Forecasting Long-term Global Fertilizer Demand

by

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Contents

Abstract

Long term fertilizer requirement forecasts are key to the success of long term plans for global food security and the profitability of the fertilizer industry. The study forecasts fertilizer demand in relation to soil nutrient status in nine regions. Asia is expected to account for about 40% of the global forecast of 187.7 million Mt in 2015 and 223.1 million Mt in 2030. Sub-Saharan Africa, where soil nutrient depletion is prevalent, will remain the region with the lowest consumption, about 1.1% of global consumption. Soil nutrient drawdown in regions with inadequate fertilizer use indicates soil nutrient depletion which will in the long run exacerbate food shortages and undermine biofuels production plans. Food and fertilizer policy, farmer education, research and technology development, and other actions will be required to counter soil nutrient depletion.

Key words: forecast, fertilizer demand, nutrient buildup, nutrient drawdown, regions

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Introduction

The knowledge of the amount of fertilizer needed to support crop production in the future is important to both public and private organizations with interest in the fertilizer industry. Forecasts of fertilizer demand are necessary for planning future fertilizer plant size. Also, since inappropriate use of fertilizer has negative environmental repercussions, policy makers could use it to better align fertilizer use with projected crop productions.

Nutrient imbalance has become an issue of concern because of increased pressure on food demand and land resources (Grote et al, 2005). In 1997, Vlek et al. estimated annual global plant nutrients removal to be 230 million Mt while global fertilizer consumption was only 130 million Mt, thus resulting in negative nutrient balance. This imbalance varies in different parts of the world due to different fertilizer use and cropping practices. In Sub-Saharan Africa fertilizer application rate is about 9kg/ha, 73kg/ha in Latin America, and over 250kg/ha in Western Europe and U.S. (Molden 2007). These differences have left varying impacts on soil fertility. Because some fertilizer nutrients persist in the soil long after application (e.g. P: phosphate; K: potash), fertilizer demand is affected by whether soil fertility is being built or drawn down. For example, building soil phosphate levels has been a key practice opening large areas in Australia to cropping in the early 20th century and before that in some marginal soils in Europe and North America. Large P and K applications are an essential part of putting new land into crop production in Brazil (Schnepf et al. 2001; Ag Brazil 2003). Some fertilizer industry representatives have argued that a similar program of building soil P and K fertility would revitalize agriculture in certain parts of Asia and Africa (Fairhurst 2002). In Sub-Saharan Africa, continuous cropping with little or no fertilizer application has resulted in soil nutrient depletion, thus further exacerbating food shortages. Fertilizer has a significant role to play in this. Developing countries can mitigate the current food crises with improvement in soil fertility and water management (Molden 2007). Developed countries considering biofuels production will require increased fertilizer to meet both food and fuel needs. The Food and Agriculture Organization (FAO) of United Nations has made crop projections for the years 2015 and 2030, but fertilizer requirement implications of these crop forecasts are lacking. The high food and energy prices have increased the economic penalty for over or under estimating soil nutrients requirements. (Fixen 2008). The goal of this study is to determine fertilizer requirement projection in relation to the status of soil nutrient build up or draw down in nine fertilizer consuming categorized regions.

Studies of fertilizer demand can be traced back to the late 1950s when Griliches (1958; 1959) studied the impact of fertilizer prices, crop prices and regional effects on U.S. fertilizer demand. There have been many other country level studies (e.g. Burrell 1989 for UK and Bonnieux and Rainelli 1987 for France), but only a few global fertilizer demand studies (Heffer and Prud'homme 2005; Isherwood 1998; Bumb and Baanante 1996; Alexandratos 1998; FAO 2000; and Tenkorang 2006). None of these studies estimated regional soil nutrient status in relation with fertilizer forecast. This study is intended to fill that gap.

METHOD

Specifying a forecasting model is always a challenge, especially the model type and relevant variables. The common models are time series models where the forecast is based on past observations of the variable being forecasted. Causal models and qualitative methods have also been used. Causal models such as simple linear regression models are preferable when projections of the exogenous variables are available (Allen and Fildes 2001). Qualitative methods such as expert opinion are popular when insufficient data is available to estimate a model or when there is the need to augment the results of a quantitative method (Parthasarathy 1994; Armstrong 2001). This study uses causal model because it has the potential to estimate changes in soil nutrient status, as well as forecast fertilizer demand. Also projected information on relevant variables such as crop production and cropland are available.

Model

A causal model based on agronomic relationships is used because it facilitates estimation of soil nutrient changes. Tenkorang (2006) made forecasts based on economic optimization assumptions (e.g. profit maximization). Quantity levels in those forecasts are similar, but they are difficult to link to soil nutrient levels.

From a previous study (FAO 2000) the following relationship was established between fertilizer requirement forecast and past fertilizer demand and past and future crop outputs based on agronomic relationships:

$$(1) \qquad F_t = F_{t\text{-}1} + (Y_1 - Y_{t\text{-}1})/(Y_{t\text{-}1}/F_{t\text{-}1})$$

where

- F is unadjusted fertilizer application rate (by nutrient)
- Y is output
- t is a time index

Equation (1) is an accounting identity and cannot be subjected to a regression analysis. The essence of referring to it is to postulate and establish expected relationship between fertilizer demand and crop output to be used in a time series regression model. From equation (1) the relationship expected to exist between current fertilizer consumption and i) previous year's fertilizer consumption is positive; ii) projected crop output is positive; and iii) previous year's crop output is negative. Relationship (i) models the persistence of fertilizer use patterns over time. High fertilizer consuming countries may continue to consume more and consumption rates in low fertilizer use areas tend to change only slowly over time. Relationship (ii) links higher fertilizer to more crop production; and the last relationship reflects the "a good year is followed by a bad year" crop production syndrome in most poor regions. Farmers are therefore not motivated to increase production in the year following a bumper harvest.

In the light of these relationships and on the availability of historical data and future projections of the relevant variables, the following fertilizer demand model is specified:

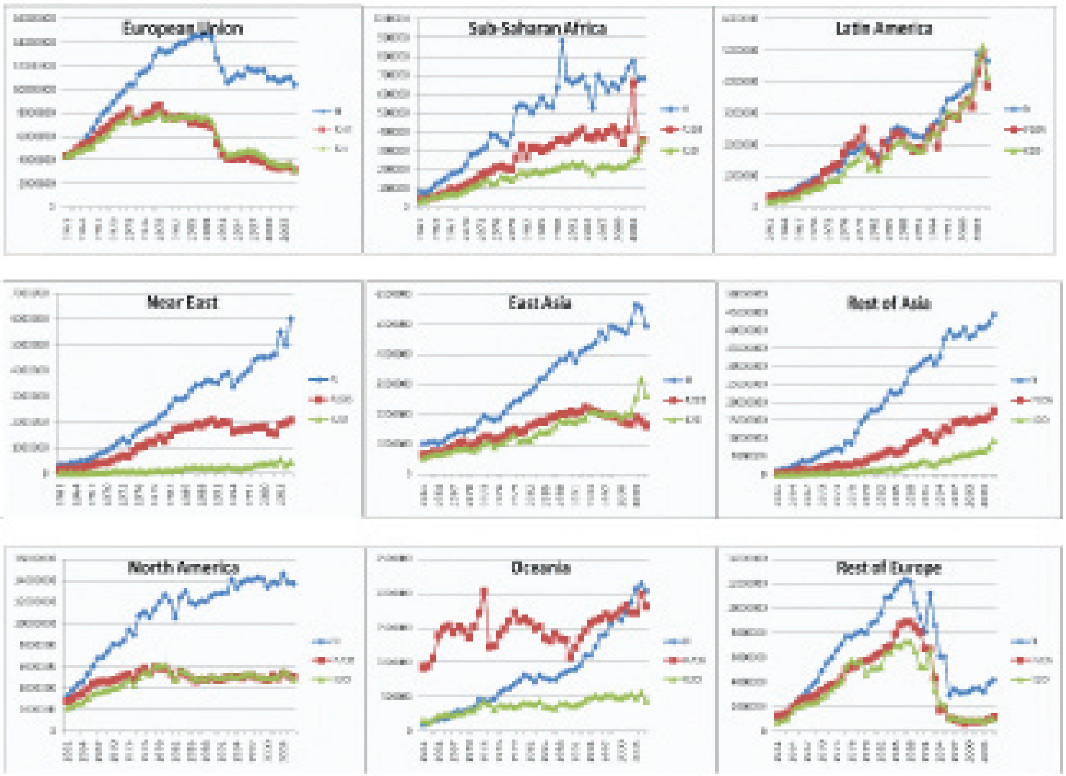
$$(2) \qquad F_{i\,t} = a_{i\,0} + \beta_{i1}\, Y_{i\,t} + \beta_{\,i2} Y_{i\,t-1} + \beta_{\,i3} F_{i\,t-1} + \theta_i\, L_{i\,t} + \gamma_i\, T + \delta_i\, D + \varepsilon_{i\,t}$$

where $F_{i,t}$ is fertilizer nutrients used by a region in year t (i=N,P_2O_5 or K_2O), $Y_{i,t}$ is total crop output of a region in year t, Y_{t-1} is total crop output of a region in year t-1, $L_{i,t}$ is total cultivated land in a region in year t, and D is dummy variable which captures the structural shift in fertilizer consumption that occurred in the late1980s. Only regions where a structural shift is identified in their time series plot will have D in their model. The trend variable (T) is included in a specific region's model if time series plots of its past fertilizer consumption shows a significant trend.

The final model for each region may differ based on the characteristics of their historical data, that is, whether a time trend and/or dummy variable is included. The difference among the regional models occurs because fertilizer consumption patterns differ and no single econometric model is a good fit for all the regions. The goal is to obtain the most accurate fertilizer demand forecast possible.

FIGURE 1

Time series plot of fertilizer nutrients consumption (Mt) by region, 1961-2005



Based on the time series plots (Figure 1) only European Union (EU) and the Rest of Europe (RE) will have a dummy variable in all three nutrient models, which takes values of 1 from 1990 to 2005 for EU, from 1988 to 1995 for RE, and zero otherwise. East Asia will have a dummy varible in only its P model, which takes on values of 1 from 1991 to 2005, and zero otherwise. A trend variable was suggested for all regions, but not included in all final estimates because of multicollinearity. Please see Annex 1 for the list of countries in each regions.

Potential Estimation Problems

The suggested model was influenced by availability of future values of the independent variables to enable forecast of the dependent variable. However, it is subject to many estimation problems. The inclusion of both crop output and land is likely to cause multicollinearity. Although multicollinearity does not affect the BLUE properties of ordinary least squares (OLS) estimator and does not reduce the predictive power of the overall model, it renders the individual coefficients unreliable. The unreliable coefficients will in turn make nutrient drawdown/buildup estimation unreliable. As a result, with the exception of crop output, variables associated with this problem (determined by their variance inflation factor) were removed from the model. A variance inflation factor (VIF) of less than 10 is acceptable (Chatterjee and Price 1991). However, VIF of about 40 does not necessarily undermine the regression analysis and can be tolerated (O'brien 2007). Another potential problem is autocorrelation. Autocorrelation does not make the coefficients unbiased but it renders test of significance unliable due to underestimated standard errors. Durbin Watson statistic (DW) was obtained for final models without a lagged dependent variable, and Durbin's h for final models including a lagged dependent variable. AUTOREG procedue in SAS was used to estimate any model with autocorrelation.

Drawdown and Buildup Equation

Regions with a substantial build up of fertilizer nutrients are expected to have moderate fertilizer demand. The sign of the output coefficient in (2) is useful in estimating buildup/drawdown estimates, but the magnitude of the coefficient varies with the units used and so is difficult to interpret. Converting to elasticity facilitates interpretation because they are unitless. The product of the output coefficient and the ratio of average crop output ($\overline{Y}$) to average fertilizer use ($\overline{F}$) is the elasticity of fertilizer use with respect to output evaluated at the average output and average fertilizer use. This product is the fertilizer build up/draw down elasticity (ε_{i1}):

$$(3)\quad \varepsilon_{i1} = \frac{\partial \ln F}{\partial \ln Y} = \frac{\partial F}{\partial Y} * \frac{\overline{Y}}{\overline{F}} = \%\text{change in } F \text{ due to a 1\% change in } Y$$

$$\text{From equation (2)} \quad \frac{\partial F}{\partial Y} = \beta_{i1}$$

$$\text{hence } \varepsilon_{i1} = \beta_{i1} * \frac{\overline{Y}}{\overline{F}}$$

Elasticities are unitless, so the units of fertilizer and output do not matter in interpretation.

Statistical significance of the elasticities is determined by Z test. The Z statistics are computed by first obtaining the standard errors (SE_ε) of the elasticities (ε_{il}) using the Delta method (Greene 2000). This proceeds as follows:

$$SE_\varepsilon = \frac{\partial \varepsilon_{il}}{\partial \beta_{i1}} * SE_\beta$$

Then the empirical Z* statistic is obtained using the elasticity and its standard error to test the null hypothesis that the drawdown/buildup elasticity is equal to one:

$$Z^* = \frac{\varepsilon_{il} - 1}{SE_\varepsilon}$$

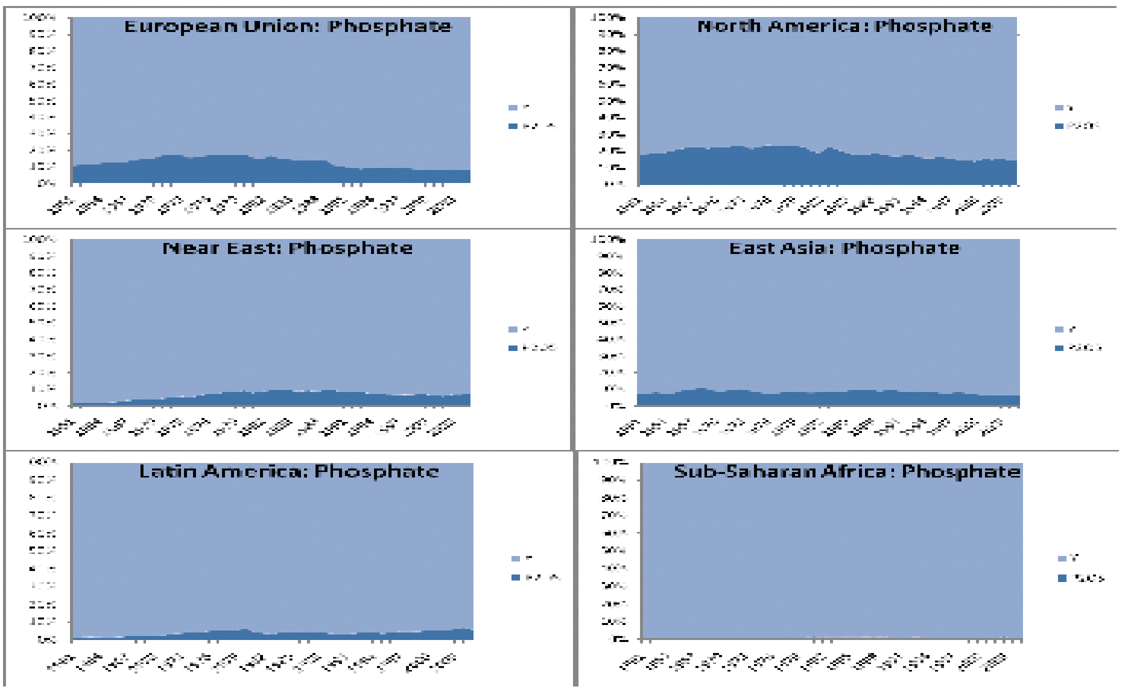
For elasticities less than one, and Z* > Z critical, output increases require less fertilizer than currently used on average, an indication of nutrient drawdown. If it is greater than one, the amount of fertilizer needed for increasing production is greater than currently used per unit of output, an indication of nutrient buildup. Most fertilizer response functions from field experiments show either constant or diminishing returns to inputs. That means in most cases increasing production requires more than a proportional increase in fertilizer. Figure 2 shows time series plots of 100% stacked line of crop output and phosphate use for selected regions (See Annex 2 for more plots). This is the relationship between crop output and phosphate use while holding crop output constant.

From these plots P buildup could be occurring in the Near East between the mid1960s and mid 1980s, while North America and EU could have experienced buildups until the late 1970s and early 1980s, respectively. In sub-Saharan Africa (SSA) phosphate consumption is extremely low relative to crop output, while East Asia's plot is inconclusive.

For a regional study in which land expansion is expected, for instance Latin America, diminishing returns to fertilizer may not be observed. If fertilizer demand does not rise at the same rate as output (i.e. $\varepsilon_{i1} < 1$) then nutrients from other sources may be used. In places where livestock production is important, manure may supply part of the N, P & K. Nitrogen fixation by legumes or by mineralization of soil organic matter is additional source of nitrogen. Plants may draw down the P and K in the soil. In some parts of the world it is more profitable in the short run for farmers to clear new land for agriculture, than it is to apply adequate fertilizer to existing land. In other parts of the world (e.g. Europe) it is common for P & K soil test levels to be substantially above levels required for optimal yields; their drawdown may be a good economic and environmental choice. Thus, the fertilizer-output elasticity may be a rough measure of buildup or drawdown of the soil nutrients, especially in the case of P and K outside of heavy livestock production zones. If the elasticity is substantially less than one then soil P and K may be drawn down to satisfy current production needs. If the elasticity is greater than one, build up may be occurring.

FIGURE 2

100% Stacked line of crop output and phosphate use for selected regions



Data

The study involves 182 countries that have been categorized into nine regional groups based on their fertilizer consumption levels and geographical locations. The regions are North America, Latin America and Caribbean, Sub-Saharan Africa (SSA), Oceania, European Union (EU), the Rest of Europe, Near East, East Asia and the Rest of Asia.

The annual total consumption of each fertilizer nutrient (N, P, and K) in million Mt for each region was obtained from the FAOSTAT website. Crop production is in millions of calories while cropland is in thousands of hectares. The available data period does not include the recent increase in biofuels demand, but it does reflect the economic and food demand growth in the developing world, especially India and China. Data is available from 1961 to 2005.

RESULTS

The initial estimated forecasting models were frosted with multicollinearity (MC). The trend variable (Year), lagged output (Y_{t-1}) and land (L) were the most culprits. The results of the MC corrected models are presented in Annex 3. Any missing independent variable (from equation 2) had a very high variance inflation factor (VIF), mostly over 100. In most cases, removal of independent variables with high VIF reduced the VIF of the remaining independent variables to single digits. In the few cases with double digits VIF, they ranged between 12 and 31.

Most of the R^2 were above 0.9 or close to it except for the P models for SSA, Near East, North America, and Oceania. Output coefficients were significantly different from zero at 10% test level for N models in all regions except SSA and Near East. For the P models, EU, Latin America, and Oceania had insignificant output coefficients at 10%, while North America, Oceania and the Rest of Europe had it for the K models also at 10%.

Fertilizer Buildup and Drawdown

Fertilizer buildup or drawdown is determined using the product of the coefficient of output and output-fertilizer ratio. Table 1 presents the drawdown/buildup elasticity (ε_{i1}) for nitrogen, phosphate and potash by region. This elasticity has been dubbed 'fertilizer nutrient-output elasticity.'

In principle, drawdown or buildup is associated with P and K since they stay in the soil for a long time. For the period under investigation (1961-2005), estimated ε_{i1} suggests that most regions are drawing down soil P and K reserves and organic matter to increase production while a few are just maintaining soil fertility levels. Elasticities for 2005 fertilizer and output levels are reported in Table 1, but elasticities calculated at the mean for the 1961 to 2005 period are similar. Most of the estimated elasticities were less than one in absolute terms. Near East is the only region that seems to be building up P. EU, Latin America, East Asia, North America, and Oceania show elasticities

TABLE 1
Fertilizer Nutrient Buildup or Draw down Elasticities, 2005

Region	N	P	K
EU	0.26*	0.24*	0.53*
SSA	0.15*	0.69	0.15*
Latin America	0.22*	0.11*	0.02*
Near East	0.19*	1.82*	0.70**
East Asia	0.59*	0.82*	0.40*
Rest of Asia	0.86	0.69**	1.22
North America	1.19*	0.26*	0.01*
Oceania	0.21*	0.22*	0.06*
Rest of Europe	0.42*	1.08	0.97

Source: Author's derivation from estimated models
*Elasticity is statistically significantly different from 1 at 5% level, 2-tail z test
** Elasticity is statistically significantly different from 1 at 10% level, 2-tail z test
Alternative hypothesis: Ha: $E > 1$ = > buildup;
$E < 1$ = > draw down

significantly less than one for P and K indicating drawdown. Estimated elasticities that are not statistically different from "1" indicate that soil nutrients may be being maintained in those regions. For potash, the Rest of Asia and the Rest of Europe coefficients are close to one and not statistically significant at any conventional level. For phosphate, the Rest of Europe coefficient is not significantly different from one. The phosphate coefficient for Africa is estimated at 0.69, but is not significantly different from one because of the relatively high variance. It is worth noting that most of these elasticities are very small (less than 0.3) which might have different interpretation for different regions. In the poor regions, it suggests severe nutrient drawdown, but in the advanced regions nutrient use efficiency may be a contributing factor.

Because nitrogen does not carryover from season to season in many climates, the nitrogen fertilizer-output elasticity requires a somewhat different interpretation. All of the elasticities are less than one, except in North America. This suggests that in North America increasing output by 1% requires more than a 1% increase in nitrogen use, while in the rest of the world other sources of nitrogen supply an important part of the nutrient. Although nutrient use efficiency has increased in U.S., drawdown of organic matter by removing or burning crop residues and failing to apply manure may be part of the picture where the elasticity is less than one. The low SSA N elasticity estimate suggest that organic matter draw down may be most serious in SSA.

Fertilizer Requirements for 2015 and 2030

A comparison between the global actual fertilizer nutrients consumption and model estimated consumption (Figure 3) shows the models track historical data well. The mean absolute percentage error (MAPE) for in-sample forecasts (1962-1999) and out-of-sample forecasts (2000-2005) are presented in Table 2. It is worth noting that although in-sample forecasts have the lowest MAPE, it is out-of-sample forecast

FIGURE 3
World fertilizer nutrients (N, P and K): Actual versus in-sample forecast, and 2015 and 2030 fertilizer requirement forecasts

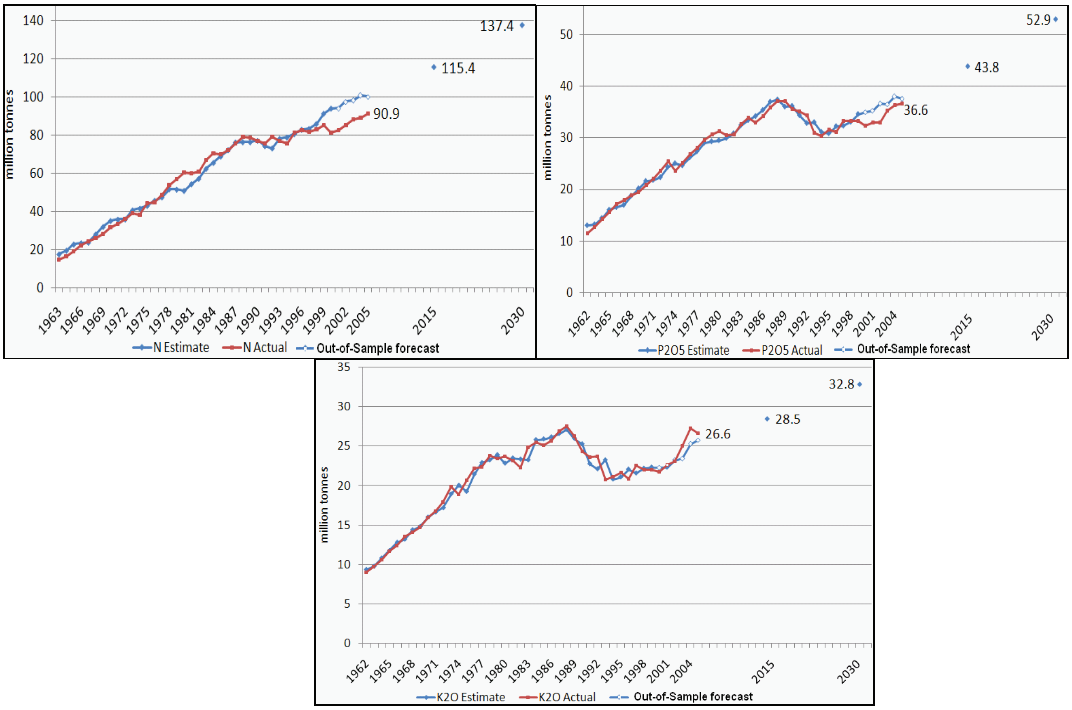


TABLE 2
Forecasting Accuracy Criteria for Total Global Fertilizer Nutrients

	Mean Absolute Percentage Error		
	N	*P*	*K*
In-Sample	7.06	3.39	3.10
Out-of-Sample	12.73	5.90	3.63

that are more informative and reliable. Nitrogen out-of-sample forecast was the least accurate, with MAPE of 12.73 %. The poor performance of the N models is reflected in the big difference between out-of-sample N forecast and actual N used.

Detailed nutrients forecasts by regions for 2015 and 2030 are presented in Table 3. The projected global fertilizer nutrients forecasts are 187.7 million Mt and 223.1 million Mt for 2015 and 2030, respectively. The results show that the Rest of Asia will continue its dominance in fertilizer consumption in the future. It is forecasted to be about 43% of global consumption while North America will account for about 18%. Consumption in EU is expected to be next to that of North America. Total consumption in SSA will remain the lowest in spite of the over 100% expected increase by 2030.

TABLE 3
Annual Fertilizer Nutrients Projections for 2015 and 2030 by Region.

Region	Year	N	P	K	Total
			Million Mt		
EA	2005	4.9	1.6	2.6	9.2
	2015	5.6	1.8	2.6	10.1
	2030	6.6	2.1	2.9	11.5
EU	2005	10.4	3.1	3.2	16.7
	2015	14.9	4.3	5.0	24.2
	2030	15.3	5.2	6.0	26.4
LA	2005	4.7	3.9	4.2	12.7
	2015	5.3	4.4	4.1	13.9
	2030	6.1	5.3	4.1	15.5
NA	2005	13.7	5.0	4.8	23.6
	2015	21.2	6.6	5.2	33.0
	2030	28.1	8.2	5.8	42.0
NE	2005	6.0	2.1	0.4	8.5
	2015	8.4	2.8	0.6	11.8
	2030	11.7	3.4	0.7	15.8
OC	2005	1.8	1.7	0.4	3.9
	2015	2.4	1.9	0.6	4.8
	2030	2.7	1.9	0.7	5.3
RA	2005	44.3	17.6	9.5	71.4
	2015	52.3	20.2	8.7	81.2
	2030	61.0	25.1	10.7	96.8
RE	2005	4.2	1.1	1.0	6.4
	2015	4.4	1.2	1.2	6.7
	2030	4.6	1.1	1.4	7.1
SSA	2005	0.7	0.4	0.4	1.4
	2015	0.9	0.6	0.5	1.9
	2030	1.2	0.8	0.6	2.7
Total	2005	90.7	36.6	26.6	153.8
	2015	115.4	43.8	28.5	187.7
	2030	137.4	52.9	32.8	223.1

Source: 2005 – FAOSTAT database; 2015 and 2030 - Author's computation

The N:P:K ratio remains fairly constant over the projection periods. The ratio, which was 1:0.40:0.29 in 2005 is projected to be 1:0.38:0.25 and 1:0.39:0.24 in 2015 and 2030 respectively. This means slightly more N is expected to be consumed in the future relative to the other nutrients.

The fertilizer requirement forecasts shown in Table 3 were generated by an estimated model using historical fertilizer consumption data. Hence, the fertilizer nutrient draw down identified has an effect on the projected figures if the relationship between regional crop output and fertilizer consumption is maintained in the foreseeable future. Bearing in mind that the FAO crop output projections will not eradicate global hunger, but aim to minimize it, regions with fertilizer nutrient drawdown may need more fertilizer to achieve social and economic goals. In many ways SSA is the worst case scenario, the projected N and K use may need to increase by 85% to restore soil fertility and produce the projected food needs. This confirms IFDC (1992) study that found that doubling West Africa fertilizer application rates will not be enough to offset nutrient deficits.

CONCLUSION

Improved forecasts of fertilizer demand are needed for fertilizer industry planning and government policy decision making. A simple econometric model with fertilizer nutrient demand as a dependent variable, and crop production and other variables as independent variables, was estimated for each of the nine fertilizer consuming regions. Nutrient drawdown and build up elasticities derived from the estimated coefficients showed P and K drawdown in most regions. This is an indication that forecast fertilizer requirement does not keep pace with crop output increases. The estimated N drawdown elasticity indicates that soil organic matter drawdown may be occurring in all regions except North America. While the model does not include the soil nutrients from animal manure or the N fixed by legumes, it provides a preliminary global perspective on the relationship of fertilizer demand and soil fertility maintenance.

The fertilizer demand forecasts indicate that the fertilizer industry can expect a substantial global increase and some changes in fertilizer used. Demand may be even larger if biofuels expansion continues and economic growth in developing countries (particularly India and China) continues. The increase is expected in all regions. The apparent draw down of soil nutrients in most of the world poses an opportunity and a challenge for fertilizer businesses. Is this in part an educational issue? Do growers understand that by drawing down soil stocks of P, K and organic matter they are undermining the long term productivity of their soils? Or is this an economic/ environmental issue? A concerted effort of food and fertilizer policy reform, farmer education and technology development would be needed to reverse the widespread soil nutrient depletion estimated. Grote et al. (2005) have suggested policy measures to ensure global nutrient balance. These measures require both developed and developing countries to play significant roles. They indicate that developed countries need to reduce production subsidies, regulate nutrient disposal, and implement nutrient trading permits. In their view developing countries should increase inputs subsidies, implement credit schemes, and extension and training programs to encourage fertilizer consumption.

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Annex 1
Fertilizer Consuming Countries by Region

Sub Saharan Africa		Latin America		Near East
Angola	Madagascar	Argentina	Haiti	Afghanistan
Benin	Malawi	Bolivia	Honduras	Egypt
Botswana	Mail	Brazil	Jamaica	Iran
Burkina Faso	Mauritania	Chile	Nicaragua	Iraq
Burundi	Mauritius	Colombia	Panama	Israel
Cameroon	Mozambique	Costa Rica	Paraguay	Jordan
Central African Rep.	Nigeria	Cuba	Peru	Lebanon
Cote d'Ivoire	Niger	Dominican Rep.	Surinam	Libya
Chad	Rwanda	Ecuador	Tri. & Tobago	S. Arabia
Congo Rep.	Senegal	El Salvador	Uruguay	Sudan
Eritrea	Sierra Leone	Guatemala	Venezuela	Syria
Ethiopia	Somalia	Guyana		Turkey
Gabon	Swaziland			Yemen
Gambia	Tanzania	**East Asia**	**Rest of Asia_**	Algeria
Ghana	Toto	Indonesia	Bangladesh	Morocco
Guinea	Uganda	Japan	Cambodia	Tunisia
Kenya	Zaire	Malaysia	China	
Lesotho	Zambia	Myanmar	India	**European Union**
Liberia	Zimbabwe	Philippines	North Korea	EU15
		South Korea	Laos	Other W. Europe
North America	**Oceania**	Thailand	Nepal	
Canada	Australia		Pakistan	**Rest of Europe**
Mexico	New Zealand		Sri Lanka	Eastern Europe
USA	South Africa		Viet man	FSU

Source: Tenkorang (2006)

Annex 2

100 % Stacked Line of Crop Output and Fertilizer Use by Region

Source of Data: FAOSTAT

Annex 3

Forecast models Estimates by region

TABLE 3.1

Nitrogen Forecast Model Estimates by Region

Region		Constant	Output *(Y)*	Land *(L)*	Yt_{-1}	Dummy *(D)*	$N\ t_{-1}$	Trend	Model Fit *R^2*	*F Value*	Durbin Stat. *DW/Dh*
European	Coefficient	16700729*	0.076**	-138.78*	0.01	-1496401*	0.80*	MC	0.98	431.1	-0.79^{h}
Union	P-value	(0.0003)	(0.055)	(0.001)	(0.826)	(<.0001)	(<.0001)			(0.0001)	(0.21)
	VIF		2.3	12.5	2.2	6.6	7.9				
Sub Saharan	Coefficient	25759	0.002	MC	MC	NO	0.84*	MC	0.90	187.7	0.79^{h}
Africa	P-value	(0.428)	(0.292)				(<.0001)			(0.0001)	(0.21)
	VIF		3.6				3.6				
[1]Latin	Coefficient	-2.91E+05	0.015**	MC	MC	NO	0.86*	MC	0.98	863.4	0.86^{h}
America	P-value	(0.1701)	(0.082)				(<.0001)			(0.0001)	(0.0001)
	VIF		14.4				14.4				
[1]Near East	Coefficient	-2.62E+05	0.048	MC	MC	NO	0.84*	MC	0.98	847.4	0.65^{h}
	P-value	(0.3384)	(0.197)				(<.0001)			(0.0001)	(0.0001)
	VIF		31.0				31.0				
[1]East Asia	Coefficient	-6.66E+06*	0.119*	97.80*	MC	NO	MC	MC	0.97	830.9	0.58^{W}
	P-value	(<.0001)	(<.0001)	(<.0001)						(0.0001)	
	VIF		15.3	15.3							
[1]North	Coefficient	-6.63E+07*	0.546*	250.29*	MC	NO	MC	MC	0.89	165.7	1.03^{W}
America	P-value	(<.0001)	(<.0001)	(<.0001)						(0.0001)	
	VIF		1.0	1.0							
Oceania	Coefficient	244700	0.038*	-6.26	MC	NO	0.94*	MC	0.98	1205.2	0.48^{h}
	P-value	(0.2593)	(0.015)	(0.161)			(<.0001)			(0.0001)	(0.3136)
	VIF		13.4	7.9			6.7				
[1]Rest of Asia	Coefficient	-95176173*	0.270*	274.38*	MC	NO	MC	MC	0.93	290.7	0.21^{W}
	P-value	(0.0001)	(0.001)	(0.003)						(0.0001)	
	VIF		13.5	13.5							
[1]Rest of	Coefficient	2022896	0.076**	-14.59	MC	-700296	0.91*	MC	0.92	120.9	-1.76^{h}
Europe	P-value	(0.759)	(0.085)	(0.633)		(0.154)	(<.0001)			(0.0001)	(0.0397)
	VIF		2.1	1.7		1.5	1.7				

Source: Author's derivation from estimated models; Sample Size, N = 44 for all regions; P-value in parenthesis

1 - Model estimated by SAS AUTOREG procedure; *Statistically significant at 5% test level; **Statistically significant at 10% level.

Durbin statistic: W - DW; h - Dh; MC = removed because of multicollinearity, NO = not in the original model

TABLE 3.2
Phosphate Forecast Model Estimates by Region

Region		Constant	Output (Y)	Land (L)	Y_{t-1}	Dummy (D)	P_{t-1}	Trend	Model Fit R^2	F value	Durbin Stat. DW/Dh
European Union	Coefficient	3653267	0.021	-8.42	-0.060*	-708609*	0.865*	NO	0.97	269.77	0.53^{h}
	P-value	(0.137)	(0.440)	(0.639)	(0.040)	(0.015)	(<.0001)			(0.0001)	(0.296)
	VIF		1.6	3.6	1.8	8.5	4.7				
[1]Sub Saharan Africa	Coefficient	-11365	0.006*	MC	MC	NO	0.526*	MC	0.77	73.87	-2.15^{h}
	P-value	(0.7162)	(0.0132)				(0.0006)			(0.0001)	(0.0157)
	VIF		4.0				4.0				
Latin America	Coefficient	-2061769*	0.006	22.09**	MC	NO	0.594*	MC	0.91	138.61	0.04^{h}
	P-value	(0.0419)	(0.697)	(0.0976)			(<.0001)			(0.0001)	(0.484)
	VIF		16.0	15.6			7.0				
[1]Near East	Coefficient	5759032*	0.158*	-71.66*	MC	NO	MC	MC	0.81	92.1	8.70^{h}
	P-value	(0.0062)	(<.0001)	(0.0037)							(0.0001)
	VIF		7.0	7.0							
East Asia	Coefficient	26442	0.013*	MC	MC	-151968*	0.884*	MC	0.97	538.87	0.19^{h}
	P-value	(0.5359)	(0.0291)			(0.0004)	(<.0001)			(0.0001)	(0.4254)
	VIF		8.5			2.4	5.6				
[1]North America	Coefficient	-12763882*	0.044*	63.90*	MC	NO	MC	NO	0.33	11.8	0.52^{W}
	P-value	(0.0043)	(0.0054)	(0.0003)						(0.0001)	
	VIF		1.0	1.0							
Oceania	Coefficient	939715	0.038	-10.03	MC	NO	0.643*	NO	0.50	15.54	0.22^{h}
	P-value	(0.1005)	(0.2114)	(0.413)			(<.0001)			(0.0001)	(0.4124)
	VIF		7.9	8.6			1.4				
[1]Rest of Asia	Coefficient	-304206115*	0.086*	50.33*	MC	NO	MC	MC	0.98	588.18	1.03^{W}
	P-value	(0.0003)	(0.0002)	(0.0196)					0.00	(0.0001)	
	VIF		20.5	15.2							
[1]Rest of Europe	Coefficient	3625961	0.053*	-20.70	MC	-1025353*	0.984*	MC	0.97	337.62	-1.86^{h}
	P-value	(0.2631)	(0.0318)	(0.1697)		(0.0002)	(<.0001)			(0.0001)	(0.0316)
	VIF		2.6	1.6		1.6	2.3				

Source: Author's derivation from estimated models; Sample Size, N = 44 for all regions; P-value in parenthesis
1 - Model estimated by SAS AUTOREG procedure; *Statistically significant at 5% test level; **Statistically significant at 10% level.
Durbin statistic: W - DW; h - Dh; MC = removed because of multicollinearity, NO = not in the original model

TABLE 3.3

Potash Forecast Model Estimates by Region

Region		Constant	Output (Y)	Land (L)	Y_{t-1}	Dummy (D)	K_{t-1}	Trend	Model Fit R^2	Model Fit F value	Durbin Stat. DW/Dh
[1]European Union	Coefficient	4847919*	0.047**	-29.23	-0.04334	-937074*	0.83*	NO	0.967	254.06	0.213^h
	P-value	(0.0358)	(0.081)	(0.102)	(0.1234)	(0.0008)	(<.0001)			(0.0001)	(0.0415)
	VIF		1.8	4.1	2.0	8.4	4.8				
Sub Saharan Africa	Coefficient	-2112	0.001**	MC	MC	NO	0.87*	MC	0.92	271.59	-0.128^h
	P-value	(0.8047)	(0.0573)				(<.0001)			(0.0001)	(0.44)
	VIF		3.9				3.9				
Latin America	Coefficient	-513351*	0.022*	MC	MC	NO	0.77*	MC	0.95	433.36	0.864^h
	P-value	(0.0589)	(0.0233)				(<.0001)			(0.0001)	(0.194)
	VIF		9.2				9.2				
[1]Near East	Coefficient	-93046*	0.013*	MC	MC	NO	0.37*	MC	0.875	151.7	4.21^h
	P-value	(0.0045)	(0.0003)				(0.0228)			(0.0001)	(0.0001)
	VIF		7.9				7.9				
East Asia	Coefficient	-95549	0.043*	MC	MC	NO	0.59*	MC	0.945	370.6	1.21^h
	P-value	(0.1647)	(<.0001)				(<.0001)			(0.0001)	(0.114)
	VIF		7.2				7.2				
North America	Coefficient	-1906247	0.002	10.50	MC	NO	0.82*	NO	0.86	92.86	-0.821^h
	P-value	(0.6226)	(0.8935)	(0.4909)			(<.0001)			(0.0001)	(0.251)
	VIF		2.3	1.9			3.1				
[1]Oceania	Coefficient	-132706	0.002	4.13135	MC	NO	0.63*	NO	0.859	88.61	-1.44^h
	P-value	(0.3479)	(0.7452)	(0.176)			(<.0001)			(0.0001)	(0.0741)
	VIF		8.8	9.4			5.7				
[1]Rest of Asia	Coefficient	52444012	0.082*	21.37	MC	NO	MC	-32533	0.94	231.8	0.903^W
	P-value	(0.3269)	(<.0001)	(0.1453)				(0.2484)		(0.0001)	
	VIF		20.5	15.2				16.2			
[1]Rest of Europe	Coefficient	744272	0.044	-7.57	0.00783	-662135**	0.92*	NO	0.908	86.2	-1.89^h
	P-value	(0.8747)	(0.2686)	(0.734)	(0.8442)	(0.0592)	(<.0001)			(0.0001)	(0.0294)
	VIF		3.4	1.7	3.5	1.5	2.5				

Source: Author's derivation from estimated models; Sample Size, N = 44 for all regions; P-value in parenthesis

1 - Model estimated by SAS AUTOREG procedure *Statistically significant at 5% test level; **Statistically significant at 10% level.

Durbin statistic: W - DW; h - Dh; MC = removed because of multicollinearity, NO = not in the original mode