-stat	-4.744	5.201	1.850	1.787
p-value	0.000	0.000	0.068	0.077

For some commodities (sorghum, sunflower, and sugarcane) we estimated a production function of the form $y = A(N + P + K)^{\alpha} e^{\varepsilon}$ because we did not have enough observations of nutrient use but observations on aggregate nutrients use by crop were available, especially for India. In other cases (soybeans, rapeseed, and sugar beet) we estimated the following form of production function: $y = AN^{\alpha}(P + K)^{\beta} e^{\varepsilon}$, because the estimate of the P or K elasticity was of the unexpected sign.

The estimated Cobb-Douglas elasticities of yield with respect to fertilizer rate are shown in Table 3 for each nutrient and for each commodity. It is important to highlight that these elasticities are then multiplied by the share of fertilizers in the total cost of production, so that we are not attributing all the change in yields to changes in fertilizer application rates.

Table 3. Estimated Cobb-Douglas Yield Elasticities

	Wheat, All	**Corn**	**Barley**	**Oats**	**Rye**	**Sorghum**	**Soybeans**	**Peanut**	**Rapeseed**	**Sunflower**	**Palm Oil**	**Rice, All**	**Cotton**	**Sugar Beet**	**Sugar Cane**
N	0.736	0.480	0.366	0.712	0.712	0.147	0.072	0.072	0.325	0.141	0.043	0.249	0.573	0.245	0.124
P	0.064	0.174	0.066	0.127	0.127	0.147	0.262	0.262	0.034	0.141	0.043	0.046	0.074	0.342	0.124
K	0.064	0.067	0.066	0.127	0.127	0.147	0.262	0.262	0.034	0.141	0.043	0.048	0.074	0.342	0.124

Our results will be improved as we find more country-specific data on input use by crop (fertilizer and other inputs), so that its own production function can be estimated.

FAPRI U.S. Model. Within the FAPRI-ISU model, projections for the commodities covered in the U.S. come from another model, the "U.S. model." These commodities are wheat, corn, oats, rye, sorghum, soybeans, rapeseed, sunflower, peanuts, sugar beet, sugarcane, rice, and cotton. Also, the model divides the U.S. into the following six regions: Central Plains, Corn Belt, Delta States, Lake-States Northeast, Northern Plains, and Southeast. As a result, each commodity and region requires a fertilizer application rate (by nutrient) and the elasticity of yields with respect to each nutrient.

From USDA-ERS, fertilizer use by nutrient, by crop, and by state is available for wheat, corn, soybeans, and cotton between 1980 and 2007. This dataset was used to calculate the N, P, and K application rates for the base years, and to estimate the required elasticities (note that yields by state and by crop are available at USDA-NASS). Below, in Table 4, we show our estimated elasticities for soybeans in the U.S. coming from a Cobb-Douglas production function in which P and K are lumped together and in which regional dummy variables are included (relative to the Southeast region).

Table 4. Estimated elasticities for soybeans in the United States (Equation: $\ln(y) = \ln(A) + \alpha \ln(N) + \beta \ln(P + K)$)

Variable	$\ln(A)$	$\ln(N)$	$\ln(P+K)$	Central Plains	Corn Belt	Delta States	Lake States	North-east	Northern Plains
Coefficient	-0.947	0.072	0.262	0.489	0.355	-0.004	0.410	0.219	0.373
Std. Error	0.282	0.029	0.061	0.058	0.029	0.033	0.044	0.099	0.071
t-stat	-3.363	2.435	4.328	8.378	12.063	-0.115	9.357	2.223	5.284
p-value	0.001	0.015	0.000	0.000	0.000	0.909	0.000	0.027	0.000

Elasticities of yield are significant and with the expected sign. The low value of the elasticity with respect to N is reasonable because of the low response of soybean yields to the addition of nitrogen fertilizer. For the cases of soybeans, wheat, and cotton we estimated elasticities with data from the U.S. However, for the remaining commodities we applied the elasticities estimated from the world production function. These elasticities are shown in Table 5.

Table 5. Estimated Cobb-Douglas yield elasticities for the United States

	Wheat, All	Corn	Barley	Oats	Rye	Sorghum	Soybeans	Peanut	Rapeseed	Sunflower	Rice, All	Cotton	Sugar Beet	Sugar Cane
N	0.170	0.480	0.366	0.712	0.712	0.147	0.072	0.072	0.325	0.141	0.249	0.573	0.369	0.124
P	0.037	0.174	0.066	0.127	0.127	0.147	0.262	0.262	0.034	0.141	0.046	0.074	0.203	0.124
K	0.037	0.067	0.066	0.127	0.127	0.147	0.262	0.262	0.034	0.141	0.048	0.074	0.203	0.124
	*	**	**	**	**	**	*	**	**	**	**	*	**	**

(*): Based on U.S. data only. (**): Corresponds with world production function.

Fertilizer Demand Baseline Projections

We present fertilizer demand projections by nutrient, by crop, and by year, for the world and a selected group of countries and crops. The complete set of projections, including all the countries and crops covered by the model, are available at http://www.fapri.iastate.edu/outlook/2011/ . Baseline projections are through year 2025/26.

World fertilizer use in 2025/26 is projected to be 185 mmt, composed of 107 mmt of nitrogen (N) fertilizers, 43 mmt of phosphorous (P), and 35 mmt of potassium (K). This increase of 5.50% relative to the 2010/11 crop season reflects the expansion of the world's cropland by 4.36% and also the more intensive use of fertilizers at the world level in commodities such as corn, barley, rapeseed, peanut, and cotton. These are shown in the tables in Appendix D.

World fertilizer use in corn is projected to be 17.20 mmt of N, 5.29 mmt of P, and 4.93 mmt of K, which represent increments of 4.63%, 8.01%, and 15.09%, respectively, relative to 2010/11. The higher percentage increase of P and K relative to N hinges upon their more elastic behavior relative to corn price changes. The higher fertilizer use in corn is due to the increase in both corn harvested areas and fertilizer application rates. World N use in soybean is projected at 1.43 mmt, 4.72 mmt of P, and 4.41 mmt of K in 2025. These imply similar levels of N and increases of 6.29% and 3.64% in P and K, respectively, relative to 2010. This is caused by the increase in soybean harvested area of 7.66% that offsets the decrease in nutrients application rates per hectare (induced by lower-than-2010 soybean prices projected to 2025). Fertilizer use in wheat at the world level is projected at 17.85 mmt of N, 6.25 mmt of P, and 2.11 mmt of K, which implies levels similar to 2010/11 because the increase in harvested areas of 0.88% compensates for the less intensive use of fertilizers in this crop.

Fertilizer use in the U.S. increases by 6.09%, driven by the higher use of fertilizers in corn, sorghum, and rapeseed, as shown in Appendix D. Corn N use in the U.S. in 2025 is projected at 5.66 mmt, 2.42 of P, and 3.21 mmt of K, which represents increments of 10.45%, 12.39%, and 17.51%, respectively, with respect to 2010. Both the more intensive and extensive corn production contributes to these changes. Fertilizer use in soybean experiences a reduction of 2.96% because of the decrease in U.S. soybean areas in that period. The case of wheat is similar, with even a stronger reduction of 10.09%, but in this case this is induced by the reduction in area as well as the fertilizer application rates.

China, India, the U.S., and the EU-27 countries account for more than two-thirds (65%) of the world's fertilizer consumption in agriculture. China is the world's top consuming country, followed by the U.S. China is characterized not only by large crop areas but also by an intensive use of fertilizers, which is comparable to (and even higher than in the cases of wheat, sunflower seed, peanuts, cotton, sugarcane, and sugar beet) those of the U.S. and EU-27 countries. India, on the other hand, is the third-largest fertilizer consumer, given its larger crop areas, but it has more moderate fertilizer application rates. China's fertilizer use slightly increases from 2010 to 2025, induced by the increase in the use of N because there is a shift in area toward crops that are more intensive in the use of N, such as corn, sugar beet, and cotton. China is expected to use 33.70 mmt of N, 12.16 mmt of P, and 6.49 mmt of K, which represents increments of 3.00%, 0.55% and 2.91% respectively, with respect to 2010. Indian fertilizer use increases over the projected period, driven by higher uses in oilseeds, wheat, and sugarcane. India's projected use in 2025 is 15.37 mmt of N, 5.78 mmt of P, and 2.75 mmt of K, which relative to 2010 is respectively 4.03%, 0.89% and 4.60% higher.

Fertilizer demand projections are a function of projected fertilizer application rates and harvested areas. We report fertilizer application rates by nutrient for all countries and commodities from our WorldNPK model in http://www.fapri.iastate.edu/outlook/2011/. For illustration purposes we show the projection of China's rates by crop in Appendix E. The main drivers of these rates are the variables included in the intensification component of each crop and country yield equation. Examples are the crop price and other input prices. We usually do not expect significant changes in the levels of these application rates, because small changes translate into sizable effects on a nutrient's total demand. Corn N rates are expected to increase by 1.12%, P rates by 3.09%, and K rates by 8.16%. Rates for P and K in corn are more responsive to output price changes than are N rates, and other cereals such as barley and wheat have similar rate responses. The reason is that while P and K are nutrients that can be stored in the soil, N has to be applied every year, and this makes it less elastic to changes in relevant variables. Soybean rates are expected to decrease over the projected period as a result of similar behavior of world soybean projected prices. An analogous result is expected for sunflower seed.

Further Extensions (Step 2)

So far, the model assumes a horizontal world supply of each nutrient such that changes in demand are satisfied without affecting fertilizer prices. We plan to introduce a supply curve, not only to overcome this simplified assumption but also to project a world fertilizer price of equilibrium that clears the world fertilizer market. The supply of fertilizers will have a short-term component that reflects capacity constraints in the industry and a long-term component that is more elastic with respect to prices to reflect capacity building.

Therefore, the output of the model once this change is introduced will be a country- and crop-specific nutrient application rate that is a function of the relevant variables in the fertilizing decision process, and when multiplied by the harvested areas will give projections of fertilizer demands by crop and country. Also, we will be able to project an endogenous world price for each nitrogen, phosphorous, and potash component consistent with the fertilizer market clearing assumption.

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Appendix A. Worldwide Fertilizer Consumption (Source: IFA 2009)

Fertilizer Use by Crop ('000 t nutrients)
2006 + 2006/07

Last update: 7 April 2009

				CEREALS								OILSEEDS													
				Wheat		Rice		Maize		Other CG		Soybean		Oil Palm		Other OS		Cotton		Sugar Crops		Fruits & Veg.		Other Crops	
		Total	% of World	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty
China	N	30,200	31.5%	14.1%	4,258	18.2%	5,496	16.1%	4,862	1.0%	302	1.5%	453	0.0%	6	4.8%	1,450	4.1%	1,238	1.5%	453	30.0%	9,060	8.7%	2,621
	P_2O_5	11,600	30.3%	16.5%	1,914	15.3%	1,775	6.6%	766	1.0%	116	3.3%	383	0.0%	2	5.0%	580	3.9%	452	2.2%	255	34.0%	3,944	12.2%	1,413
	K_2O	5,800	21.4%	4.4%	255	28.0%	1,624	2.2%	128	1.0%	58	1.0%	58	0.1%	6	2.3%	133	1.2%	70	4.8%	278	50.0%	2,900	5.0%	290
	N+P+K	47,600	29.5%	13.5%	6,427	18.7%	8,895	12.1%	5,755	1.0%	476	1.9%	894	0.0%	14	4.5%	2,163	3.7%	1,760	2.1%	987	33.4%	15,904	9.1%	4,325
India	N	13,773	14.4%	21.0%	2,892	30.0%	4,132	2.5%	344	4.5%	620	1.0%	138	0.0%	0	4.5%	620	6.5%	895	5.0%	689	7.0%	964	18.0%	2,479
	P_2O_5	5,543	14.5%	20.0%	1,109	25.0%	1,386	1.5%	83	5.0%	277	2.5%	139	0.0%	0	7.0%	388	8.0%	443	4.5%	249	11.0%	610	15.5%	859
	K_2O	2,335	8.6%	8.0%	187	34.0%	794	1.0%	23	2.5%	58	1.0%	23	0.0%	0	5.0%	117	5.5%	128	10.0%	234	22.0%	514	11.0%	257
	N+P+K	21,651	13.4%	19.3%	4,188	29.2%	6,312	2.1%	451	4.4%	955	1.4%	300	0.0%	0	5.2%	1,125	6.8%	1,467	5.4%	1,172	9.6%	2,088	16.6%	3,595
USA	N	11,970	12.5%	13.4%	1,604	1.9%	227	48.4%	5,793	3.4%	407	0.8%	96	0.0%	0	1.5%	180	2.4%	287	1.0%	120	4.2%	503	23.0%	2,753
	P_2O_5	4,148	10.8%	13.7%	568	0.9%	37	48.6%	2,016	2.3%	95	7.4%	307	0.0%	0	2.1%	87	3.1%	129	1.1%	46	5.8%	241	15.0%	622
	K_2O	4,657	17.1%	4.8%	224	0.8%	37	50.0%	2,329	1.0%	47	10.8%	503	0.0%	0	2.0%	93	3.3%	154	2.9%	135	6.8%	317	17.6%	820
	N+P+K	20,775	12.9%	11.5%	2,396	1.5%	302	48.8%	10,138	2.6%	549	4.4%	906	0.0%	0	1.7%	360	2.7%	570	1.4%	300	5.1%	1,060	20.2%	4,195
EU-27	N	10,746	11.2%	26.0%	2,794	0.4%	43	12.0%	1,290	16.0%	1,719	0.1%	11	0.0%	0	9.2%	989	0.5%	54	2.1%	226	7.5%	806	26.2%	2,815
	P_2O_5	3,091	8.1%	19.5%	603	0.5%	15	13.2%	408	15.9%	491	0.3%	9	0.0%	0	8.2%	253	0.7%	22	3.6%	111	13.4%	414	24.7%	763
	K_2O	3,592	13.2%	12.7%	456	0.9%	32	11.9%	427	12.8%	460	0.3%	11	0.0%	0	9.9%	356	0.6%	22	5.9%	212	14.4%	517	30.6%	1,099
	N+P+K	17,429	10.8%	22.1%	3,853	0.5%	91	12.2%	2,125	15.3%	2,671	0.2%	31	0.0%	0	9.2%	1,598	0.6%	97	3.1%	549	10.0%	1,737	26.8%	4,678
Brazil	N	2,297	2.4%	3.0%	69	7.1%	163	29.4%	675	4.1%	94	3.8%	87	0.2%	5	0.1%	2	7.4%	170	23.3%	535	6.8%	156	14.8%	340
	P_2O_5	3,149	8.2%	2.1%	66	4.6%	145	20.6%	649	2.0%	63	41.3%	1,301	0.1%	3	0.1%	3	4.5%	142	8.7%	274	5.0%	157	11.0%	346
	K_2O	3,460	12.7%	1.8%	62	4.1%	142	16.7%	578	0.9%	31	34.7%	1,201	0.2%	7	0.1%	3	4.1%	142	20.6%	713	5.4%	187	11.4%	394
	N+P+K	8,906	5.5%	2.2%	197	5.1%	450	21.4%	1,902	2.1%	188	29.1%	2,588	0.2%	15	0.1%	9	5.1%	454	17.1%	1,522	5.6%	500	12.1%	1,081
Pakistan	N	2,649	2.8%	37.9%	1,004	9.4%	249	4.8%	127	0.6%	16	0.0%	0	0.0%	0	1.1%	29	18.8%	498	6.6%	175	3.8%	101	17.0%	450
	P_2O_5	979	2.6%	35.2%	345	9.1%	89	6.2%	61	0.5%	5	0.0%	0	0.0%	0	1.5%	15	16.0%	157	8.1%	79	4.1%	40	19.3%	189
	K_2O	43	0.2%	34.0%	15	11.0%	5	11.0%	5	0.0%	0	0.0%	0	0.0%	0	0.0%	0	9.0%	4	11.0%	5	11.0%	5	13.0%	6
	N+P+K	3,671	2.3%	37.1%	1,363	9.3%	343	5.2%	193	0.6%	21	0.0%	0	0.0%	0	1.2%	44	17.9%	659	7.1%	259	4.0%	146	17.6%	645
Indonesia	N	2,350	2.5%	0.0%	0	45.0%	1,058	15.0%	353	0.0%	0	0.4%	9	13.0%	306	1.0%	24	0.1%	1	2.0%	47	9.0%	212	14.6%	342
	P_2O_5	480	1.3%	0.0%	0	22.0%	106	15.0%	72	0.0%	0	3.0%	14	25.0%	120	3.0%	14	0.2%	1	5.0%	24	10.0%	48	16.9%	81
	K_2O	800	2.9%	0.0%	0	14.0%	112	10.0%	80	0.0%	0	0.6%	5	48.0%	384	1.0%	8	0.1%	0	9.0%	72	12.0%	96	5.4%	43
	N+P+K	3,630	2.3%	0.0%	0	35.1%	1,275	13.9%	505	0.0%	0	0.8%	29	22.3%	810	1.3%	46	0.1%	2	3.9%	143	9.8%	356	12.8%	466
Canada	N	1,758	1.8%	33.6%	591	0.0%	0	8.9%	156	14.7%	258	0.5%	9	0.0%	0	20.4%	359	0.0%	0	0.5%	9	0.6%	11	20.8%	366
	P_2O_5	469	1.2%	36.9%	173	0.0%	0	8.8%	41	17.6%	83	6.2%	29	0.0%	0	16.9%	79	0.0%	0	0.6%	3	0.7%	3	12.3%	58
	K_2O	382	1.4%	9.4%	36	0.0%	0	22.5%	86	2.8%	11	8.1%	31	0.0%	0	20.8%	79	0.0%	0	0.6%	2	1.9%	7	33.9%	129
	N+P+K	2,609	1.6%	30.6%	800	0.0%	0	10.9%	284	13.5%	352	2.6%	69	0.0%	0	19.8%	517	0.0%	0	0.5%	14	0.8%	21	21.2%	553
Vietnam	N	1,123	1.2%	0.0%	0	68.0%	764	12.0%	135	0.0%	0	0.7%	8	0.0%	0	1.5%	17	0.2%	2	4.0%	45	3.0%	34	10.6%	119
	P_2O_5	600	1.6%	0.0%	0	72.0%	432	7.5%	45	0.0%	0	1.5%	9	0.0%	0	3.0%	18	0.1%	1	2.5%	15	4.0%	24	9.4%	56
	K_2O	408	1.5%	0.0%	0	66.0%	269	6.5%	27	0.0%	0	1.5%	6	0.0%	0	3.0%	12	0.1%	0	8.0%	33	5.0%	20	9.9%	40
	N+P+K	2,131	1.3%	0.0%	0	68.7%	1,465	9.7%	206	0.0%	0	1.1%	23	0.0%	0	2.2%	47	0.2%	3	4.3%	93	3.7%	78	10.1%	216
Turkey	N	1,407	1.5%	41.5%	584	0.9%	13	6.8%	96	12.1%	170	0.1%	1	0.0%	0	4.6%	65	5.4%	76	2.0%	28	17.0%	239	9.6%	135
	P_2O_5	605	1.6%	41.7%	252	0.9%	5	4.7%	28	13.1%	79	0.1%	1	0.0%	0	4.4%	27	5.2%	31	3.4%	21	14.4%	87	12.1%	73
	K_2O	99	0.4%	15.2%	15	0.5%	0	6.1%	6	2.9%	3	0.1%	0	0.0%	0	5.4%	5	4.2%	4	13.2%	13	40.4%	40	12.0%	12
	N+P+K	2,111	1.3%	40.3%	851	0.9%	19	6.2%	130	12.0%	252	0.1%	2	0.0%	0	4.6%	97	5.3%	112	2.9%	62	17.4%	366	10.4%	220
Australia	N	858	0.9%	30.7%	263	0.0%	0	0.7%	6	24.1%	207	0.0%	0	0.0%	0	10.3%	88	0.7%	6	8.2%	70	8.4%	72	16.9%	145
	P_2O_5	984	2.6%	28.9%	284	0.0%	0	0.4%	4	24.0%	236	0.0%	0	0.0%	0	7.7%	76	0.3%	3	3.1%	31	4.9%	48	30.7%	302
	K_2O	224	0.8%	12.6%	28	0.0%	0	0.2%	0	5.7%	13	0.0%	0	0.0%	0	3.4%	8	0.4%	1	19.8%	44	24.0%	54	33.9%	76
	N+P+K	2,066	1.3%	27.9%	576	0.0%	0	0.5%	10	22.1%	456	0.0%	0	0.0%	0	8.3%	172	0.5%	10	7.0%	145	8.4%	174	25.3%	523
Malaysia	N	540	0.6%	0.0%	0	15.0%	81	0.5%	3	0.0%	0	0.0%	0	65.0%	351	0.2%	1	0.0%	0	0.3%	2	3.0%	16	16.1%	87
	P_2O_5	230	0.6%	0.0%	0	19.0%	44	0.5%	1	0.0%	0	0.0%	0	55.0%	127	0.2%	0	0.0%	0	0.3%	1	6.0%	14	19.0%	44
	K_2O	1,000	3.7%	0.0%	0	5.0%	50	0.1%	1	0.0%	0	0.0%	0	85.0%	850	0.1%	1	0.0%	0	0.2%	2	2.0%	20	7.7%	77
	N+P+K	1,770	1.1%	0.0%	0	9.9%	175	0.3%	5	0.0%	0	0.0%	0	75.0%	1,328	0.1%	2	0.0%	0	0.2%	4	2.8%	50	11.7%	207

				CEREALS								OILSEEDS													
				Wheat		Rice		Maize		Other CG		Soybean		Oil Palm		Other OS		Cotton		Sugar Crops		Fruits & Veg.		Other Crops	
Iran	N	1,150	1.2%	36.0%	414	7.5%	86	5.5%	63	8.0%	92	0.2%	2	0.0%	0	4.5%	52	2.0%	23	3.5%	40	15.0%	173	17.8%	205
	P_2O_5	500	1.3%	34.0%	170	5.5%	28	5.0%	25	7.5%	38	0.8%	4	0.0%	0	6.5%	33	1.5%	8	3.5%	18	23.0%	115	12.7%	63
	K_2O	200	0.7%	24.0%	48	4.0%	8	3.5%	7	5.5%	11	0.3%	1	0.0%	0	4.5%	9	1.5%	3	2.5%	5	44.0%	88	10.2%	20
	N+P+K	1,850	1.1%	34.2%	632	6.6%	122	5.1%	95	7.6%	141	0.4%	7	0.0%	0	5.0%	93	1.8%	34	3.4%	63	20.3%	376	15.6%	289
Thailand	N	1,034	1.1%	0.0%	0	30.0%	310	7.0%	72	0.5%	5	0.1%	1	3.0%	31	1.0%	10	1.0%	10	5.0%	52	28.0%	290	24.4%	252
	P_2O_5	333	0.9%	0.0%	0	25.0%	83	7.0%	23	0.5%	2	1.0%	3	6.0%	20	1.5%	5	1.0%	3	10.0%	33	30.0%	100	18.0%	60
	K_2O	341	1.3%	0.0%	0	5.0%	17	10.0%	34	0.5%	2	0.1%	0	10.0%	34	1.0%	3	1.0%	3	13.0%	44	36.0%	123	23.4%	80
	N+P+K	1,708	1.1%	0.0%	0	24.0%	411	7.6%	130	0.5%	9	0.3%	5	5.0%	85	1.1%	19	1.0%	17	7.6%	129	30.0%	512	23.0%	392
Bangladesh	N	1,193	1.2%	1.2%	14	93.3%	1,113	0.3%	4	0.0%	0	0.0%	0	0.0%	0	0.8%	10	0.2%	2	0.7%	8	1.5%	18	2.0%	24
	P_2O_5	285	0.7%	1.5%	4	83.0%	237	0.3%	1	0.0%	0	0.0%	0	0.0%	0	2.0%	6	0.2%	1	1.5%	4	5.0%	14	6.5%	19
	K_2O	170	0.6%	1.7%	3	81.0%	138	0.3%	1	0.0%	0	0.0%	0	0.0%	0	2.0%	3	0.4%	1	2.0%	3	5.0%	9	7.6%	13
	N+P+K	1,648	1.0%	1.3%	21	90.2%	1,487	0.3%	5	0.0%	0	0.0%	0	0.0%	0	1.1%	19	0.2%	3	1.0%	16	2.5%	41	3.4%	56
Russia	N	956	1.0%	42.0%	402	1.2%	11	7.3%	70	22.0%	210	0.4%	4	0.0%	0	2.3%	22	0.0%	0	9.6%	92	1.0%	10	14.2%	136
	P_2O_5	423	1.1%	40.0%	169	1.1%	5	5.5%	23	21.0%	89	1.1%	5	0.0%	0	7.1%	30	0.0%	0	15.0%	63	1.4%	6	7.8%	33
	K_2O	268	1.0%	26.0%	70	0.1%	0	5.7%	15	23.0%	62	0.8%	2	0.0%	0	4.1%	11	0.0%	0	24.0%	64	3.7%	10	12.6%	34
	N+P+K	1,647	1.0%	38.9%	640	1.0%	16	6.6%	108	21.9%	361	0.6%	11	0.0%	0	3.8%	63	0.0%	0	13.3%	220	1.5%	25	12.3%	203
Mexico	N	1,120	1.2%	5.3%	59	0.5%	6	61.3%	687	1.8%	20	0.0%	0	1.2%	13	0.2%	2	0.5%	6	6.1%	68	14.9%	167	8.2%	92
	P_2O_5	260	0.7%	2.9%	8	0.8%	2	40.0%	104	0.8%	2	1.2%	3	4.0%	10	0.2%	1	1.2%	3	8.8%	23	32.0%	83	8.1%	21
	K_2O	220	0.8%	1.2%	3	0.9%	2	9.0%	20	0.0%	0	0.9%	2	4.5%	10	0.0%	0	0.9%	2	27.8%	61	47.1%	104	7.7%	17
	N+P+K	1,600	1.0%	4.3%	70	0.6%	10	50.6%	810	1.4%	22	0.3%	5	2.1%	34	0.2%	3	0.7%	11	9.5%	152	22.1%	354	8.1%	130
Egypt	N	1,260	1.3%	24.0%	302	9.0%	113	27.0%	340	4.5%	57	0.1%	1	0.0%	0	1.0%	13	3.5%	44	4.0%	50	19.0%	239	7.9%	100
	P_2O_5	240	0.6%	14.5%	35	8.5%	20	10.5%	25	2.5%	6	0.2%	0	0.0%	0	1.5%	4	4.5%	11	3.0%	7	45.0%	108	9.8%	24
	K_2O	49	0.2%	20.0%	10	0.0%	0	15.0%	7	2.0%	1	0.1%	0	0.0%	0	0.5%	0	4.0%	2	15.0%	7	35.0%	17	8.4%	4
	N+P+K	1,549	1.0%	22.4%	347	8.6%	134	24.1%	373	4.1%	64	0.1%	2	0.0%	0	1.1%	16	3.7%	57	4.2%	65	23.5%	365	8.2%	127
Argentina	N	759	0.8%	36.9%	280	0.7%	5	29.0%	220	5.3%	40	6.6%	50	0.0%	0	3.3%	25	0.7%	5	3.3%	25	7.2%	55	7.0%	53
	P_2O_5	639	1.7%	25.8%	165	0.4%	3	17.2%	110	6.3%	40	34.4%	220	0.0%	0	3.1%	20	0.2%	1	0.2%	1	6.3%	40	6.1%	39
	K_2O	55	0.2%	2.2%	1	4.2%	2	2.2%	1	0.5%	0	2.0%	1	0.0%	0	0.9%	0	0.2%	0	10.0%	6	54.5%	30	23.3%	13
	N+P+K	1,453	0.9%	30.7%	446	0.7%	10	22.8%	331	5.6%	81	18.7%	271	0.0%	0	3.1%	45	0.5%	7	2.2%	32	8.6%	125	7.2%	105
South Africa	N	429	0.4%	7.2%	31	0.0%	0	48.0%	206	1.4%	6	0.1%	0	0.0%	0	4.3%	18	0.3%	1	11.5%	49	11.5%	49	15.7%	67
	P_2O_5	204	0.5%	10.0%	20	0.0%	0	41.0%	84	1.7%	3	0.7%	1	0.0%	0	6.2%	13	0.6%	1	13.0%	27	12.0%	24	14.8%	30
	K_2O	153	0.6%	4.6%	7	0.0%	0	13.5%	21	0.5%	1	0.3%	0	0.0%	0	1.1%	2	0.2%	0	43.0%	66	25.0%	38	11.8%	18
	N+P+K	786	0.5%	7.4%	58	0.0%	0	39.5%	310	1.3%	10	0.3%	2	0.0%	0	4.2%	33	0.4%	3	18.0%	142	14.3%	112	14.7%	116
Philippines	N	520	0.5%	0.0%	0	40.0%	208	20.0%	104	0.0%	0	0.0%	0	0.5%	3	2.0%	10	0.0%	0	2.0%	10	20.0%	104	15.5%	81
	P_2O_5	110	0.3%	0.0%	0	30.0%	33	12.0%	13	0.0%	0	0.0%	0	0.5%	1	5.0%	6	0.0%	0	6.0%	7	30.0%	33	16.5%	18
	K_2O	110	0.4%	0.0%	0	10.0%	11	5.0%	6	0.0%	0	0.0%	0	3.0%	3	3.0%	3	0.0%	0	15.0%	17	50.0%	55	14.0%	15
	N+P+K	740	0.5%	0.0%	0	34.1%	252	16.6%	123	0.0%	0	0.0%	0	0.9%	6	2.6%	19	0.0%	0	4.5%	34	25.9%	192	15.4%	114
Chile	N	254	0.3%	18.0%	46	0.8%	2	12.0%	30	6.0%	15	0.0%	0	0.0%	0	0.8%	2	0.0%	0	1.6%	4	20.0%	51	40.8%	104
	P_2O_5	143	0.4%	18.0%	26	1.3%	2	6.7%	10	6.0%	9	0.0%	0	0.0%	0	0.6%	1	0.0%	0	1.2%	2	10.0%	14	56.2%	80
	K_2O	95	0.3%	6.0%	6	2.0%	2	9.0%	9	2.0%	2	0.0%	0	0.0%	0	0.5%	0	0.0%	0	6.0%	6	45.0%	43	29.5%	28
	N+P+K	492	0.3%	15.7%	77	1.2%	6	9.9%	49	5.2%	26	0.0%	0	0.0%	0	0.7%	3	0.0%	0	2.3%	11	21.9%	108	43.1%	212
Morocco	N	226	0.2%	28.0%	63	0.4%	1	3.0%	7	19.0%	43	0.0%	0	0.0%	0	2.2%	5	0.0%	0	5.5%	12	20.0%	45	21.9%	49
	P_2O_5	153	0.4%	28.0%	43	0.3%	0	3.5%	5	19.0%	29	0.0%	0	0.0%	0	3.6%	6	0.0%	0	5.5%	8	18.0%	28	22.1%	34
	K_2O	53	0.2%	14.0%	7	0.0%	0	2.8%	1	11.0%	6	0.0%	0	0.0%	0	1.4%	1	0.0%	0	9.5%	5	50.0%	27	11.3%	6
	N+P+K	432	0.3%	26.3%	114	0.3%	1	3.2%	14	18.0%	78	0.0%	0	0.0%	0	2.6%	11	0.0%	0	6.0%	26	23.0%	99	20.7%	89
ROW	N	7,257	7.6%	13.0%	943	14.0%	1,016	13.0%	943	6.0%	435	0.5%	36	0.7%	51	5.0%	363	5.0%	363	5.0%	363	18.0%	1,306	19.8%	1,437
	P_2O_5	3,070	8.0%	10.0%	307	12.0%	368	10.0%	307	6.0%	184	5.0%	154	1.0%	31	5.0%	154	5.0%	154	6.0%	184	20.0%	614	20.0%	614
	K_2O	2,643	9.7%	7.0%	185	12.0%	317	10.0%	264	4.0%	106	3.0%	79	4.0%	106	4.0%	106	3.0%	79	12.0%	317	25.0%	661	16.0%	423
	N+P+K	12,970	8.0%	11.1%	1,435	13.1%	1,702	11.7%	1,515	5.6%	725	2.1%	269	1.4%	187	4.8%	622	4.6%	596	6.7%	864	19.9%	2,581	19.1%	2,474
World	N	95,829	100.0%	17.3%	16,614	15.8%	15,098	17.3%	16,587	4.9%	4,718	0.9%	907	0.8%	765	4.5%	4,354	3.8%	3,682	3.3%	3,173	15.3%	14,679	15.9%	15,252
	P_2O_5	38,238	100.0%	16.4%	6,261	12.6%	4,815	12.8%	4,904	4.8%	1,848	6.8%	2,582	0.8%	313	4.7%	1,816	4.1%	1,561	3.9%	1,486	17.8%	6,810	15.3%	5,843
	K_2O	27,157	100.0%	6.0%	1,617	13.1%	3,563	15.0%	4,075	3.2%	870	7.1%	1,924	5.2%	1,400	3.5%	955	2.3%	616	8.6%	2,344	21.7%	5,880	14.4%	3,914
	N+P+K	161,224	100.0%	15.2%	24,492	14.6%	23,476	15.9%	25,566	4.6%	7,435	3.4%	5,412	1.5%	2,478	4.4%	7,125	3.6%	5,859	4.3%	7,002	17.0%	27,369	15.5%	25,009

Source: International Fertilizer Industry Association. AgCom/09/28

Fertilizer Use by Crop ('000 t nutrients)

Last update: 7 April 2009

2007 + 2007/08

				CEREALS								OILSEEDS												
				Wheat		Rice		Maize		Other CG		Soybean		Oil Palm		Other OS		Cotton		Sugar Crops		Fruits & Veg.		Other Crops	
		Total	% of World	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%	Qty
China	N	32,000	31.8%	13.5%	4,320	17.6%	5,632	15.8%	5,056	1.0%	320	1.4%	448	0.0%	6	4.5%	1,440	4.3%	1,376	1.6%	512	31.0%	9,920	9.3%	2,970
	P_2O_5	12,000	30.5%	16.0%	1,920	15.0%	1,800	7.0%	840	1.0%	120	3.0%	360	0.0%	2	4.7%	564	4.1%	492	2.3%	276	34.0%	4,080	12.9%	1,546
	K_2O	6,200	21.5%	4.0%	248	28.0%	1,736	2.2%	136	1.0%	62	1.0%	62	0.1%	6	2.2%	136	1.3%	81	5.0%	310	50.0%	3,100	5.2%	322
	N+P+K	50,200	29.8%	12.9%	6,488	18.3%	9,168	12.0%	6,032	1.0%	502	1.7%	870	0.0%	14	4.3%	2,140	3.9%	1,949	2.2%	1,098	34.1%	17,100	9.6%	4,838
India	N	14,633	14.6%	21.0%	3,073	30.0%	4,390	2.5%	366	4.5%	658	1.0%	146	0.0%	0	4.5%	658	6.5%	951	5.0%	732	7.0%	1,024	18.0%	2,634
	P_2O_5	5,726	14.6%	20.0%	1,145	25.0%	1,432	1.5%	86	5.0%	286	2.5%	143	0.0%	0	7.0%	401	8.0%	458	4.5%	258	11.0%	630	15.5%	888
	K_2O	2,657	9.2%	8.0%	213	34.0%	903	1.0%	27	2.5%	66	1.0%	27	0.0%	0	5.0%	133	5.5%	146	10.0%	266	22.0%	585	11.0%	292
	N+P+K	23,016	13.6%	19.3%	4,431	29.2%	6,725	2.1%	478	4.4%	1,011	1.4%	316	0.0%	0	5.2%	1,192	6.8%	1,555	5.5%	1,255	9.7%	2,239	16.6%	3,814
USA	N	11,610	11.5%	13.2%	1,533	2.2%	255	46.7%	5,422	3.5%	406	1.0%	116	0.0%	0	1.6%	186	2.2%	255	1.0%	116	4.4%	511	24.2%	2,810
	P_2O_5	4,080	10.4%	14.7%	600	1.1%	45	43.9%	1,791	2.3%	94	10.5%	428	0.0%	0	2.1%	86	2.7%	110	1.1%	45	6.0%	245	15.6%	636
	K_2O	4,540	15.7%	5.0%	227	1.0%	45	45.8%	2,079	1.0%	45	14.9%	676	0.0%	0	2.1%	95	3.0%	136	2.9%	132	6.8%	309	17.5%	795
	N+P+K	20,230	12.0%	11.7%	2,359	1.7%	346	45.9%	9,292	2.7%	546	6.0%	1,221	0.0%	0	1.8%	367	2.5%	502	1.4%	293	5.3%	1,064	21.0%	4,241
EU-27	N	11,617	11.6%	27.8%	3,230	0.4%	46	11.9%	1,382	16.7%	1,940	0.1%	12	0.0%	0	8.7%	1,011	0.5%	58	1.8%	209	7.1%	825	25.0%	2,904
	P_2O_5	3,454	8.8%	21.8%	753	0.5%	17	13.0%	449	17.3%	598	0.3%	10	0.0%	0	7.9%	273	0.6%	21	3.1%	107	12.4%	428	23.1%	798
	K_2O	3,865	13.4%	14.3%	553	0.8%	31	12.2%	472	13.1%	506	0.3%	12	0.0%	0	9.8%	379	0.5%	19	5.3%	205	13.8%	533	29.9%	1,156
	N+P+K	18,936	11.2%	24.0%	4,535	0.5%	95	12.2%	2,303	16.1%	3,044	0.2%	34	0.0%	0	8.8%	1,662	0.5%	98	2.8%	521	9.4%	1,786	25.7%	4,858
Brazil	N	2,751	2.7%	2.9%	80	5.3%	146	31.1%	856	4.0%	110	3.9%	107	0.2%	6	0.1%	3	8.4%	231	22.3%	613	6.6%	182	15.2%	418
	P_2O_5	3,659	9.3%	2.1%	77	3.9%	143	20.0%	732	1.9%	70	42.4%	1,551	0.1%	4	0.1%	4	4.4%	161	8.6%	315	5.0%	183	11.5%	421
	K_2O	4,175	14.5%	1.8%	75	3.7%	154	18.5%	772	1.0%	42	34.1%	1,424	0.2%	8	0.1%	4	3.7%	154	20.4%	852	5.3%	221	11.2%	468
	N+P+K	10,585	6.3%	2.2%	232	4.2%	443	22.3%	2,360	2.1%	221	29.1%	3,082	0.2%	18	0.1%	11	5.2%	547	16.8%	1,780	5.5%	586	12.3%	1,307
Indonesia	N	2,596	2.6%	0.0%	0	45.0%	1,168	15.0%	389	0.0%	0	0.4%	10	13.0%	337	1.0%	26	0.1%	1	2.0%	52	9.0%	234	14.6%	378
	P_2O_5	510	1.3%	0.0%	0	22.0%	112	15.0%	77	0.0%	0	3.0%	15	25.0%	128	3.0%	15	0.2%	1	5.0%	26	10.0%	51	16.9%	86
	K_2O	850	2.9%	0.0%	0	14.0%	119	10.0%	85	0.0%	0	0.6%	5	48.0%	408	1.0%	9	0.1%	0	9.0%	77	12.0%	102	5.4%	45
	N+P+K	3,956	2.3%	0.0%	0	35.4%	1,399	13.9%	551	0.0%	0	0.8%	31	22.1%	873	1.3%	50	0.1%	2	3.9%	154	9.8%	387	12.9%	509
Pakistan	N	2,923	2.9%	37.0%	1,082	9.1%	266	4.8%	140	0.6%	18	0.0%	0	0.0%	0	1.2%	35	18.5%	541	7.9%	231	4.1%	120	16.8%	491
	P_2O_5	627	1.6%	34.1%	214	8.5%	53	6.1%	38	0.5%	3	0.0%	0	0.0%	0	1.6%	10	15.7%	98	9.6%	60	4.8%	30	19.1%	120
	K_2O	29	0.1%	27.0%	8	11.0%	3	11.0%	3	0.0%	0	0.0%	0	0.0%	0	0.0%	0	8.0%	2	15.0%	4	15.0%	4	13.0%	4
	N+P+K	3,579	2.1%	36.4%	1,303	9.0%	322	5.1%	182	0.6%	21	0.0%	0	0.0%	0	1.3%	45	17.9%	642	8.3%	295	4.3%	154	17.2%	615
Canada	N	1,939	1.9%	29.6%	574	0.0%	0	10.5%	204	16.6%	322	0.5%	10	0.0%	0	22.9%	444	0.0%	0	0.5%	10	0.6%	12	18.8%	365
	P_2O_5	508	1.3%	31.9%	162	0.0%	0	10.7%	54	20.6%	105	5.3%	27	0.0%	0	19.4%	99	0.0%	0	0.5%	3	0.6%	3	11.0%	56
	K_2O	354	1.2%	7.7%	27	0.0%	0	26.9%	95	3.1%	11	7.4%	26	0.0%	0	24.4%	86	0.0%	0	0.5%	2	1.8%	6	28.2%	100
	N+P+K	2,801	1.7%	27.2%	763	0.0%	0	12.6%	353	15.6%	437	2.2%	63	0.0%	0	22.5%	629	0.0%	0	0.5%	14	0.8%	21	18.6%	520
Vietnam	N	1,136	1.1%	0.0%	0	68.0%	772	12.0%	136	0.0%	0	0.7%	8	0.0%	0	1.5%	17	0.2%	2	4.0%	45	3.0%	34	10.6%	120
	P_2O_5	631	1.6%	0.0%	0	72.0%	454	7.5%	47	0.0%	0	1.5%	9	0.0%	0	3.0%	19	0.1%	1	2.5%	16	4.0%	25	9.4%	59
	K_2O	433	1.5%	0.0%	0	66.0%	286	6.5%	28	0.0%	0	1.5%	6	0.0%	0	3.0%	13	0.1%	0	8.0%	35	5.0%	22	9.9%	43
	N+P+K	2,200	1.3%	0.0%	0	68.8%	1,513	9.6%	212	0.0%	0	1.1%	24	0.0%	0	2.2%	49	0.2%	3	4.4%	96	3.7%	81	10.1%	223
Australia	N	848	0.8%	30.7%	260	0.0%	0	0.7%	6	24.1%	204	0.0%	0	0.0%	0	10.3%	87	0.7%	6	8.2%	70	8.4%	71	16.9%	143
	P_2O_5	982	2.5%	28.9%	284	0.0%	0	0.4%	4	24.0%	236	0.0%	0	0.0%	0	7.7%	76	0.3%	3	3.1%	30	4.9%	48	30.7%	301
	K_2O	227	0.8%	12.6%	29	0.0%	0	0.2%	0	5.7%	13	0.0%	0	0.0%	0	3.4%	8	0.4%	1	19.8%	45	24.0%	54	33.9%	77
	N+P+K	2,057	1.2%	27.8%	573	0.0%	0	0.5%	10	22.0%	453	0.0%	0	0.0%	0	8.3%	171	0.5%	10	7.0%	145	8.5%	174	25.4%	522
Turkey	N	1,356	1.3%	41.5%	563	0.9%	12	6.8%	92	12.1%	164	0.1%	1	0.0%	0	4.6%	62	5.4%	73	2.0%	27	17.0%	231	9.6%	130
	P_2O_5	516	1.3%	41.7%	215	0.9%	5	4.7%	24	13.1%	68	0.1%	1	0.0%	0	4.4%	23	5.2%	27	3.4%	18	14.4%	74	12.1%	62
	K_2O	109	0.4%	15.2%	17	0.5%	1	6.1%	7	2.9%	3	0.1%	0	0.0%	0	5.4%	6	4.2%	5	13.2%	14	40.4%	44	12.0%	13
	N+P+K	1,981	1.2%	40.1%	794	0.9%	17	6.2%	123	11.9%	235	0.1%	2	0.0%	0	4.6%	91	5.3%	105	3.0%	59	17.6%	349	10.4%	206
Russia	N	1,175	1.2%	42.0%	494	1.2%	14	7.3%	86	22.0%	259	0.4%	5	0.0%	0	2.3%	27	0.0%	0	9.6%	113	1.0%	12	14.2%	167
	P_2O_5	470	1.2%	40.0%	188	1.1%	5	5.5%	26	21.0%	99	1.1%	5	0.0%	0	7.1%	33	0.0%	0	15.0%	71	1.4%	7	7.8%	37
	K_2O	296	1.0%	26.0%	77	0.1%	0	5.7%	17	23.0%	68	0.8%	2	0.0%	0	4.1%	12	0.0%	0	24.0%	71	3.7%	11	12.6%	37
	N+P+K	1,941	1.2%	39.1%	758	1.0%	20	6.6%	128	21.9%	425	0.6%	12	0.0%	0	3.7%	73	0.0%	0	13.1%	254	1.5%	29	12.4%	241

				CEREALS								OILSEEDS													
				Wheat		Rice		Maize		Other CG		Soybean		Oil Palm		Other OS		Cotton		Sugar Crops		Fruits & Veg.		Other Crops	
Malaysia	N	600	0.6%	0.0%	0	15.0%	90	0.5%	3	0.0%	0	0.0%	0	65.0%	390	0.2%	1	0.0%	0	0.3%	2	3.0%	18	16.1%	96
	P_2O_5	250	0.6%	0.0%	0	19.0%	47	0.5%	1	0.0%	0	0.0%	0	55.0%	138	0.2%	1	0.0%	0	0.3%	1	6.0%	15	19.0%	48
	K_2O	1,050	3.6%	0.0%	0	5.0%	53	0.1%	1	0.0%	0	0.0%	0	85.0%	893	0.1%	1	0.0%	0	0.2%	2	2.0%	21	7.7%	80
	N+P+K	1,900	1.1%	0.0%	0	10.0%	190	0.3%	5	0.0%	0	0.0%	0	74.7%	1,420	0.1%	2	0.0%	0	0.2%	5	2.8%	54	11.8%	224
Argentina	N	903	0.9%	37.7%	340	0.6%	5	29.9%	270	5.5%	50	6.6%	60	0.0%	0	3.3%	30	0.6%	5	2.8%	25	6.6%	60	6.4%	58
	P_2O_5	695	1.8%	25.9%	180	0.4%	3	17.3%	120	6.5%	45	34.5%	240	0.0%	0	2.9%	20	0.1%	1	0.1%	1	7.2%	50	5.1%	35
	K_2O	65	0.2%	2.3%	1	3.8%	2	1.5%	1	0.5%	0	2.0%	1	0.0%	0	0.9%	1	0.2%	0	10.8%	7	53.8%	35	24.2%	16
	N+P+K	1,663	1.0%	31.4%	522	0.6%	11	23.5%	391	5.7%	95	18.1%	301	0.0%	0	3.0%	51	0.4%	6	2.0%	33	8.7%	145	6.6%	109
Bangladesh	N	1,240	1.2%	1.1%	14	93.5%	1,159	0.4%	5	0.0%	0	0.0%	0	0.0%	0	0.8%	10	0.2%	2	0.6%	7	1.5%	19	1.9%	24
	P_2O_5	220	0.6%	2.1%	5	78.0%	172	0.4%	1	0.0%	0	0.0%	0	0.0%	0	2.5%	6	0.2%	0	1.5%	3	6.0%	13	9.3%	20
	K_2O	170	0.6%	1.6%	3	80.3%	137	0.4%	1	0.0%	0	0.0%	0	0.0%	0	2.0%	3	0.4%	1	2.0%	3	5.0%	9	8.3%	14
	N+P+K	1,630	1.0%	1.3%	21	90.0%	1,468	0.4%	7	0.0%	0	0.0%	0	0.0%	0	1.2%	19	0.2%	3	0.9%	14	2.5%	40	3.6%	59
Iran	N	1,000	1.0%	36.0%	360	7.5%	75	5.5%	55	8.0%	80	0.2%	2	0.0%	0	4.5%	45	2.0%	20	3.5%	35	15.0%	150	17.8%	178
	P_2O_5	440	1.1%	34.0%	150	5.5%	24	5.0%	22	7.5%	33	0.8%	4	0.0%	0	6.5%	29	1.5%	7	3.5%	15	23.0%	101	12.7%	56
	K_2O	180	0.6%	24.0%	43	4.0%	7	3.5%	6	5.5%	10	0.3%	1	0.0%	0	4.5%	8	1.5%	3	2.5%	5	44.0%	79	10.2%	18
	N+P+K	1,620	1.0%	34.1%	553	6.6%	106	5.1%	83	7.6%	123	0.4%	6	0.0%	0	5.0%	82	1.8%	29	3.4%	55	20.4%	330	15.6%	252
Mexico	N	1,140	1.1%	5.3%	60	0.5%	6	61.3%	699	1.8%	21	0.0%	0	1.2%	14	0.2%	2	0.5%	6	6.1%	70	14.9%	170	8.2%	93
	P_2O_5	250	0.6%	2.9%	7	0.8%	2	40.0%	100	0.8%	2	1.2%	3	4.0%	10	0.2%	1	1.2%	3	8.8%	22	32.0%	80	8.1%	20
	K_2O	220	0.8%	1.2%	3	0.9%	2	9.0%	20	0.0%	0	0.9%	2	4.5%	10	0.0%	0	0.9%	2	27.8%	61	47.1%	104	7.7%	17
	N+P+K	1,610	1.0%	4.4%	70	0.6%	10	50.8%	819	1.4%	23	0.3%	5	2.1%	34	0.2%	3	0.7%	11	9.5%	153	22.0%	353	8.1%	131
Egypt	N	1,250	1.2%	24.0%	300	9.0%	113	27.0%	338	4.5%	56	0.1%	1	0.0%	0	1.0%	13	3.5%	44	4.0%	50	19.0%	238	7.9%	99
	P_2O_5	244	0.6%	14.5%	35	8.5%	21	10.5%	26	2.5%	6	0.2%	0	0.0%	0	1.5%	4	4.5%	11	3.0%	7	45.0%	110	9.8%	24
	K_2O	50	0.2%	20.0%	10	0.0%	0	15.0%	8	2.0%	1	0.1%	0	0.0%	0	0.5%	0	4.0%	2	15.0%	8	35.0%	18	8.4%	4
	N+P+K	1,544	0.9%	22.4%	345	8.6%	133	24.0%	371	4.1%	63	0.1%	2	0.0%	0	1.1%	16	3.7%	57	4.2%	65	23.6%	365	8.2%	127
Thailand	N	872	0.9%	0.0%	0	30.0%	262	7.0%	61	0.5%	4	0.1%	1	3.0%	26	1.0%	9	1.0%	9	5.0%	44	28.0%	244	24.4%	213
	P_2O_5	276	0.7%	0.0%	0	25.0%	69	7.0%	19	0.5%	1	1.0%	3	6.0%	17	1.5%	4	1.0%	3	10.0%	28	30.0%	83	18.0%	50
	K_2O	305	1.1%	0.0%	0	5.0%	15	10.0%	31	0.5%	2	0.1%	0	10.0%	31	1.0%	3	1.0%	3	13.0%	40	36.0%	110	23.4%	71
	N+P+K	1,453	0.9%	0.0%	0	23.8%	346	7.6%	111	0.5%	7	0.3%	4	5.0%	73	1.1%	16	1.0%	15	7.6%	111	30.1%	437	23.0%	334
South Africa	N	439	0.4%	8.0%	35	0.0%	0	41.0%	180	1.6%	7	0.3%	1	0.0%	0	5.7%	25	0.3%	1	13.0%	57	14.0%	61	16.1%	71
	P_2O_5	192	0.5%	10.5%	20	0.0%	0	32.0%	61	1.8%	3	1.5%	3	0.0%	0	7.5%	14	0.6%	1	14.5%	28	15.5%	30	16.1%	31
	K_2O	137	0.5%	2.3%	3	0.0%	0	10.5%	14	0.5%	1	0.6%	1	0.0%	0	1.3%	2	0.2%	0	43.0%	59	28.0%	38	13.6%	19
	N+P+K	768	0.5%	7.6%	58	0.0%	0	33.3%	256	1.5%	11	0.7%	5	0.0%	0	5.4%	41	0.4%	3	18.7%	144	16.9%	130	15.7%	120
Philippines	N	530	0.5%	0.0%	0	40.0%	212	20.0%	106	0.0%	0	0.0%	0	0.5%	3	2.0%	11	0.0%	0	2.0%	11	20.0%	106	15.5%	82
	P_2O_5	120	0.3%	0.0%	0	30.0%	36	12.0%	14	0.0%	0	0.0%	0	0.5%	1	5.0%	6	0.0%	0	6.0%	7	30.0%	36	16.5%	20
	K_2O	115	0.4%	0.0%	0	10.0%	12	5.0%	6	0.0%	0	0.0%	0	3.0%	3	3.0%	3	0.0%	0	15.0%	17	50.0%	58	14.0%	16
	N+P+K	765	0.5%	0.0%	0	33.9%	260	16.5%	126	0.0%	0	0.0%	0	0.9%	7	2.6%	20	0.0%	0	4.6%	35	26.1%	200	15.4%	118
Chile	N	268	0.3%	18.0%	48	0.7%	2	13.0%	35	6.0%	16	0.0%	0	0.0%	0	0.8%	2	0.0%	0	1.6%	4	20.0%	54	39.9%	107
	P_2O_5	163	0.4%	18.5%	30	1.2%	2	7.5%	12	6.0%	10	0.0%	0	0.0%	0	0.6%	1	0.0%	0	1.2%	2	10.0%	16	55.0%	90
	K_2O	92	0.3%	5.7%	5	1.8%	2	8.5%	8	2.0%	2	0.0%	0	0.0%	0	0.5%	0	0.0%	0	5.7%	5	45.0%	41	30.8%	28
	N+P+K	523	0.3%	16.0%	84	1.0%	5	10.5%	55	5.3%	28	0.0%	0	0.0%	0	0.7%	4	0.0%	0	2.2%	11	21.3%	111	43.0%	225
Morocco	N	235	0.2%	32.0%	75	0.4%	1	1.8%	4	22.0%	52	0.0%	0	0.0%	0	1.7%	4	0.0%	0	5.0%	12	18.0%	42	19.1%	45
	P_2O_5	158	0.4%	29.0%	46	0.4%	1	3.9%	6	20.0%	32	0.0%	0	0.0%	0	3.3%	5	0.0%	0	5.6%	9	17.0%	27	20.8%	33
	K_2O	53	0.2%	20.0%	11	0.0%	0	1.2%	1	13.0%	7	0.0%	0	0.0%	0	1.2%	1	0.0%	0	9.0%	5	46.0%	24	9.6%	5
	N+P+K	446	0.3%	29.5%	132	0.4%	2	2.5%	11	20.2%	90	0.0%	0	0.0%	0	2.2%	10	0.0%	0	5.7%	25	21.0%	94	18.6%	83
ROW	N	7,468	7.4%	13.0%	971	14.0%	1,046	13.0%	971	6.0%	448	0.5%	37	0.7%	52	5.0%	373	5.0%	373	5.0%	373	18.0%	1,344	19.8%	1,479
	P_2O_5	3,316	8.4%	10.0%	332	12.0%	398	10.0%	332	6.0%	199	5.0%	166	1.0%	33	5.0%	166	5.0%	166	6.0%	199	20.0%	663	20.0%	663
	K_2O	2,703	9.4%	7.0%	189	12.0%	324	10.0%	270	4.0%	108	3.0%	81	4.0%	108	4.0%	108	3.0%	81	12.0%	324	25.0%	676	16.0%	432
	N+P+K	13,487	8.0%	11.1%	1,492	13.1%	1,768	11.7%	1,573	5.6%	755	2.1%	284	1.4%	194	4.8%	647	4.6%	620	6.6%	897	19.9%	2,683	19.1%	2,574
World	N	100,529	100.0%	17.3%	17,411	15.6%	15,673	16.8%	16,861	5.1%	5,135	1.0%	966	0.8%	834	4.5%	4,521	3.9%	3,955	3.4%	3,420	15.6%	15,680	16.0%	16,074
	P_2O_5	39,324	100.0%	16.2%	6,362	12.3%	4,840	12.4%	4,883	5.1%	2,008	7.5%	2,969	0.8%	331	4.7%	1,857	4.0%	1,563	3.9%	1,545	17.9%	7,028	15.1%	6,100
	K_2O	28,875	100.0%	6.0%	1,741	13.3%	3,832	14.2%	4,087	3.3%	947	8.1%	2,327	5.1%	1,467	3.5%	1,011	2.2%	637	8.8%	2,547	21.5%	6,204	14.1%	4,073
	N+P+K	168,728	100.0%	15.1%	25,514	14.4%	24,345	15.3%	25,832	4.8%	8,091	3.7%	6,261	1.6%	2,632	4.4%	7,389	3.6%	6,156	4.5%	7,512	17.1%	28,912	15.6%	26,248

Source: International Fertilizer Industry Association. AgCom/09/28

Appendix B. Fertilizer Application Rates, 2007/08 (Source: IFA 2009 and Author Calculations)

NITROGEN APPLICATION RATES (KG/HA of nutrients)

	Wheat, All	Corn	Barley	Oats	Rye	Sorghum	Soybeans	Peanut	Rapeseed	Sunflower Seed	Palm Oil	Rice, All	Cotton	Sugar Beet	Sugar Cane
Africa													12		
Algeria	28	17	10												
Argentina	57	79	92			18	4	16		10		30	17		84
Australia	21	87	35			35			68			0	91		183
Bangladesh												104			
Brazil	43	58	4				5					51	215		88
Cambodia												7			
Cameroon												3			
Canada	66	149	60	45			8		71			0	0	41	
China	182	172	80				51	101	169	108		195	222	293	283
Cote d'Ivoire												5			
Egypt	233	469										168		187	234
EU	131	164	98	105	105		34		137	34		110	139	116	183
Ghana												6			
Guinea												14			
Hong Kong												0			
India	110	44				83	17	29	82			100	101		145
Indonesia		121									80	98	130		148
Iran	52											119		124	233
Iraq												49			
Japan	68	16	77				14		118			124	0	145	45
Kazakhstan													87		
Kenya												54			
Malaysia		115									98	138			150
Mali												27			
Mexico	84	95	7			10	0	58				86	52		104
Morocco	29													164	141
Mozambique												5			
Myanmar												7			
Nigeria						1						6			
Pakistan	129	137	40			45						104	180	113	186
Paraguay							3								
Philippines		39										49			27
Russia	20	66	16	17	18								0	103	
Senegal												28			
Sierra Leona												3			
South Africa		55	32			54						0			186
South Korea	59	74					15					127	0		
Taiwan	0	85					0					109	0		
Tanzania												9			
Thailand		61										25			43
Tunisia	34														
Turkey												128	141	90	
U.S.	74	155	67	56		101	4	45	268	47		230	60	148	123
Ukraine	27	73	17	19	18				105	31				100	
Uruguay												65			
Uzbekistan													184		
Vietnam		119										104			
Colombia															70
Cuba															58
Guatemala															76
Peru															69
Venezuela															113
Africa, Other	30	13	13	38	94	1	10	9	21	11	45	1	0	0	29
Americas, Other	46	58	126	129	143	139	17	9	123	17	47	76	21	228	101
Asia, Other	34	55	32	46	14	53	5	42	70	45	32	88	72	124	202
Europe, Other	54	71	27	32	22	0	9	0	11	5	0	69	28	31	0
Oceania, Other	124	141	171	34	43	0	19	13	68	13	59	0	0	0	183
World	80	105	48	53	61	31	11	37	112	28	78	101	120	118	123

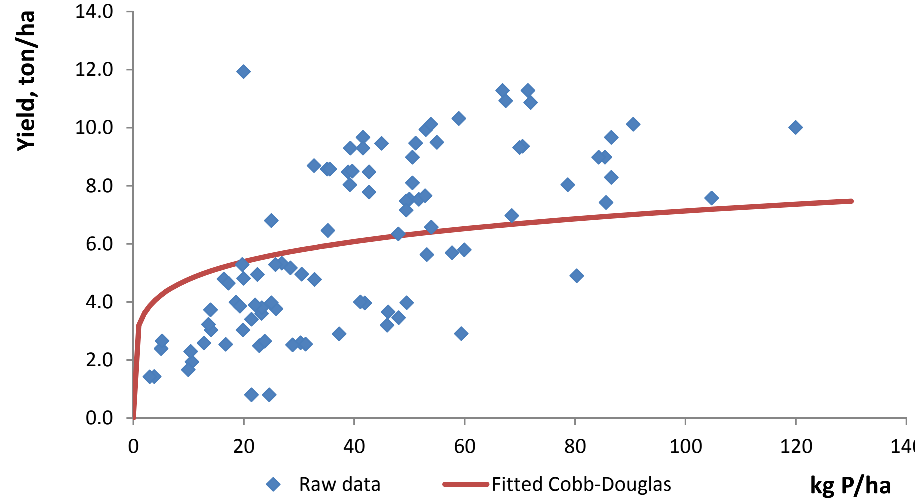
PHOSPHOROUS APPLICATION RATES (KG/HA of nutrients)

	Wheat, All	Corn	Barley	Oats	Rye	Sorghum	Soybeans	Peanut	Rapeseed	Sunflower Seed	Palm Oil	Rice, All	Cotton	Sugar Beet	Sugar Cane
Africa													10		
Algeria	17	25	8												
Argentina	30	35	44			44	15	13		7		15	2		2
Australia	23	58	40			40			59			0	45		80
Bangladesh												15			
Brazil	41	50	26				73					50	149		45
Cambodia												5			
Cameroon												1			
Canada	19	40	19	15			23		16			0	0	18	
China	81	28	35				41	59	55	27		62	79	170	151
Cote d'Ivoire												2			
Egypt	27	36										31		29	33
EU	30	53	34	24	24		30		35	13		41	50	59	80
Ghana												2			
Guinea												10			
Hong Kong												0			
India	41	10				36	16	40	25			33	49		51
Indonesia		24									30	9	77		73
Iran	22											38		63	83
Iraq												21			
Japan	20	5	72				50		216			52	0	267	18
Kazakhstan													54		
Kenya												30			
Malaysia		48									34	73			63
Mali												21			
Mexico	10	14	1			1	48	13				30	27		33
Morocco	18													134	62
Mozambique												3			
Myanmar												3			
Nigeria						0						2			
Pakistan	25	37	8			7						21	33	37	48
Paraguay							11								
Philippines		5										8			18
Russia	8	20	9	2	3								0	64	
Senegal												21			
Sierra Leona												1			
South Africa		19	20			23						0			91
South Korea	17	23					52					53	0		
Taiwan	0	26					0					45	0		
Tanzania												5			
Thailand		19										7			27
Tunisia	21														
Turkey												49	52	58	
U.S.	29	51	16	13		23	17	42	121	11		40	26	53	53
Ukraine	10	22	9	3	3				23	37				95	
Uruguay												59			
Uzbekistan													46		
Vietnam		41										61			
Colombia															70
Cuba															40
Guatemala															61
Peru															69
Venezuela															75
Africa, Other	9	3	14	33	106	0	36	6	27	5	27	1	0	0	24
Americas, Other	13	31	77	50	21	37	62	23	109	16	29	32	3	104	21
Asia, Other	13	17	12	12	2	18	17	13	12	6	19	23	45	34	29
Europe, Other	12	21	15	4	4	0	11	0	10	6	0	29	17	16	0
Oceania, Other	36	43	196	24	30	0	69	23	59	23	36	0	0	0	80
World	29	31	21	16	13	12	33	29	34	14	31	31	47	68	52

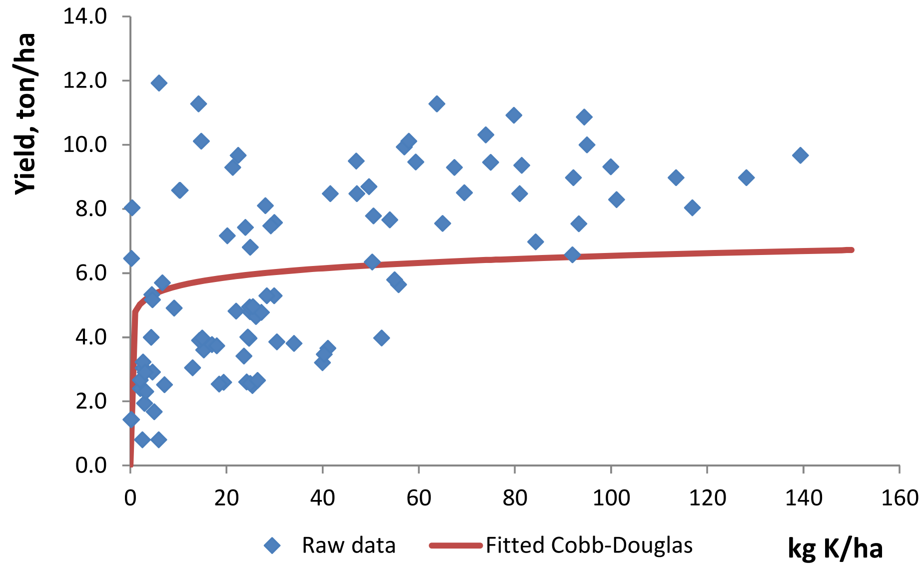
POTASSIUM APPLICATION RATES (KG/HA of nutrients)

	Wheat, All	Corn	Barley	Oats	Rye	Sorghum	Soybeans	Peanut	Rapeseed	Sunflower Seed	Palm Oil	Rice, All	Cotton	Sugar Beet	Sugar Cane
Africa													9		
Algeria	4	3	1												
Argentina	0	0	0			0	0	0		0		13	0		23
Australia	2	7	2			2			6			0	14		118
Bangladesh												12			
Brazil	41	52	22				67					54	143		122
Cambodia												0			
Cameroon												0			
Canada	3	70	2	1			22		14			0	0	93	
China	10	5	25				7	11	14	14		60	13	125	178
Cote d'Ivoire												0			
Egypt	8	10										0		21	40
EU	22	56	28	21	21		34		54	8		73	46	113	118
Ghana												0			
Guinea												8			
Hong Kong												0			
India	8	3				8	3	17	4			21	15		53
Indonesia		26									97	10	43		219
Iran	6											11		10	45
Iraq												20			
Japan	25	5	74				33		107			51	0	132	12
Kazakhstan													29		
Kenya												0			
Malaysia		40									223	81			175
Mali												17			
Mexico	4	3	0			0	31	0				30	18		92
Morocco	4													59	92
Mozambique												0			
Myanmar												0			
Nigeria						0						0			
Pakistan	1	3	0			0						1	1	1	3
Paraguay							0								
Philippines		2										3			44
Russia	3	13	6	1	2								0	65	
Senegal												17			
Sierra Leona												0			
South Africa		4	4			5						0			192
South Korea	22	25					34					52	0		
Taiwan	0	28					0					44	0		
Tanzania												0			
Thailand		31										1			39
Tunisia	5														
Turkey												6	9	48	
U.S.	11	59	4	4		14	26	82	97	13		41	32	76	279
Ukraine	4	14	7	1	2				23	11				110	
Uruguay												19			
Uzbekistan													6		
Vietnam		24										39			
Colombia															70
Cuba															83
Guatemala															38
Peru															69
Venezuela															75
Africa, Other	11	0	3	10	18	0	24	5	3	1	70	1	0	0	19
Americas, Other	17	25	7	0	19	46	40	19	62	16	74	31	1	278	144
Asia, Other	3	18	5	13	2	0	2	5	6	6	49	18	24	35	63
Europe, Other	11	24	10	2	2	0	5	0	3	2	0	28	9	31	0
Oceania, Other	46	47	11	3	4	0	45	3	6	3	91	0	0	0	118
World	8	26	11	7	11	4	26	12	22	6	137	25	19	86	92

Appendix C: Estimated Cobb-Douglas Production Function for Phosphorous and Potassium



Cobb-Douglas Production Function for Phosphorous



Cobb-Douglas Production Function for Potassium

Appendix D: Projected Fertilizer Use for the World, U.S., China, and India in the Period 2011-2025

World Fertilizer Use

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2023	2025
Fertilizer Use													
Corn					(Thousand Metric Tons)								
Nitrogen	16,435	16,735	16,504	16,788	16,829	16,995	17,009	17,043	17,062	17,110	17,125	17,160	17,195
Phosphorous	4,899	5,073	5,023	5,127	5,151	5,215	5,226	5,235	5,233	5,256	5,265	5,281	5,291
Potassium	4,284	4,508	4,511	4,628	4,679	4,770	4,812	4,826	4,822	4,864	4,882	4,915	4,931
Barley													
Nitrogen	2,390	2,450	2,574	2,510	2,554	2,545	2,558	2,552	2,557	2,558	2,554	2,560	2,557
Phosphorous	1,011	1,055	1,135	1,095	1,120	1,119	1,137	1,133	1,132	1,143	1,148	1,155	1,153
Potassium	486	505	536	525	533	535	540	539	540	544	545	546	545
Oats													
Nitrogen	625	650	669	678	668	677	667	675	669	675	672	676	678
Phosphorous	186	196	201	203	199	202	198	201	199	203	204	207	209
Potassium	81	85	87	87	86	87	87	88	88	89	89	91	92
Rye													
Nitrogen	358	406	437	428	450	449	464	463	476	477	488	501	511
Phosphorous	76	87	93	92	96	97	100	100	103	103	106	109	111
Potassium	61	70	75	74	78	78	81	81	83	84	86	89	91
Sorghum													
Nitrogen	1,088	1,146	1,077	1,110	1,071	1,083	1,064	1,071	1,068	1,076	1,076	1,087	1,098
Phosphorous	458	478	453	464	450	455	448	451	450	454	454	460	466
Potassium	183	198	185	194	188	191	188	190	189	190	190	191	193
Wheat, All													
Nitrogen	17,705	17,900	18,314	18,016	18,060	18,044	18,058	18,038	18,016	17,978	17,996	17,913	17,845
Phosphorous	6,416	6,452	6,615	6,409	6,394	6,367	6,364	6,350	6,312	6,304	6,326	6,289	6,254
Potassium	2,159	2,233	2,240	2,180	2,185	2,183	2,188	2,183	2,172	2,167	2,166	2,149	2,114
Soybeans													
Nitrogen	1,438	1,435	1,419	1,414	1,417	1,418	1,423	1,427	1,430	1,432	1,434	1,433	1,434
Phosphorous	4,436	4,444	4,407	4,413	4,441	4,456	4,481	4,500	4,523	4,549	4,579	4,657	4,715
Potassium	4,255	4,240	4,189	4,182	4,199	4,203	4,226	4,240	4,256	4,276	4,301	4,357	4,410
Rapeseed													
Nitrogen	3,592	3,656	3,650	3,659	3,674	3,680	3,692	3,712	3,730	3,746	3,761	3,806	3,834
Phosphorous	1,113	1,164	1,151	1,146	1,148	1,149	1,139	1,142	1,152	1,157	1,151	1,154	1,160
Potassium	689	725	716	714	719	723	723	728	736	742	739	750	759
Sunflower Seed													
Nitrogen	656	669	650	648	647	645	644	643	642	641	639	634	631
Phosphorous	334	342	336	336	336	336	336	337	338	338	338	339	339
Potassium	152	155	152	151	151	151	151	151	151	151	151	151	151
Peanut													
Nitrogen	837	854	865	877	886	898	907	915	922	924	925	925	923
Phosphorous	611	615	619	621	621	622	623	623	622	620	619	613	609
Potassium	247	252	254	255	255	256	257	257	257	257	257	257	257
Palm Kernel													
Nitrogen	1,081	1,140	1,164	1,179	1,203	1,227	1,234	1,236	1,256	1,268	1,274	1,318	1,358
Phosphorous	424	446	454	460	469	478	481	483	490	495	497	515	530
Potassium	1,855	1,945	1,977	1,997	2,035	2,073	2,084	2,080	2,113	2,133	2,144	2,217	2,282
Rice, All													
Nitrogen	15,805	15,603	15,585	15,547	15,569	15,564	15,566	15,566	15,552	15,543	15,535	15,578	15,536
Phosphorous	4,941	4,880	4,875	4,862	4,869	4,867	4,869	4,871	4,868	4,866	4,865	4,881	4,873
Potassium	3,797	3,734	3,726	3,710	3,713	3,709	3,709	3,707	3,702	3,698	3,696	3,704	3,692
Cotton													
Nitrogen	4,012	4,894	5,003	5,007	5,068	5,106	5,129	5,140	5,157	5,169	5,185	5,221	5,248
Phosphorous	1,533	1,689	1,678	1,656	1,661	1,667	1,672	1,674	1,680	1,685	1,694	1,715	1,729
Potassium	653	737	742	726	725	728	727	726	728	730	736	754	762
Sugar Cane													
Nitrogen	2,981	3,063	3,065	3,099	3,126	3,155	3,195	3,240	3,284	3,322	3,351	3,438	3,485
Phosphorous	1,293	1,329	1,331	1,346	1,359	1,373	1,392	1,413	1,434	1,452	1,466	1,509	1,531
Potassium	2,381	2,455	2,458	2,492	2,521	2,553	2,595	2,644	2,692	2,734	2,766	2,868	2,923
Sugar Beet													
Nitrogen	567	588	584	585	587	589	591	593	594	595	595	597	598
Phosphorous	321	332	330	331	332	333	334	335	336	337	337	338	338
Potassium	392	403	398	398	399	400	402	403	403	403	403	402	402
Crops, Other													
Nitrogen	32,141	32,894	33,063	33,059	33,181	33,305	33,362	33,415	33,461	33,507	33,551	33,664	33,703
Phosphorous	13,241	13,496	13,549	13,484	13,524	13,568	13,599	13,620	13,631	13,673	13,714	13,797	13,837
Potassium	10,602	10,885	10,877	10,909	10,985	11,072	11,135	11,168	11,208	11,270	11,315	11,457	11,533
TOTAL													
Nitrogen	101,708	104,081	104,621	104,605	104,990	105,381	105,562	105,729	105,877	106,021	106,161	106,510	106,632
Phosphorous	41,291	42,077	42,251	42,047	42,168	42,305	42,399	42,468	42,504	42,636	42,762	43,017	43,145
Potassium	32,278	33,129	33,123	33,223	33,453	33,713	33,904	34,010	34,139	34,331	34,467	34,899	35,136

* Other crops includes roots and tubers, pulses, nuts, rubber, coffee, tea, tobacco, ornamentals, turf, pasture, and forestry. World total fertilizer use projection of other crops is assumed to increase each year at the same rate as the world total nutrient use of the sum of all modeled commodities.

United States Fertilizer Use

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2023	2025
Fertilizer Use													
Corn					(Thousand Metric Tons)								
Nitrogen	5,100	5,235	5,280	5,421	5,482	5,543	5,539	5,562	5,586	5,596	5,584	5,633	5,663
Phosphorous	2,142	2,202	2,223	2,285	2,315	2,347	2,352	2,365	2,378	2,386	2,383	2,408	2,421
Potassium	2,708	2,798	2,828	2,917	2,969	3,028	3,056	3,085	3,108	3,133	3,135	3,182	3,205
Barley													
Nitrogen	78	67	75	75	74	73	71	71	70	69	68	65	66
Phosphorous	19	16	18	18	18	17	17	17	17	16	16	16	16
Potassium	5	4	4	4	4	4	4	4	4	4	4	4	4
Oats													
Nitrogen	33	32	36	35	35	34	33	33	33	32	32	31	31
Phosphorous	8	7	8	8	8	8	8	8	7	7	7	7	7
Potassium	2	2	2	2	2	2	2	2	2	2	2	2	2
Sorghum													
Nitrogen	173	214	207	215	215	218	216	219	220	219	220	224	230
Phosphorous	69	85	82	85	85	87	86	87	87	87	88	90	92
Potassium	52	62	60	62	62	63	62	63	63	63	63	65	66
Wheat, All													
Nitrogen	1,477	1,521	1,476	1,432	1,447	1,444	1,444	1,437	1,431	1,425	1,416	1,395	1,334
Phosphorous	709	734	705	680	684	683	684	682	677	674	670	662	630
Potassium	647	690	658	635	640	638	640	637	633	630	626	615	583
Soybeans													
Nitrogen	555	549	540	539	539	538	542	544	544	546	547	546	551
Phosphorous	1,630	1,605	1,578	1,571	1,569	1,563	1,571	1,575	1,576	1,578	1,582	1,577	1,590
Potassium	2,401	2,358	2,316	2,300	2,295	2,284	2,295	2,299	2,299	2,300	2,305	2,292	2,308
Rapeseed													
Nitrogen	160	165	168	169	170	170	171	173	175	176	178	186	193
Phosphorous	73	76	77	77	78	78	79	79	80	81	82	85	89
Potassium	57	59	60	60	61	61	61	62	62	63	63	66	69
Sunflower Seed													
Nitrogen	37	37	36	36	36	36	36	36	36	36	36	36	37
Phosphorous	8	9	8	8	8	8	8	8	8	8	8	8	9
Potassium	10	10	10	10	10	10	10	10	10	10	10	10	10
Peanut													
Nitrogen	24	25	26	25	25	25	25	25	25	25	25	25	25
Phosphorous	23	24	24	24	24	24	24	24	24	24	24	24	24
Potassium	43	45	46	45	45	45	45	45	45	45	44	44	44
Rice, All													
Nitrogen	314	258	248	249	248	249	249	245	246	248	253	283	272
Phosphorous	54	44	42	42	42	42	42	42	42	42	43	48	46
Potassium	54	44	43	43	43	43	43	42	42	42	43	48	47
Cotton													
Nitrogen	424	554	588	566	555	549	547	541	536	536	538	546	549
Phosphorous	204	266	283	273	268	267	266	264	263	264	265	269	271
Potassium	229	302	322	311	306	305	305	303	301	301	303	304	303
Sugar Cane													
Nitrogen	41	43	41	39	39	38	38	37	37	37	37	36	36
Phosphorous	18	19	18	17	17	16	16	16	16	16	16	16	16
Potassium	92	97	94	89	87	87	86	85	84	83	83	82	82
Sugar Beet													
Nitrogen	69	68	61	59	59	58	58	58	58	58	58	59	60
Phosphorous	25	24	22	21	21	21	21	21	21	21	21	21	21
Potassium	35	35	31	30	30	30	30	30	30	30	30	30	31
Crops, Other													
Nitrogen	3,361	3,440	3,457	3,457	3,470	3,483	3,489	3,494	3,499	3,504	3,508	3,520	3,524
Phosphorous	889	906	910	905	908	911	913	914	915	918	921	926	929
Potassium	1,138	1,168	1,168	1,171	1,179	1,189	1,195	1,199	1,203	1,210	1,215	1,230	1,238
TOTAL													
Nitrogen	11,846	12,208	12,240	12,319	12,393	12,459	12,459	12,476	12,495	12,507	12,500	12,587	12,572
Phosphorous	5,870	6,017	5,998	6,016	6,046	6,072	6,088	6,102	6,111	6,122	6,125	6,156	6,160
Potassium	7,473	7,675	7,643	7,680	7,733	7,787	7,833	7,864	7,885	7,915	7,926	7,975	7,992

China Fertilizer Use

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2023	2025
Fertilizer Use													
Corn					(Thousand Metric Tons)								
Nitrogen	5,371	5,354	5,261	5,325	5,327	5,395	5,425	5,453	5,479	5,515	5,547	5,583	5,619
Phosphorous	883	887	870	880	881	895	903	907	910	920	928	935	942
Potassium	140	143	140	141	141	145	147	148	148	151	153	155	156
Barley													
Nitrogen	55	56	60	56	58	57	57	57	57	57	57	56	55
Phosphorous	23	22	23	22	23	22	23	22	23	23	23	23	23
Potassium	16	16	17	16	16	16	16	16	16	16	16	16	16
Wheat, All													
Nitrogen	4,416	4,345	4,486	4,392	4,368	4,323	4,319	4,302	4,287	4,239	4,259	4,187	4,182
Phosphorous	1,919	1,899	1,978	1,912	1,906	1,892	1,894	1,884	1,874	1,862	1,876	1,844	1,838
Potassium	248	245	255	247	246	244	245	243	242	240	242	238	237
Soybeans													
Nitrogen	430	428	421	417	416	414	413	411	411	409	407	396	387
Phosphorous	346	343	339	336	335	334	333	331	330	329	327	319	312
Potassium	60	59	58	58	58	57	57	57	57	57	56	55	54
Rapeseed													
Nitrogen	1,217	1,232	1,213	1,207	1,203	1,196	1,189	1,184	1,179	1,173	1,166	1,138	1,113
Phosphorous	393	411	398	397	396	397	389	387	388	386	380	370	361
Potassium	102	107	104	103	103	103	101	101	101	100	99	96	94
Sunflower Seed													
Nitrogen	97	94	90	89	89	89	88	88	87	87	86	83	81
Phosphorous	24	24	23	23	23	22	22	22	22	22	22	21	21
Potassium	13	12	12	12	12	12	12	12	11	11	11	11	11
Peanut													
Nitrogen	476	486	491	500	508	517	523	528	532	531	530	521	513
Phosphorous	265	264	262	262	261	260	259	257	255	252	249	240	232
Potassium	51	51	50	50	50	50	50	49	49	48	48	46	45
Rice, All													
Nitrogen	5,716	5,584	5,569	5,507	5,498	5,466	5,448	5,430	5,403	5,373	5,350	5,301	5,227
Phosphorous	1,836	1,794	1,789	1,769	1,766	1,756	1,750	1,744	1,736	1,726	1,719	1,703	1,679
Potassium	1,726	1,686	1,682	1,663	1,660	1,650	1,645	1,640	1,631	1,622	1,615	1,600	1,578
Cotton													
Nitrogen	1,312	1,889	2,157	2,161	2,196	2,204	2,217	2,219	2,223	2,222	2,220	2,216	2,216
Phosphorous	420	481	489	482	484	486	488	489	490	490	489	488	488
Potassium	69	79	80	79	80	80	80	80	81	81	80	80	80
Sugar Cane													
Nitrogen	504	508	509	511	512	515	517	520	522	524	527	533	537
Phosphorous	269	271	272	273	273	275	276	277	279	280	281	284	287
Potassium	318	321	321	322	323	325	326	328	329	331	332	336	339
Sugar Beet													
Nitrogen	76	86	89	90	90	90	90	90	90	89	89	88	87
Phosphorous	44	50	51	52	52	52	52	52	52	52	52	51	51
Potassium	32	36	38	38	38	38	38	38	38	38	38	37	37
Crops, Other													
Nitrogen	13,047	13,352	13,421	13,419	13,469	13,519	13,543	13,564	13,583	13,601	13,619	13,665	13,681
Phosphorous	5,674	5,784	5,807	5,779	5,796	5,815	5,828	5,837	5,842	5,860	5,877	5,913	5,930
Potassium	3,531	3,625	3,622	3,633	3,658	3,687	3,708	3,719	3,733	3,753	3,768	3,815	3,841
TOTAL													
Nitrogen	32,717	33,413	33,768	33,675	33,734	33,784	33,828	33,846	33,853	33,821	33,857	33,767	33,698
Phosphorous	12,096	12,229	12,301	12,185	12,196	12,206	12,216	12,212	12,200	12,200	12,223	12,190	12,163
Potassium	6,305	6,380	6,379	6,362	6,386	6,408	6,425	6,431	6,436	6,449	6,461	6,487	6,488

India Fertilizer Use

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2023	2025
Fertilizer Use													
Corn						(Thousand Metric Tons)							
Nitrogen	354	369	342	339	329	324	318	315	312	311	309	302	299
Phosphorous	79	82	75	72	68	66	64	64	63	63	63	61	60
Potassium	22	22	19	18	15	14	14	14	13	13	13	13	13
Sorghum													
Nitrogen	578	584	559	562	540	541	528	531	532	538	536	543	548
Phosphorous	251	254	243	244	235	235	229	231	231	234	233	236	238
Potassium	58	59	56	57	54	55	53	54	54	54	54	55	55
Wheat, All													
Nitrogen	3,131	3,105	3,266	3,191	3,221	3,223	3,242	3,252	3,260	3,272	3,284	3,318	3,336
Phosphorous	1,093	1,053	1,088	1,020	1,002	977	959	960	960	964	968	979	984
Potassium	203	196	202	189	186	181	178	178	178	179	180	182	183
Soybeans													
Nitrogen	158	159	158	158	158	159	160	161	162	162	162	162	163
Phosphorous	153	154	153	153	154	155	156	156	157	157	157	158	159
Potassium	28	29	28	28	29	29	29	29	29	29	29	29	29
Rapeseed													
Nitrogen	539	546	560	567	571	575	579	584	590	596	602	620	635
Phosphorous	154	158	159	157	154	152	150	150	152	154	155	160	164
Potassium	23	24	24	24	23	23	23	23	23	23	24	24	25
Peanut													
Nitrogen	176	180	185	187	188	190	192	194	196	197	199	204	208
Phosphorous	241	244	249	251	252	254	256	258	258	259	260	263	265
Potassium	104	105	108	108	109	110	110	111	111	112	112	113	114
Rice, All													
Nitrogen	4,370	4,357	4,355	4,363	4,378	4,385	4,393	4,403	4,412	4,418	4,428	4,463	4,474
Phosphorous	1,444	1,440	1,440	1,442	1,447	1,450	1,452	1,455	1,459	1,461	1,464	1,475	1,479
Potassium	870	868	868	869	872	873	875	877	879	880	882	889	891
Cotton													
Nitrogen	1,063	1,152	980	982	992	1,007	1,011	1,015	1,019	1,023	1,026	1,021	1,023
Phosphorous	532	559	539	534	535	538	540	542	544	546	548	545	546
Potassium	163	171	165	163	164	165	165	166	167	167	168	167	167
Sugar Cane													
Nitrogen	700	730	733	739	742	746	752	758	765	770	774	788	798
Phosphorous	246	257	258	260	261	263	265	267	269	271	273	278	281
Potassium	254	265	266	268	269	271	273	275	278	280	281	286	290
Crops, Other													
Nitrogen	3,703	3,790	3,809	3,809	3,823	3,837	3,844	3,850	3,855	3,860	3,865	3,878	3,883
Phosphorous	1,530	1,560	1,566	1,559	1,563	1,568	1,572	1,574	1,575	1,580	1,585	1,595	1,599
Potassium	905	929	928	931	937	945	950	953	956	962	965	977	984
TOTAL													
Nitrogen	14,770	14,972	14,946	14,897	14,942	14,987	15,018	15,062	15,103	15,146	15,185	15,301	15,366
Phosphorous	5,725	5,761	5,770	5,693	5,672	5,657	5,643	5,657	5,669	5,689	5,706	5,750	5,776
Potassium	2,631	2,667	2,664	2,656	2,659	2,665	2,670	2,679	2,688	2,699	2,708	2,736	2,752

Appendix E: Projected Fertilizer Application Rates for China in the period 2011-2025

China Fertilizer Use

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Rate of Application					(Kilograms per Hectare)											
Corn																
Nitrogen	170.52	171.25	171.12	171.05	171.07	171.45	171.69	171.68	171.55	171.90	172.20	172.15	172.27	172.33	172.40	172.42
Phosphorous	28.04	28.37	28.31	28.28	28.29	28.46	28.57	28.56	28.51	28.67	28.80	28.78	28.84	28.86	28.90	28.90
Potassium	4.43	4.57	4.55	4.53	4.54	4.61	4.65	4.65	4.63	4.69	4.75	4.74	4.77	4.78	4.79	4.80
Barley																
Nitrogen	78.86	78.51	78.10	77.91	77.97	78.01	78.12	78.09	78.15	78.40	78.57	78.67	78.68	78.80	78.86	78.93
Phosphorous	32.31	31.52	30.62	30.21	30.33	30.43	30.65	30.58	30.71	31.25	31.63	31.86	31.87	32.14	32.28	32.45
Potassium	23.08	22.51	21.87	21.58	21.66	21.73	21.89	21.84	21.94	22.32	22.59	22.76	22.77	22.96	23.06	23.18
Wheat, All																
Nitrogen	181.73	181.83	181.98	181.76	181.81	181.86	181.89	181.88	181.83	181.92	181.97	181.97	181.96	181.97	181.96	181.93
Phosphorous	78.98	79.48	80.22	79.12	79.36	79.61	79.75	79.68	79.47	79.88	80.17	80.15	80.13	80.13	80.12	79.97
Potassium	10.20	10.27	10.36	10.22	10.25	10.28	10.30	10.29	10.27	10.32	10.36	10.35	10.35	10.35	10.35	10.33
Soybeans																
Nitrogen	51.15	51.39	51.21	50.97	50.96	51.04	51.00	51.02	51.11	51.16	51.08	51.07	51.07	51.07	51.06	51.05
Phosphorous	41.13	41.19	41.15	41.09	41.09	41.11	41.10	41.10	41.12	41.14	41.12	41.11	41.11	41.11	41.11	41.11
Potassium	7.08	7.09	7.09	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08
Rapeseed																
Nitrogen	168.97	169.65	169.33	169.35	169.39	169.52	169.28	169.25	169.38	169.40	169.20	169.15	169.13	169.12	169.11	169.12
Phosphorous	54.54	56.65	55.61	55.68	55.79	56.21	55.45	55.35	55.77	55.83	55.20	55.03	54.98	54.93	54.90	54.93
Potassium	14.18	14.73	14.45	14.47	14.50	14.61	14.41	14.39	14.50	14.51	14.35	14.30	14.29	14.28	14.27	14.28
Sunflower Seed																
Nitrogen	104.17	103.38	101.95	101.65	101.40	101.23	100.93	100.74	100.66	100.54	100.28	100.24	100.19	100.15	100.09	100.03
Phosphorous	26.33	26.13	25.77	25.69	25.63	25.59	25.51	25.46	25.44	25.41	25.35	25.34	25.32	25.31	25.30	25.28
Potassium	13.69	13.58	13.40	13.36	13.32	13.30	13.26	13.24	13.23	13.21	13.18	13.17	13.16	13.16	13.15	13.14
Peanut																
Nitrogen	108.23	112.04	114.89	117.87	121.09	124.74	127.56	130.40	133.16	135.18	136.57	138.05	139.58	141.18	142.73	144.29
Phosphorous	60.31	60.89	61.31	61.75	62.21	62.72	63.11	63.49	63.86	64.12	64.31	64.50	64.69	64.90	65.09	65.29
Potassium	11.58	11.69	11.77	11.85	11.94	12.04	12.11	12.19	12.26	12.31	12.34	12.38	12.42	12.46	12.49	12.53
Rice, All																
Nitrogen	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34	192.34
Phosphorous	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79	61.79
Potassium	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07	58.07
Cotton																
Nitrogen	257.23	338.71	388.73	396.45	401.68	401.87	401.87	401.87	401.87	401.87	401.87	401.87	401.87	401.87	401.87	401.87
Phosphorous	82.30	86.20	88.10	88.36	88.53	88.54	88.54	88.54	88.54	88.54	88.54	88.54	88.54	88.54	88.54	88.54
Potassium	13.54	14.18	14.50	14.54	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57
Sugar Cane																
Nitrogen	283.40	283.53	283.59	283.72	283.84	283.97	284.07	284.16	284.26	284.32	284.32	284.32	284.33	284.32	284.30	284.28
Phosphorous	151.21	151.28	151.31	151.38	151.45	151.51	151.57	151.61	151.67	151.70	151.70	151.70	151.71	151.70	151.69	151.68
Potassium	178.83	178.91	178.94	179.03	179.10	179.18	179.25	179.30	179.37	179.41	179.41	179.41	179.41	179.41	179.40	179.38
Sugar Beet																
Nitrogen	293.64	293.87	293.94	294.05	294.14	294.23	294.30	294.37	294.45	294.52	294.56	294.58	294.61	294.62	294.63	294.64
Phosphorous	169.84	170.08	170.15	170.27	170.37	170.46	170.53	170.61	170.69	170.76	170.81	170.83	170.86	170.87	170.88	170.89
Potassium	124.79	124.97	125.02	125.11	125.18	125.25	125.30	125.36	125.42	125.47	125.50	125.52	125.54	125.55	125.56	125.56