Fertilizer Use by Crop at the Country Level (1990–2010)

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Abstract

We compute the fertilizer use in corn, cotton, soybeans, and rapeseed in the period from 1990 to 2010 for a set of selected countries. In each case, we present the consumption of nitrogen, phosphate, and potash by crop and by year, reporting both the fertilizer application rates (in kilograms per hectare) and the fertilizer consumption (in thousand metric tonnes). We allocate a country's total nutrient consumption in a given year among competing crops based on publicly available statistics. The resulting allocation of fertilizer among crops is a function of the country's nutrients total use, the country's cropped areas, crop world prices, and crop- and country-specific fertilizer application rates for some years. In this report we show results on fertilizer consumption by crop for the top fertilizer consuming countries, and a downloadable MS Excel file "FertilizerDemandByCropData.xls" shows the complete set of results.

Keywords: agriculture, fertilizer, nitrogen, phosphate, potash

JEL codes: Q10, Q12, Q18

Introduction

The use of nutrients in agricultural production has important global consequences both on the availability of food, feed, and fuels, and on the environment. First, crop yields are highly dependent on the amount of fertilizer used during the growing season, and as a result, a driver of the supply of agricultural products. Second, the use of certain fertilizer products (especially nitrogenous and phosphate fertilizers) are a source of pollutants emitted from agricultural fields to the air and waterways.

While there is an increasing interest in analyzing these topics from various angles, there exists very limited statistical information on historical fertilizer consumption by crop, by nutrient, and at the country level. Except for a few exceptions which cover a limited number of years (IFA 2009; FAO 2006; FAO 2002; Rosas 2011), or a single country (USDA-ERS 2012), this type of data is not readily available.

In this study, we compute historical quantities of fertilizer consumption by crop at the country level, and for the three macronutrients (nitrogen, phosphate, and potash). We present a selected number of crops (corn, cotton, rapeseed, and soybeans) in the period from 1990 to 2010 for a list of countries shown in Table 1.

Using data on each country's consumption by nutrient from the International Fertilizer Association (IFA) statistics, and each country's harvested area from the Food and Agriculture Organization of the United Nations (FAO) and from the U.S. Department of Agriculture Foreign Agricultural Service (USDA-FAS), we calculate the growth in the nutrient's use that is not due to area change (i.e., the growth rate of the country's application rate per hectare for each year). Then, a growth rate that is crop-specific is obtained using historical crop prices. The growth rate is then applied to the 2007 nutrient's application rate of each crop from the WorldNPK model (Rosas 2011) or from other trustable sources (such as FAO). Using this top-down approach guarantees data consistent with the total fertilizer consumption of each listed country.

The fertilizer rates presented here cover the years 1990 to 2010, and focus on the nutrients nitrogen, phosphate, and potash, as applied to corn, soybean, cotton, and rapeseed. The most relevant producing countries for each crop are also noted.

To estimate the fertilizer application rates with the required coverage (of nutrients, crops, countries, and years), we use historical data on use of fertilizers by each country, fertilizer application rates by crop for selected years, harvested areas by crop and country, and crop prices.

Methods

For each year between 1990 and 2010, we calculate the quantity of macronutrients (nitrogen, phosphate, and potash) used in each crop in a given country, such that the aggregation of uses over all the crops is consistent with the total use of nutrients in that country.

We start by noting that the country's total consumption of a given nutrient in each year is equal to the fertilizer application rate times the crop's area, and aggregated over the crops—that is,

$$F_{it} = \sum_j A_{ijt} r_{ijt}, \tag{1}$$

where F_{it} is the total nutrient consumption in country i and time t, A_{ijt} is the area of crop j in the same country and time, and r_{ijt} is the nutrient application rate per hectare used in crop j.

Because we seek to calculate historical values of fertilizer consumption by crop (with t between 1990 and 2010), the values of F_{it} and A_{ijt}, for all periods, countries, and crops are observed and available for this study. However, the values of r_{ijt} are not known for most of the time periods and are, therefore, quantities we seek to compute.

We rewrite equation (1) by substituting r_{ijt} by $r_{ijt} = r_{ij,t-1}(1 + \alpha_{ij,t-1})$; that is, the time-t application rate can be calculated as the previous period rate times a growth factor—a growth coefficient that is country-, crop-, and time-specific:

$$F_{it} = \sum_j A_{ijt} r_{ij,t-1}(1 + \alpha_{ij,t-1}). \qquad (2)$$

The problem becomes finding the growth rate so that, for each country and time, equation (2) holds true.

Because the value of r_{ijt} is known for at least one year in the period of interest, we use this approach to calculate the rest of the time series using data on observed crop areas, total consumption of nutrients, the previous year's application rate, and the growth factor of the application rate.

Besides being a function of the variables mentioned in the previous paragraph, we assume the fertilizer application growth factor ($\alpha_{ij,t-1}$) to be a function of the crop expected own-price—because it is likely that farmers will increase (decrease) the fertilization rates when expecting higher (lower) prices for the harvesting season. Farmers base their fertilizer application decision, among other factors, on the expected relative crop prices at the moment of deciding how much to apply. We assume a price expectation structure in which the relevant expected crop price is approximated by the previous period spot price—that is, $E(p_{jt}) = p_{j,t-1}$.[1] We use a world price that is regarded as a benchmark for each crop. Table 2 shows the list of prices used.

We explicitly solve for a deterministic period *t* growth factor that when multiplied to the period *t*-1 fertilizer application rate and the period *t* crop areas, and aggregated across the country's crops, results in the total observed fertilizer demand of that country in *t*. While in each case it is possible to obtain more than one growth factor that satisfies this condition, we solve for the one that is proportional to the expected prices rate of change (applying the same proportion for all the crops in a given country and year), such that the resulting fertilizer application rates aggregate to the total use in the country in *t*.

Incorporating own-crop prices into the growth factor allows us to compute per hectare fertilizer application rates, which in each year and country grow at different rates. Note that this approach is sensible to the set of world crop prices used and, as a result, the calculated application rates (and fertilizer demand) are regarded as an informed approximation to the actual quantities applied in the field.

Data

Computing fertilizer application rates by crop and by country requires the use of several sources of data. Below we list those used in this analysis:

1. "Fertilizer Consumption by Nutrient," International Fertilizer Industry Association (hereafter IFA 1012)
2. "Assessment of Fertilizer Use by Crop at the Global Level 2006/07 – 2007/08," International Fertilizer Industry Association, April 2009 (hereafter IFA 2009)

[1] A common assumption is to consider that farmers look at futures market to form their price expectations. The lack of future markets for some of the treated crops, the variety of countries considered, and the different growing seasons in diverse regions prevent us from using this alternative approach.

3. “World Fertilizer Model –The WorldNPK Model” 2011. Francisco Rosas.
4. “Fertilizers Europe data base on nutrient application rate by crop”. Fertilizers Europe 2010
5. “Fertilizer Use and Price.” USDA – ERS (hereafter USDA-ERS 2012)
6. “Fertilizer Use by Crop.” FAO 2006 (hereafter FAO 2006)
7. “Fertilizer Use by Crop.” FAO 2002 (hereafter FAO 2002)
8. “Fertilizer Use by Crop for Specific Countries” FAO 2002-2005 (hereafter FAO 2002-2005)
9. “Fertilizer Consumption by country” FAOSTAT (hereafter FAO 2012a)
10. “Harvested area by crop,” Production, Supply and Distribution Online, USDA – FAS (hereafter PSD 2012)
11. “Harvested area by crop,” FAOSTAT (hereafter FAO 2012b)
12. “Harvested area by crop,” EUROSTAT (EUROSTAT 2012)

While the focus of this study is on corn, cotton, rapeseed, and soybeans, we include for each country other crops that compete for the total agricultural area and are users of fertilizer products. These crops are: barley, oats, oil palm, peanuts, rice, rye, sorghum, sugar beet, sugar cane, sunflower, wheat, and an aggregated category representing other crops. The “Other crops” category includes fruits and vegetables, industrial crops, sugar crops, roots and tubers, other cereals, other oilseeds, pasture land, and managed forest. The inclusion of most of the competing crops in a given country considerably improves the accuracy of the results.

The crop-specific prices that enter the function of the growth factor, and are considered a benchmark for the crops above, are listed and described in Table 2.

Results

We present the complete set of results in the file “FertilizerDemandDataByCountry.xls” that accompanies this report. It is available for downloading at: http://www.card.iastate.edu/publications/synopsis.aspx?id=1178. For each nitrogen (N), phosphate (P_2O_5), and potash (K_2O) we show the total demand by crop, country, and year, as well as fertilizer application rates by crop, country, and year. Total demand of nutrients is defined as crop area multiplied by fertilizer application rate, and is expressed in thousand metric tons (MT). Application rates are expressed in kilograms per hectare (Kg/ha). In this report, we also summarize the main results by presenting the fertilizer demand of some key fertilizer consuming countries for each crop for the period 1995 to 2010.

Table 3 shows the top five countries in N, P_2O_5, and K_2O demand in corn (the United States, China, European Union, Brazil, and Mexico). The United States and China dominate the use of N and P_2O_5 in corn due to large harvested areas, as well as high fertilizer application rates. In the case of K_2O, the United States and Brazil are the most important players, with the latter being characterized by high per hectare application rates.

Soybeans typically require low N application rates, which translates to lower use of this nutrient relative to P_2O_5 and K_2O. As shown in Table 4, Brazil is the country that uses more P_2O_5 and K_2O in soybean production because it not only has extended crop areas but also it requires high quantities of nutrients per hectare.

China and India are the two most important players in cotton production, and as Table 5 shows, this translates into high use of nutrients on cotton crop. While India is the country with the largest harvested area of cotton, China employs fertilizing practices that are more intensive than India's, and as a result, China consumes more N and P_2O_5 than India. India, however, applies a relatively high K_2O rate per hectare, making it the main country in K_2O consumption in cotton production.

Finally, Table 6 shows fertilizer use in rapeseed. China, Canada, the European Union, and India not only are the main world producers, but also have similar-sized crop areas. Therefore, their difference in total use of nutrients is driven by the fertilizer application rates. China is the main consuming country of N and P_2O_5, and the European Union uses more K_2O.

Conclusion

This report documents the methodology used to calculate fertilizer demand by crop, by nutrient, by country, and by year. An MS Excel file "FertilizerDemandByCropData.xls" accompanies this report (and is available for downloading at: http://www.card.iastate.edu/publications/synopsis.aspx?id=1178. It contains results for a selected set of countries (listed in Table 1) and crops (corn, cotton, soybeans, and rapeseed) that are the focus of this study. In each case, we compute the demand of nitrogen, phosphate, and potash in the period from 1990 to 2010, as well as the corresponding fertilizer application rates.

We employ an approach that allocates a country's total nutrient consumption in a given year among competing crops. Based on publicly available statistics of cropped areas, a country's nutrients use, crop prices, and crop- and country-specific fertilizer application rates for some years, we compute a crop- and country-specific growth factor of application rates that is consistent with the total consumption of the nutrient in each country and year.

To our knowledge, there are no antecedents of the data reported in this analysis, or at least none available for public access. Therefore, we contribute to the research and business community with relevant fertilizer statistics.

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Table 1. Crop and country coverage

Corn		Cotton	Rapeseed	Soybeans
Argentina	Kenya	Argentina	Australia	Argentina
Australia	Lao	Australia	Canada	Bolivia
Austria	Lebanon	Azerbaijan	Chile	Brazil
Azerbaijan	Lithuania	Bangladesh	China	Canada
Bangladesh	Malawi	Brazil	Croatia	China
Belgium	Malaysia	China	Czech Republic	Colombia
Brazil	Mexico	Colombia	Estonia	Croatia
Bulgaria	Myanmar	Costa Rica	EU-27	Ecuador
Cambodia	Netherlands	Ecuador	India	Egypt
Canada	New Zealand	Egypt	Japan	EU-27
Chile	Nicaragua	EU-27	Lithuania	Guatemala
China	Pakistan	Ghana	New Zealand	Honduras
Colombia	Paraguay	Guatemala	Poland	Hungary
Costa Rica	Philippines	India	Romania	India
Croatia	Poland	Israel	USA	Indonesia
Czech Republic	Portugal	Kazakhstan		Japan
DPR Korea	Rep. Moldova	Madagascar		Mexico
Dominican Republic	Russian Federation	Mexico		Nicaragua
Ecuador	Romania	Pakistan		Paraguay
Egypt	Slovakia	Paraguay		Philippines
El Salvador	South Africa	South Africa		Romania
Ethiopia	Spain	Sudan		Rep. Moldova
EU-27	Switzerland	Syria		South Africa
France	Syria	Togo		Thailand
Germany	Thailand	Turkey		Turkey
Greece	Togo	Tanzania		USA
Guatemala	Turkey	USA		Uruguay
Guinea	Ukraine	Uzbekistan		Venezuela
Honduras	Tanzania	Venezuela		Viet Nam
Hungary	USA	Zimbabwe		Zambia
India	Uruguay			
Indonesia	Venezuela			
Israel	Viet Nam			
Italy	Zambia			
Japan	Zimbabwe			

Table 2. World benchmark prices by crop

Crop	World Price
Barley	Barley, No. 1 feed, WCE, cash, I/S Lethbridge, Canada
Corn	Corn, No. 2, Yellow, Gulf ports, Louisiana Gulf, barge delivered
Cotton	Cotton, Cotlook A Index *
Oats	Oats, US No. 2 Heavy. CBoT nearby futures
Palm Oil	Rotterdam Price (C.I.F., EU)
Peanut	Peanuts Price: US Runners 40/50, CIF Rotterdam
Rapeseed	Rapeseed Hamburg Price (C.I.F., EU)
Rice	Rice 100% Long Grain, Thailand Price
Rye	Canada Price
Sorghum	Sorghum, No. 2, Yellow, Gulf ports, Louisiana Gulf, barge delivered
Soybeans	Soybean Rotterdam Price (C.I.F., EU)
Sugar Beet	Caribbean Price (F.O.B.)
Sugar Cane	Caribbean Price (F.O.B.)
Sunflower Seed	Sunflower seed, Rotterdam (C.I.F., EU)
Wheat	Wheat, No.2 HRW Ordinary Protein
Other Crops	Average of the following world prices: fruits (oranges and bananas), crops (corn), pasture (beef) and industrial corps (coffee)

* The "A" index is the average of the five lowest CIF Northern European quotes of the following descriptions (Middling 1-3/32"): Memphis; Calif./Ariz.; Mexican; Central American; Paraguayan; Turkish Izmir/Antalya; Central Asian; Pakistani 1503; Indian H-4; Chinese 329; African "Franc Zone"; Tanzanian; Greek; and Australian.

Table 3. Fertilizer use in corn for selected countries (thousand MT of nutrient)

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Brazil	N	352	506	424	475	490	673	587	620	814	766	667	675	856	823	665	727
China	N	3,232	4,598	3,380	3,270	3,437	3,138	3,432	3,798	3,886	4,588	4,102	4,862	5,056	5,002	4,361	4,603
Mexico	N	696	884	805	880	849	910	898	719	806	826	710	687	699	633	580	640
United States	N	3,670	4,226	4,174	4,223	4,100	4,309	3,750	4,070	4,134	4,053	4,441	4,993	5,854	5,242	5,444	4,936
EU-27	N	988	1,410	1,151	1,018	1,049	1,022	1,059	914	1,050	1,131	850	814	1,005	866	749	907
Brazil	P_2O_5	420	591	456	505	463	648	608	643	702	691	510	649	732	590	519	521
China	P_2O_5	510	640	578	567	533	495	557	595	628	760	649	766	840	747	675	811
Egypt	P_2O_5	62	130	89	93	94	104	127	92	109	134	105	104	100	71	86	98
United States	P_2O_5	1,320	1,571	1,553	1,452	1,393	1,548	1,370	1,467	1,476	1,444	1,575	1,695	1,940	1,348	1,755	1,701
EU-27	P_2O_5	367	515	409	351	346	326	331	288	327	373	273	246	312	211	187	213
Brazil	K_2O	381	546	414	427	395	580	568	581	753	659	525	578	772	669	462	557
China	K_2O	60	73	75	74	70	70	95	97	116	151	113	128	136	104	75	97
Egypt	K_2O	6	19	21	18	16	21	21	19	25	32	20	20	20	13	16	17
United States	K_2O	1,589	1,870	1,892	1,753	1,707	1,686	1,666	1,788	1,722	1,848	1,830	1,978	2,243	1,457	2,026	1,752
EU-27	K_2O	420	585	484	397	380	363	369	319	361	408	282	263	338	228	176	238

Note: N = nitrogen; P_2O_5 = phosphate; K_2O = potash

Table 4. Fertilizer use in soybeans for selected countries (thousand MT of nutrient)

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Argentina	N	8	9	13	14	14	19	22	24	38	51	44	50	60	44	55	71
Brazil	N	22	27	44	42	45	61	63	68	123	145	118	87	107	128	118	135
China	N	303	292	349	302	299	347	349	342	444	559	491	454	448	534	433	440
India	N	58	64	87	89	80	84	90	78	113	167	141	138	146	178	155	181
United States	N	135	102	154	123	122	140	170	136	197	194	136	96	69	93	94	130
Argentina	P_2O_5	35	45	65	77	80	89	88	95	148	213	201	198	240	181	207	269
Brazil	P_2O_5	408	484	739	686	662	912	1,006	1,088	1,653	2,033	1,401	1,301	1,551	1,556	1,553	1,633
China	P_2O_5	257	218	320	281	249	294	304	287	385	497	417	384	360	386	325	375
India	P_2O_5	42	46	78	79	82	80	85	74	102	160	143	139	143	198	190	227
United States	P_2O_5	326	346	432	362	387	372	484	412	597	592	437	352	248	258	328	428
Argentina	K_2O	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1
Brazil	K_2O	383	463	695	601	587	848	974	1,019	1,837	2,010	1,497	1,201	1,424	1,535	1,202	1,518
China	K_2O	28	23	38	33	29	38	47	43	65	90	66	58	62	57	38	47
India	K_2O	7	7	11	10	11	12	14	12	17	32	27	23	27	43	38	38
United States	K_2O	584	649	896	688	706	663	669	835	1,181	919	656	666	464	452	613	834

Note: N = nitrogen; P_2O_5 = phosphate; K_2O = potash

Table 5. Fertilizer use in cotton for selected countries (thousand MT of nutrient)

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Brazil	N	124	73	128	104	120	163	138	93	224	266	145	170	231	159	144	347
China	N	1,464	1,005	930	854	704	745	982	703	1,021	1,426	1,023	1,228	1,376	1,147	871	1,200
India	N	1,066	860	934	959	859	831	992	575	737	1,037	817	895	951	792	812	1,365
Pakistan	N	541	447	478	443	457	471	530	359	483	663	524	498	541	434	468	670
United States	N	583	434	444	329	429	420	373	197	398	457	317	342	377	236	251	325
Brazil	P_2O_5	129	74	119	96	99	136	124	84	168	208	96	142	161	93	91	202
China	P_2O_5	533	323	367	342	252	271	368	254	381	545	374	446	490	367	289	453
India	P_2O_5	378	302	409	416	432	388	453	267	323	485	405	440	463	437	494	852
Pakistan	P_2O_5	117	82	110	85	106	122	125	84	105	172	151	156	99	80	98	139
United States	P_2O_5	170	149	185	148	170	167	125	57	164	188	137	141	131	64	85	119
Brazil	K_2O	131	77	122	91	95	137	130	85	202	223	111	142	155	96	74	196
China	K_2O	60	36	46	43	32	37	60	40	68	104	62	71	81	52	33	55
India	K_2O	109	76	101	95	104	102	128	76	95	166	134	128	142	156	162	235
Pakistan	K_2O	3	1	2	2	2	2	2	1	2	3	2	3	3	2	2	5
United States	K_2O	144	177	242	180	244	226	189	88	220	276	195	202	166	75	107	161

Note: N = nitrogen; P_2O_5 = phosphate; K_2O = potash

Table 6. Fertilizer use in rapeseed for selected countries (thousand MT of nutrient)

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	N	30	34	64	126	185	116	113	103	101	144	84	88	87	122	77	129
Canada	N	310	178	282	328	325	243	195	217	281	324	296	359	444	457	380	560
China	N	896	769	747	791	774	762	786	904	1,095	1,240	1,050	974	953	1,332	945	1,096
India	N	341	320	361	397	302	248	299	242	473	549	473	472	469	636	430	588
United States	N	29	18	37	67	55	62	80	62	74	55	51	58	55	57	37	94
EU-27	N	577	455	532	626	714	509	526	513	653	728	600	712	937	897	666	1,012
Australia	P_2O_5	33	32	66	105	144	104	100	86	85	117	69	76	76	92	43	83
Canada	P_2O_5	85	49	80	87	82	61	50	54	75	81	66	79	99	97	79	122
China	P_2O_5	299	226	270	290	254	255	270	299	374	435	351	324	308	387	285	376
India	P_2O_5	84	78	110	120	106	81	95	78	145	179	164	162	144	221	165	231
United States	P_2O_5	7	4	8	13	12	14	20	13	16	12	12	13	12	9	8	18
EU-27	P_2O_5	159	123	140	160	175	121	122	120	151	178	143	160	216	162	124	176
Australia	K_2O	3	3	7	10	13	10	10	8	11	14	7	8	8	13	5	7
Canada	K_2O	75	41	70	78	69	53	44	46	66	71	42	79	86	53	59	79
China	K_2O	52	38	52	56	49	53	68	72	102	127	90	80	80	86	51	72
India	K_2O	12	10	14	14	13	11	13	11	21	31	27	24	22	39	27	32
United States	K_2O	9	6	9	16	13	19	21	14	16	13	13	14	13	9	8	20
EU-27	K_2O	280	216	256	279	296	207	210	205	257	301	228	264	360	270	179	304

Note: N = nitrogen; P_2O_5 = phosphate; K_2O = potash