3.1 Nutrients

Commercial fertilizer use has declined from its peak in 1981 because of fewer planted acres and stable or falling application rates. Fertilizer prices paid by farmers had been relatively stable since 1989 but increased in 1994 over 1993. Farmers' adoption of improved nutrient practices reduces water quality problems related to fertilizer use.

During the early settlement of the United States, farmers used soils rich in nutrients deposited by the forest ecosystem. Because labor was scarce and new land was plentiful, farmers made little effort to replenish the soil nutrients being removed. Increased demand for agricultural commodities, generated by an expanding population and economic development of east coast cities during the 19th century, encouraged soil nutrient replacement. First, manure and other farm refuse were applied to the soils. Later, applications of manure were supplemented with fish, seaweed, peatmoss, leaves, straw, leached ashes, bonemeal, and Peruvian guano, materials that contained a higher percentage of nitrogen, phosphate, and potash than did manure (Wines, 1985). As manufacturing developed, production of chemical fertilizers like superphosphates and, later, urea and anhydrous ammonia replaced most fertilizers produced from recycled wastes. These commercial products could be transported economically and contained more nutrients per unit at competitive prices. Commercial fertilizers provided low-cost nutrients to support the high yielding potential of newly developed crop varieties and hybrids (Ibach and Williams, 1971). Corn and wheat yields, for example, increased from an average of 55 and 26 bushels per acre in 1960 to 131 and 39 bushels in 1992 (fig. 3.1.1).

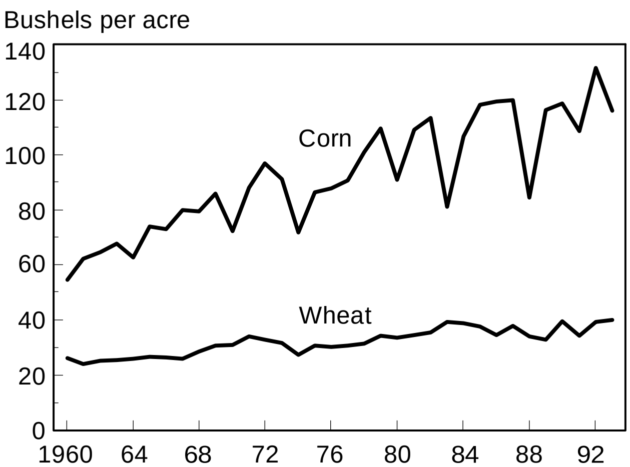
In recent years, commercial fertilizer (including chemical and natural processed and dried organic materials) has provided 65-78 percent of the total nutrients available for crop production, with the balance coming from animal waste (fig. 3.1.2). Use of animal waste as fertilizer is economically feasible only if onfarm or nearby sources exist. Recent survey data indicate that manure is applied to only 16-18 percent of corn acreage and 3-6 percent of soybeans, cotton, and wheat (USDA, 1993).

Environmental degradation, particularly of water, can occur from excessive use or improper handling or application of nutrients (see module 2.2). Large livestock operations are already under regulation as point sources of pollution, requiring installation of certain facilities and practices. In many critical areas, USDA is helping smaller livestock operations efficiently manage animal and commercial nutrients to avoid loss to the environment (see module 6.5).

Fertilizer Use Stable From 1986 Through 1993

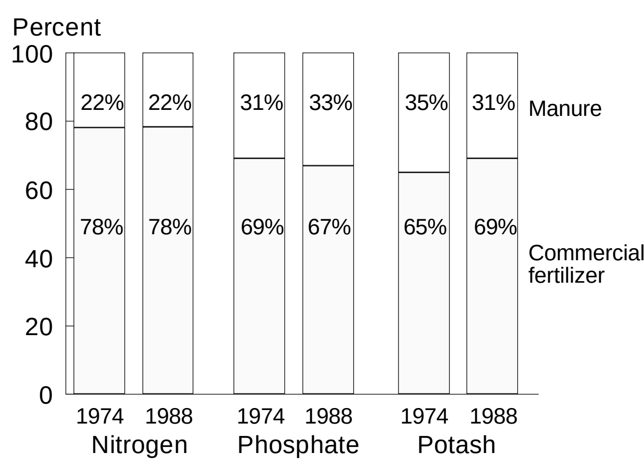
Commercial fertilizer use depends on a variety of factors including soil, climate, feasible technology, weather, crop mix, crop rotations, technological change, government programs, and commodity and

Figure 3.1.1
Corn and wheat yields per harvested acre, 1960-93



Source: USDA, various issues of *Agricultural Statistics*.

Figure 3.1.2
Availability of fertilizer for application, 1974 and 1988



Source: USDA and U.S. EPA, 1979; USDA, unpublished data.

fertilizer prices (Denbaly and Vroomen, 1993). Total fertilizer use is mostly determined by planted acreage because application rates and percentage of acres treated are relatively stable.

Table 3.1.1—U.S. commercial fertilizer use, 1960-93[1]

Year ending June 30[2]	Total fertilizer materials	Primary nutrient use			
		Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Total[3]
		Million tons			
1960	24.9	2.7	2.6	2.2	7.5
1961	25.6	3.0	2.6	2.2	7.8
1962	26.6	3.4	2.8	2.3	8.4
1963	28.8	3.9	3.1	2.5	9.5
1964	30.7	4.4	3.4	2.7	10.5
1965	31.8	4.6	3.5	2.8	10.9
1966	34.5	5.3	3.9	3.2	12.4
1967	37.1	6.0	4.3	3.6	14.0
1968	38.7	6.8	4.4	3.8	15.0
1969	38.9	6.9	4.7	3.9	15.5
1970	39.6	7.5	4.6	4.0	16.1
1971	41.1	8.1	4.8	4.2	17.2
1972	41.2	8.0	4.9	4.3	17.2
1973	43.3	8.3	5.1	4.6	18.0
1974	47.1	9.2	5.1	5.1	19.3
1975	42.5	8.6	4.5	4.4	17.6
1976	49.2	10.4	5.2	5.2	20.8
1977	51.6	10.6	5.6	5.8	22.1
1978	47.5	10.0	5.1	5.5	20.6
1979	51.5	10.7	5.6	6.2	22.6
1980	52.8	11.4	5.4	6.2	23.1
1981	54.0	11.9	5.4	6.3	23.7
1982	48.7	11.0	4.8	5.6	21.4
1983	41.8	9.1	4.1	4.8	18.1
1984	50.1	11.1	4.9	5.8	21.8
1985	49.1	11.5	4.7	5.6	21.7
1986	44.1	10.4	4.2	5.1	19.7
1987	43.0	10.2	4.0	4.8	19.1
1988	44.5	10.5	4.1	5.0	19.6
1989	44.9	10.6	4.1	4.8	19.6
1990	47.7	11.1	4.3	5.2	20.6
1991	47.3	11.3	4.2	5.0	20.5
1992	48.8	11.5	4.2	5.0	20.7
1993	49.1	11.4	4.4	5.1	20.9

[1]Includes Puerto Rico. Detailed State data shown in appendix table 2.1.1.

[2]Fertilizer use estimates for 1960-84 are based on USDA data; those for 1985-93 are Tennessee Valley Authority (TVA) estimates.

[3]Totals may not add due to rounding.

Source: Tennessee Valley Authority, *Commercial Fertilizers*, 1993 and earlier issues.

U.S. nitrogen, phosphate, and potash use for all purposes rose from 7.5 million nutrient tons in 1960 to a record 23.7 million tons in 1981 (table 3.1.1). Total nutrient use dropped from this level, as did total crop acreage, to 20.9 million nutrient tons in 1993.

Nitrogen, phosphate, and potash all contributed to the dramatic increase in fertilizer use up to 1981 (table 3.1.1, fig. 3.1.3). The relative use of nitrogen, however, increased much more rapidly. Nitrogen use in 1960 was about 37 percent of total commercial nutrient use. By 1981, nitrogen use had increased 335 percent and represented over 50 percent of total commercial nutrient use. Nitrogen use equaled 11.4 million tons in 1993, or 55 percent of total commercial nutrient use. This relative gain in nitrogen use has resulted primarily from favorable crop yield responses, especially corn, to nitrogenous fertilizers.

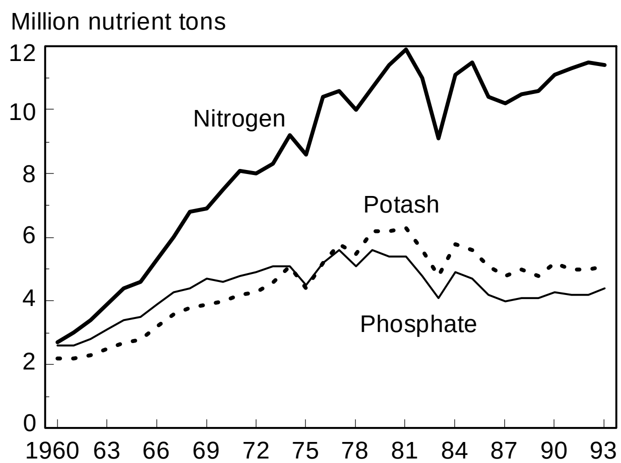
Phosphate's share of total commercial nutrient use declined from 34.5 percent in 1960 to 21.1 percent by 1993 (table 3.1.1). Potash use, historically below that of both nitrogen and phosphate, exceeded phosphate use for the first time in 1977 and will likely hold this position. In 1993, potash accounted for 24 percent of total primary nutrient use.

Product Change

In 1960, mixed fertilizers (containing 2 or more nutrients) constituted almost 63 percent of total fertilizer consumption (Taylor, 1994). This share declined to below 38 percent in 1993. The share of direct application materials (containing primarily one nutrient) increased from 37 to over 62 percent during

Figure 3.1.3

U.S. commercial fertilizer use, 1960-93



Source: Tennessee Valley Authority, *Commercial Fertilizers*, 1993 and earlier issues.

this period. The use of major direct-application nitrogen materials increased through the early 1980's. High-analysis products such as anhydrous ammonia, nitrogen solutions, and urea benefited from economies in transportation, distribution, and storage, and from the ease and accuracy of applying nitrogen solutions.

Directly applied phosphate fertilizer products have declined since the early 1970's because of the increased use of diammonium phosphate (DAP). The trend throughout the 1960's and 1970's was toward increased use of triple superphosphates (products that contained a higher percentage of phosphate) relative to normal superphosphates because of transportation, distribution, and storage economies. Since 1979, consumption of both normal and triple superphosphate has declined. The use of DAP, a mixed fertilizer containing 18 percent nitrogen and 46 percent phosphate, has dramatically increased since the 1960's (Tennessee Valley Authority, 1993).

The use of potassium chloride, the major directly applied potash fertilizer, containing about 60 percent potash, has increased dramatically since the 1960's. Total use of potassium chloride reached 5.4 million tons in 1993, up from 389,000 tons in 1960.

Regional Fertilizer Use

The Corn Belt (Ohio, Indiana, Illinois, Iowa, and Missouri) uses more commercial fertilizer than any other region (table 3.1.2). Corn, the most fertilizer-intensive crop, historically has used around 45 percent of all fertilizer. However, from 1984 to 1993, nitrogen use in the Corn Belt decreased from 3.3 to 3.0 million tons. Phosphate use decreased from 1.6 to 1.3 million tons and potash use decreased from 2.4 to 2.0 million tons. Fertilizer use is highly dependent on crop mix and planted acres. Fewer crop acres have been planted in the Corn Belt since 1981 because of government programs such as the Acreage Reduction Program (ARP) and the Conservation Reserve Program (CRP). Thus, total fertilizer use in the Corn Belt has declined even though application rates per fertilized acre and proportion of acres treated have increased since the early 1980's. The Northern Plains region (North Dakota, South Dakota, Nebraska, and Kansas) is the second highest user of nitrogen and phosphate; nitrogen use increased from 1.6 million tons in 1984 to 2.1 million tons in 1993 (table 3.1.2).

Fertilizer Prices

Fertilizer purchases have historically represented about 6 percent of total farm production costs. Throughout the 1960's, domestic prices of most fertilizer products declined as growth in industry capacity exceeded growth in demand (table 3.1.3, fig. 3.1.4). Economic Stabilization Program regulations froze domestic fertilizer prices at the producer level in 1971 (USDA, 1971-81), but prices were decontrolled in 1973. Farm fertilizer prices fell during 1983 and again in 1985/86 as a record level of crop acreage was diverted first by the payment-in-kind program (PIK) and later by the ARP and CRP programs and excess supplies (Taylor, 1994). Prices rose steadily from 1986 to 1989. Prices of most fertilizer materials have fallen from 1989 levels, but remained relatively stable through 1992. April 1994 prices increased over 1993 prices due to increased planted acres. However, real fertilizer prices (fertilizer price index adjusted by the implicit price deflator in the United States) have declined from an index of 110 in 1964 to 63 in 1992.

World fertilizer supplies have been in excess since the economic restructuring began in Eastern Europe and the former Soviet Union. World demand should rebound as affected countries improve their economic situations.

Fertilizer Use on Major Field Crops

Significant per-acre differences in fertilizer use exist among crops (Taylor, 1994; USDA, 1993).[1] U.S. farmers use more fertilizer on corn than on any other crop.

Nearly all acres in corn, fall potatoes, and rice, and over three-fourths of cotton and wheat acres received some form of commercial fertilizer in 1993 (table 3.1.4). The most frequently applied nutrient was nitrogen. In contrast, only 26-38 percent of the acres in soybeans, a nitrogen-fixing crop, received commercial fertilizer applications, usually phosphate or potash.

Nitrogen application rates have been highest for fall potatoes, averaging 206 lbs. per acre in 1993, followed by rice and corn. Fall potatoes also have the highest rate of both phosphate and potash applications, two to three times the rates for other major field crops.

Nitrogen application rates on corn dropped from 140 lbs. per acre in 1985 to 123 lbs. per acre in 1993. In contrast, the average application rates increased for

[1] Fertilizer statistics used in this report include commercial fertilizers purchased for use on farms such as chemical fertilizers and natural processed and dried organic materials. Purchased natural processed and dried organic materials historically have represented about 1 percent of total nutrient use.

Table 3.1.2—Regional commercial fertilizer use for year ending June 30, 1984-93

Product/region	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
					1,000 tons[1]					
Nitrogen:										
Northeast	322	312	278	290	278	313	306	299	328	350
Lake States	1,025	1,211	1,059	1,063	1,053	1,011	1,134	1,128	1,119	1,073
Corn Belt	3,321	3,443	3,116	2,889	2,991	3,041	3,215	3,280	3,279	2,954
Northern Plains	1,614	1,837	1,739	1,698	1,737	1,680	1,751	1,978	1,954	2,090
Appalachia	684	687	621	603	592	613	667	662	718	705
Southeast	736	720	659	665	614	643	670	627	655	682
Delta States	561	548	557	511	523	560	643	609	674	615
Southern Plains	1,118	1,110	965	1,022	1,204	1,217	1,117	1,223	1,192	1,235
Mountain	687	626	557	573	583	626	642	628	666	744
Pacific[2]	1,012	987	860	882	924	916	921	838	849	900
U.S. total[3]	11,080	11,480	10,412	10,196	10,498	10,619	11,065	11,273	11,432	11,347
Phosphate:										
Northeast	240	229	196	203	193	188	197	188	208	211
Lake States	594	612	509	493	505	477	508	479	468	474
Corn Belt	1,611	1,478	1,380	1,255	1,303	1,254	1,334	1,262	1,269	1,288
Northern Plains	507	521	498	468	486	522	550	583	577	646
Appalachia	435	422	378	378	370	361	381	384	409	410
Southeast	353	331	288	300	280	297	308	281	295	314
Delta States	208	180	164	132	153	154	177	154	180	172
Southern Plains	380	364	298	305	324	342	315	334	288	340
Mountain	267	232	213	218	228	253	279	255	270	296
Pacific[2]	301	288	250	250	281	270	289	274	248	303
U.S. total[3]	4,896	4,652	4,173	4,003	4,123	4,119	4,339	4,195	4,212	4,454
Potash:										
Northeast	282	288	263	253	249	232	261	262	267	262
Lake States	1,020	1,048	871	912	852	852	941	832	809	680
Corn Belt	2,431	2,264	2,165	2,020	2,126	1,974	2,132	2,044	1,987	1,989
Northern Plains	125	126	115	100	121	129	133	134	123	134
Appalachia	606	585	532	508	506	506	538	539	584	575
Southeast	662	607	542	524	531	558	559	517	556	680
Delta States	286	243	225	184	217	212	240	229	280	288
Southern Plains	158	169	142	133	140	149	143	150	146	168
Mountain	47	54	49	44	46	53	65	80	55	80
Pacific[2]	168	157	137	146	171	155	179	200	220	244
U.S. total[3]	5,785	5,541	5,040	4,824	4,960	4,820	5,192	4,988	5,026	5,100

[1]Totals may not add due to rounding.
[2]Includes Alaska and Hawaii.
[3]Excludes Puerto Rico.
Source: Tennessee Valley Authority, *Commercial Fertilizers*, 1993 and earlier issues.

Table 3.1.3—Average U.S. farm prices of selected fertilizers, 1960-94

Year[1]	Anhydrous ammonia	Nitrogen solutions (30%)	Urea 45-46% nitrogen	Ammonium nitrate	Sulfate of ammonium	Super-phosphate 20% phosphate	Super-phosphate 44-46% phosphate	Diammonium phosphate (18-46-0)	Potassium chloride 60% potassium
					Dollars per ton				
1960	141	NA	117	82	58	38	79	NA	51
1961	142	NA	114	83	58	38	81	NA	52
1962	134	NA	109	82	57	38	80	NA	53
1963	128	NA	107	81	52	41	81	NA	54
1964	126	NA	106	80	53	40	81	NA	54
1965	122	NA	104	79	53	41	81	NA	54
1966	119	NA	101	77	53	41	81	NA	55
1967	113	67	99	74	54	42	84	113	54
1968	91	63	92	68	54	43	78	101	49
1969	76	54	84	62	53	44	74	94	48
1970	75	54	83	60	52	45	75	94	51
1971	79	56	82	63	52	48	77	96	58
1972	80	55	81	65	52	50	78	97	59
1973	88	58	90	71	55	54	88	109	62
1974	183	111	183	139	110	91	150	181	81
1975	265	153	244	186	148	118	214	263	102
1976	191	113	166	135	98	95	158	189	96
1977	188	122	169	141	101	99	146	180	96
1978	177	118	169	140	109	104	151	186	96
1979	171	110	170	138	118	109	161	199	107
1980	229	134	221	165	138	128	247	297	135
1981	243	141	237	185	150	134	248	287	152
1982	255	151	240	195	165	NA	230	267	155
1983	237	142	214	185	149	NA	214	249	143
1984	275	145	222	198	150	NA	229	271	145
1985	255	143	221	192	156	NA	206	244	128
1986	225	122	174	171	149	NA	190	224	111
1987	187	109	161	157	144	NA	194	220	115
1988	208	137	183	166	140	NA	222	251	157
1989	224	142	212	189	154	NA	229	256	163
1990	199	132	184	180	154	NA	201	219	155
1991	210	138	212	184	151	NA	217	235	156
1992	208	141	198	178	151	NA	206	224	150
1993	213	137	202	186	157	NA	190	199	146
1994	243	137	207	196	170	NA	212	224	146

NA = Not available.

[1]April prices for 1960-76, 1986-94; all other prices are for March.

Source: USDA, NASS, *Agricultural Prices*, 1961-94.

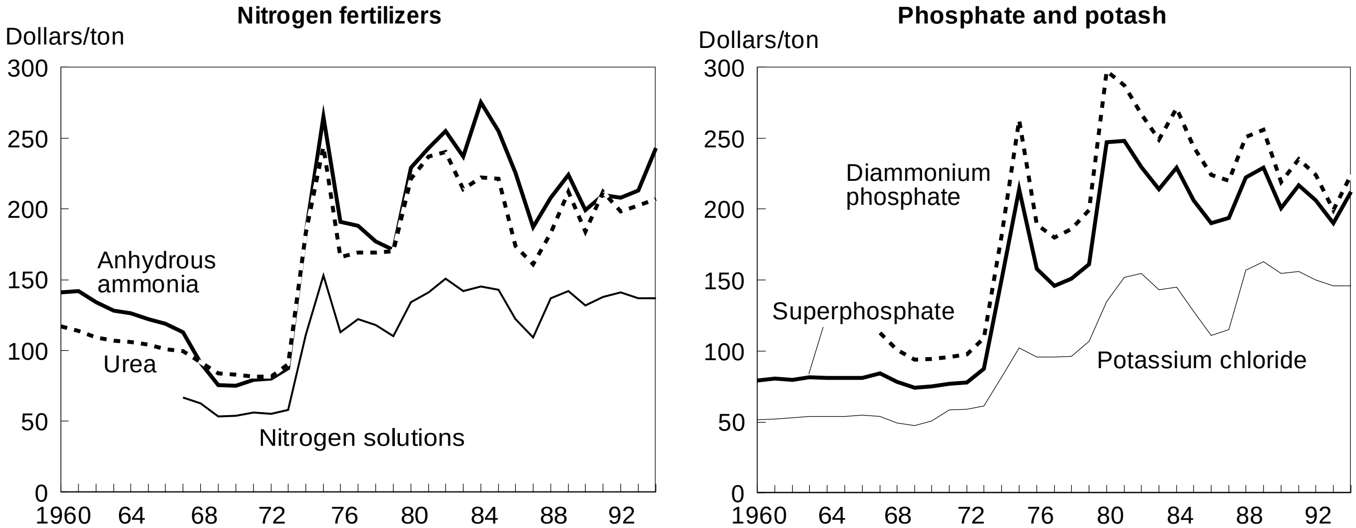
Table 3.1.4—Chemical fertilizer use on selected field crops in major producing States, 1985-93[1]

Crop/year	Acres receiving: Any fertilizer	Acres receiving: Nitrogen	Acres receiving: Phosphate	Acres receiving: Potash	Application rates: Nitrogen	Application rates: Phosphate	Application rates: Potash
	Percent				*Pounds/acre*		
Corn for grain (10 States):							
1985	98	97	86	79	140	60	84
1986	96	95	84	76	132	61	80
1987	96	96	83	75	132	61	85
1988	97	97	87	78	137	63	85
1989	97	97	84	75	131	59	81
1990	97	97	85	77	132	60	84
1991	97	97	82	73	128	60	81
1992	97	97	82	72	127	57	79
1993	97	97	82	71	123	56	79
Cotton (6 States):							
1985	76	76	50	34	80	46	52
1986	80	80	50	39	77	44	50
1987	76	76	47	33	82	44	45
1988	80	80	54	32	78	42	39
1989	79	79	54	32	84	43	40
1990	80	79	49	31	86	44	47
1991	81	81	52	34	91	47	48
1992	80	80	48	37	88	48	57
1993	85	85	54	36	89	47	58
Fall potatoes (11 States):							
1988	95	95	93	78	185	151	151
1989	99	98	94	83	192	157	155
1990	99	98	98	89	198	163	143
1991	99	99	98	88	195	158	143
1992	100	100	99	88	200	159	147
1993	100	100	98	91	206	167	156
Rice (2 States):							
1988	99	99	46	36	127	47	50
1989	99	99	46	33	125	45	45
1990	98	97	36	37	114	45	49
1991	99	99	30	32	127	46	47
1992	98	98	34	37	134	44	50
Soybeans Northern (7 States):							
1989	30	14	23	28	16	48	77
1990	27	14	20	25	22	47	87
1991	26	14	19	22	24	49	80
1992	27	13	19	23	20	46	76
1993	26	12	18	24	18	47	83
Soybeans Southern (7 States):							
1989	44	24	42	44	21	43	67
1990	41	26	38	39	28	47	70
1991	37	21	33	35	28	45	70
1992	39	22	36	37	27	49	74
1993	38	22	34	36	24	44	70
All wheat (15 States):							
1985	77	77	48	16	60	35	36
1986	79	79	48	19	60	36	44
1987	80	80	50	15	62	35	43
1988	83	83	53	18	64	37	52
1989	81	81	53	18	62	37	46
1990	79	79	52	19	59	36	44
1991	80	80	54	20	62	36	43
1992	84	83	56	18	63	34	39
1993	87	86	60	17	64	34	35

[1]Major producing States generally account for 80 percent or more of each crop's acreage. For the States included, see box, "Cropping Practices Survey," p. 82. For detailed data for 1993 by crop and State, see app. tables 3.1.2-3.1.5.

Source: USDA, ERS, Cropping Practices Survey data.

Figure 3.1.4
Average farm prices of selected fertilizers, 1960-94



Source: USDA, NASS, *Agricultural Prices*, 1994 and earlier issues.

fall potatoes and rice. The percentage of various crops receiving fertilizer, and fertilizer application rates, vary among the major growing States (see appendix tables 3.1.2-3.1.5).

Nutrient Mass Balances Help Assess Need for Better Nutrient Management

Nutrients can be carried by water runoff and eroding soil into surface-water systems, or can percolate into groundwater supplies, causing contamination. This unwanted loss of nutrients is more likely to occur where levels of nutrients exceed crop needs, or where high levels of nutrients remain in the soil during offseason months when no crop is grown.

Nutrient mass balance, the difference between nutrient inputs and outputs, indicates whether existing nutrient levels may require better management. Total inputs of a nutrient equal the amounts of nutrient applied through commercial fertilizer and animal waste and the amounts added from sources such as legume crops, crop residue, and irrigation water. Nutrient outputs equal the amount of nutrient taken up by the crop (depends on the yield achieved) and removed from the field. A positive net mass balance of that nutrient may remain in the soil, or be lost to the atmosphere or surface and ground water. A negative net balance indicates the mining of that nutrient from the soil and suggests that improved nutrient management may be needed to avoid depleting soil productivity.

The National Academy of Sciences developed nitrogen and phosphate mass balances for croplands in the United States and for individual States by aggregating nutrient inputs and outputs across all crops and nutrient sources (National Academy of Sciences, 1993). For the United States in 1987, positive mass balances of 33-40 percent were found for nitrogen and 63 percent for phosphate. Balances of that magnitude indicate significant potential losses to the environment and the need for improved nutrient management.

Cropping practices data gathered by USDA since 1990 have permitted the estimation of mass balances on an annual basis, both total and per acre, for major crops and growing States (see box, "Computing Nutrient Mass Balances," page 75). Average nitrogen mass balances during 1990-93 were uniformly positive in the top five States producing corn and cotton, but sometimes negative in three of the top five wheat States (tables 3.1.5-3.1.7). Generally, over half of the corn acreage and over 40 percent of the cotton acreage had nitrogen inputs exceeding output in the harvested crop by over 25 percent. Among the top five wheat-producing States, the proportions were generally lower, but two States (Oklahoma and Texas) had half of their acreages with mass balances over 25 percent of crop needs. Negative nitrogen balances occurred on up to one-third of the corn acreage and higher proportions of wheat acreage. These data suggest opportunities for improved nitrogen management in corn and cotton production to reduce nitrogen losses, and in wheat production to maintain soil productivity.

Table 3.1.5—Nitrogen and phosphate mass balance in corn production, top five growing States, 1990-93

State and year	Nutrient inputs				Nutrient output in harvested crop[1]	Nutrient mass balance				
	Commercial fertilizer	Previous legumes	Manure	Total		Total	Average	Above 25[2]	0-25	Negative
	---------------	---------------	1,000 pounds	---------------	---------------	---------------	Lbs./ac	--Percent of acres--		
Nitrogen:										
Illinois--										
1990	1,735,183	280,831	34,874	2,050,888	1,251,791	799,097	75	86	8	6
1991	1,805,721	299,782	50,424	2,155,927	1,163,058	992,869	89	87	8	5
1992	1,753,129	300,844	33,185	2,087,158	1,561,707	525,451	47	65	22	13
1993	1,552,381	324,705	40,349	1,917,436	1,249,528	667,908	64	76	12	12
Indiana--										
1990	780,597	130,430	32,795	943,821	660,950	282,871	51	72	9	19
1991	770,537	140,578	28,467	939,582	514,867	424,715	75	78	7	15
1992	843,777	168,211	21,679	1,033,667	860,124	173,542	28	52	19	29
1993	728,066	148,429	31,282	907,777	669,272	238,505	43	66	12	22
Iowa--										
1990	1,600,418	371,761	78,515	2,050,694	1,548,670	502,024	39	56	24	20
1991	1,458,620	355,727	114,651	1,928,998	1,411,679	517,319	41	59	21	20
1992	1,562,652	433,322	71,490	2,067,464	1,860,394	207,070	16	32	33	35
1993	1,357,213	332,306	84,214	1,773,733	919,035	854,698	71	84	6	10
Minnesota--										
1990	798,843	92,277	41,418	932,538	695,139	237,400	35	61	18	21
1991	853,036	87,686	32,055	972,779	667,343	305,436	46	58	19	23
1992	954,406	68,400	52,457	1,075,263	801,532	273,731	38	64	18	18
1993	754,071	75,126	26,887	856,084	634,344	221,740	35	61	17	22
Nebraska--										
1990	1,089,352	61,480	46,082	1,196,914	892,994	303,921	39	61	20	19
1991	1,131,962	66,227	36,363	1,234,552	953,302	281,250	34	57	17	26
1992	1,115,055	63,298	26,211	1,204,564	1,070,970	133,594	16	36	32	32
1993	1,084,819	56,712	36,634	1,179,574	770,611	408,963	51	69	14	17
Phosphate:										
Illinois--										
1990	792,346	0	18,309	810,655	486,808	323,848	31	67	9	24
1991	800,910	0	26,473	827,382	452,300	375,082	33	69	10	21
1992	706,889	0	17,422	724,311	607,331	116,980	10	49	15	36
1993	653,441	0	21,183	674,624	485,928	188,697	18	62	6	32
Indiana--										
1990	411,307	0	18,986	430,294	257,036	173,257	31	61	11	28
1991	423,887	0	16,481	440,368	200,226	240,141	42	78	6	16
1992	356,577	0	12,551	369,128	334,493	34,635	6	38	14	48
1993	335,733	0	18,111	353,843	260,273	93,571	17	51	11	38
Iowa--										
1990	624,891	0	43,876	668,767	602,261	66,506	5	40	19	41
1991	580,249	0	64,070	644,319	548,986	95,333	8	44	13	43
1992	603,329	0	39,950	643,279	723,487	-80,207	-6	27	15	58
1993	484,595	0	47,066	531,656	357,403	174,253	15	58	8	34
Minnesota--										
1990	329,148	0	19,491	348,639	270,332	78,307	12	53	6	41
1991	391,969	0	15,086	407,055	259,522	147,533	22	52	11	37
1992	295,920	0	24,686	320,606	311,707	8,899	1	32	17	61
1993	321,552	0	12,653	334,204	246,689	87,515	14	45	17	38
Nebraska--										
1990	165,504	0	23,041	188,545	347,275	-158,731	-21	6	10	84
1991	220,840	0	18,182	239,021	370,729	-131,707	-16	16	6	78
1992	213,939	0	13,105	227,044	416,488	-189,444	-23	8	8	84
1993	215,522	0	18,317	233,839	299,682	-65,843	-8	22	8	70

[1]Excludes crop residue nutrients, which decompose over time but tend to balance out on input and output sides.

[2]Percent of acres where total nutrient input exceeds nutrient output in harvested crop by 25 percent or more.

Source: USDA, ERS (See box, "Computing Nutrient Mass Balances").

Table 3.1.6—Nitrogen and phosphate mass balance in cotton production, top five growing States, 1989-93

State and year	Nutrient inputs				Nutrient output in harvested crop[1]	Nutrient mass balance				
	Commercial fertilizer	Previous legumes	Manure	Total		Total	Average	Above 25[2]	0-25	Negative
	1,000 pounds						*Lbs./ac*	*Percent of acres*		
***Nitrogen*:**										
Arkansas--										
1989	57,971	3,760	917	62,649	46,423	16,225	21	64	14	22
1991	86,545	3,375	4,000	93,920	70,010	23,910	24	43	13	44
1992	86,354	2,055	1,750	90,158	75,911	14,247	14	45	16	39
1993	98,893	1,645	34,117	103,950	51,876	52,075	53	76	3	21
California--										
1989	132,872	4,877	7,738	145,487	122,573	22,913	21	46	13	41
1991	134,066	13,671	15,222	162,958	107,831	55,128	57	60	9	31
1992	136,173	3,214	26,563	165,950	123,015	42,934	43	49	24	27
Louisiana--										
1989	70,130	845	1,673	72,648	48,895	23,754	29	43	9	48
1991	87,470	2,928	3,040	93,438	72,375	21,063	24	29	25	46
1992	67,780	3,825	9,141	80,745	59,798	20,948	24	54	16	30
1993	65,384	939	1,858	68,181	49,327	18,854	21	63	3	34
Mississippi--										
1989	132,646	1,953	3,269	137,867	75,252	62,615	51	82	9	9
1991	136,550	1,712	0	138,262	97,721	40,540	32	57	16	27
1992	149,264	2,264	3,186	154,714	92,098	62,616	46	76	4	20
1993	147,836	1,277	8,423	157,536	66,441	91,096	68	88	7	5
Texas--										
1989	180,197	2,897	3,947	187,041	164,329	22,712	4	35	5	60
1991	358,371	4,473	12,795	375,639	280,718	94,921	15	47	9	44
1992	392,839	0	0	392,839	224,600	168,239	30	64	8	28
1993	296,222	3,768	4,521	304,511	249,516	54,995	10	44	9	47
***Phosphate*:**										
Arkansas--										
1989	18,918	0	426	19,344	22,603	-3,259	-4	38	11	51
1991	25,699	0	1,857	27,556	34,087	-6,531	-7	30	4	66
1992	28,786	0	813	29,598	36,961	-7,362	-7	27	9	64
1993	36,077	0	1,584	37,662	25,257	12,404	13	55	5	40
California--										
1989	25,101	0	3,186	28,288	59,680	-31,392	-29	13	7	80
1991	27,096	0	6,268	33,364	52,502	-19,138	-20	18	6	76
1992	33,368	0	10,938	44,305	59,895	-15,590	-16	21	5	74
Louisiana--										
1989	25,618	0	687	26,305	23,806	2,498	3	49	5	46
1991	23,216	0	1,248	24,464	35,239	-10,775	-12	31	4	65
1992	26,181	0	3,752	29,933	29,115	818	1	43	8	49
1993	20,113	0	763	20,876	24,017	-3,141	-4	30	4	66
Mississippi--										
1989	31,700	0	1,479	33,180	36,640	-3,466	-3	34	6	60
1991	33,450	0	0	33,450	47,580	-14,130	-11	26	8	66
1992	30,207	0	1,442	31,649	44,842	-13,192	-10	28	7	65
1993	34,133	0	3,813	37,946	32,350	5,596	4	43	3	54
Texas--										
1989	112,564	0	1,723	114,286	80,010	34,276	6	39	4	57
1991	154,909	0	5,585	160,494	136,679	23,814	4	45	4	51
1992	148,861	0	0	148,861	109,356	39,505	7	35	7	58
1993	144,296	0	1,974	146,269	121,487	24,872	4	44	6	50

[1]Excludes crop residue nutrients, which decompose over time but tend to balance out on input and output sides.
[2]Percent of acres where total nutrient input exceeds nutrient output in harvested crop by 25 percent or more.
Source: USDA, ERS (See box, "Computing Nutrient Mass Balances.")

Table 3.1.7—Nitrogen and phosphate mass balance in wheat production, top five growing States, 1990-93

State and year	Nutrient inputs				Nutrient output in harvested crop[1]	Nutrient mass balance				
	Commercial fertilizer	Previous legumes	Manure	Total		Total	Average	Above 25[2]	0-25	Negative
	------------------------- 1,000 pounds				*-------------------------*		*Lbs./ac*	*----- Percent of acres -----*		
Nitrogen:										
Kansas--										
1990	538,921	5,429	15,759	560,109	628,924	-68,816	-6	25	17	58
1991	593,613	9,760	14,142	617,514	487,311	130,204	11	52	12	36
1992	570,825	22,995	24,428	618,248	481,984	136,264	12	50	11	39
1993	573,112	7,264	15,538	595,914	528,488	67,426	6	45	8	47
Montana--										
1990	158,989	8,078	0	167,296	219,725	-52,429	-9	22	11	67
1991	107,611	0	7,553	115,164	232,952	-117,788	-23	11	3	86
1992	113,738	0	4,431	118,168	211,334	-93,165	-18	21	9	70
1993	169,175	0	7,010	176,185	276,379	-100,195	-18	14	9	77
North Dakota--										
1990	324,307	45,427	25,886	395,620	529,274	-133,654	-12	24	7	69
1991	387,788	5,852	10,478	404,118	394,066	10,053	1	42	10	48
1992	493,544	11,090	23,902	528,536	624,734	-96,198	-8	28	10	62
1993	597,015	9,727	44,045	650,787	499,206	151,581	13	48	14	38
Oklahoma--										
1990	449,254	2,346	5,316	456,916	286,726	170,189	23	58	8	34
1991	451,176	12,813	11,146	475,135	243,327	231,807	31	67	10	23
1992	502,993	0	27,594	530,586	271,246	259,340	35	72	12	16
1993	481,129	0	41,971	523,100	255,601	267,499	37	71	9	20
Texas--										
1990	387,329	10,641	15,545	413,516	251,253	162,262	24	57	3	40
1991	412,905	17,343	43,703	473,951	235,856	238,095	38	64	3	33
1992	320,668	0	11,353	332,021	240,271	91,750	16	48	5	47
1993	370,515	1,728	18,763	391,006	270,237	120,769	20	53	5	42
Phosphate:										
Kansas--										
1990	160,753	0	7,982	168,735	314,462	-145,727	-12	19	8	73
1991	182,505	0	7,163	189,667	243,655	-53,989	-5	25	12	63
1992	186,095	0	12,373	198,468	240,992	-42,524	-4	29	7	64
1993	183,174	0	7,870	191,044	264,244	-73,200	-6	30	7	63
Montana--										
1990	92,410	0	0	92,410	109,863	-17,453	-3	27	10	63
1991	82,443	0	3,730	86,173	116,476	-30,303	-6	19	12	69
1992	73,195	0	2,188	75,383	105,667	-30,284	-6	28	7	65
1993	113,564	0	3,462	117,026	138,190	-21,164	-4	19	8	73
North Dakota--										
1990	209,663	0	10,354	220,018	264,637	-44,619	-4	24	10	66
1991	184,121	0	4,191	188,312	197,033	-8,721	-1	35	14	51
1992	242,919	0	9,561	252,480	312,367	-59,887	-5	20	13	67
1993	293,554	0	17,613	311,172	249,603	61,570	5	47	8	45
Oklahoma--										
1990	159,037	0	2,371	161,434	143,363	18,071	2	42	5	53
1991	119,105	0	5,025	124,129	121,664	2,466	0	38	4	58
1992	113,095	0	12,440	125,534	135,623	-10,089	-1	35	6	59
1993	135,883	0	18,922	154,805	127,801	27,004	4	43	5	52
Texas--										
1990	86,180	0	6,786	92,965	125,627	-32,661	-5	27	5	68
1991	94,988	0	19,077	114,065	117,928	-3,863	-1	35	3	62
1992	76,954	0	4,956	81,909	120,135	-38,226	-6	27	3	70
1993	77,352	0	8,190	85,542	135,119	-49,576	-8	21	5	74

[1]Excludes crop residue nutrients, which decompose over time but tend to balance out on input and output sides.

[2]Percent of acres where total nutrient input exceeds nutrient output in harvest crop by 25 percent or more.

Source: USDA, ERS. (See box, "Computing Nutrient Mass Balances.")

Computing Nutrient Mass Balances

Data from the Cropping Practices Survey (see box, p. 82) are used to compute the nutrient mass balances reported in tables 3.1.5-3.1.7. Assumptions used in estimating mass balances include:

(1) Total nitrogen from commercial fertilizer is the sum of that applied before planting and after planting.

(2) Nitrogen from previous legume crops is computed as follows: If the previous legume crop was soybeans, 1 pound of nitrogen credit was assumed for each bushel of soybeans harvested. If 1 crop of alfalfa existed during the previous 2 years, the nitrogen credit was 90 pounds per acre. If alfalfa crops occurred in the previous 2 years, the nitrogen credit was 135 pounds per acre. For each additional year in alfalfa crop beyond 2 years, about 45 pounds per acre of nitrogen credit was added (Meisinger and Randall, 1991).

(3) Manure nitrogen credit in each State was estimated by dividing the amount of recoverable manure nitrogen by the number of acres treated with manure. Recoverable nitrogen was estimated using the animal inventory of the 1987 Agricultural Census. Number of acres treated was estimated by multiplying the Census crop acres by the ratio of the crop acres treated with manure as shown in the CPS. The same procedures were used to estimate manure phosphate credit.

(4) The amounts of nutrient per unit of crop harvested were assumed as follows. For each bushel of corn harvested, about 0.9 pound of nitrogen and 0.35 pound of phosphate. For each bushel of wheat harvested, 1.25 pounds of nitrogen and 0.625 pound of phosphate. For each pound of cotton lint and seed, 0.027 pound of nitrogen and 0.013 pound of phosphate (Fertilizer Institute; Meisinger and Randall, 1991).

(5) Plant residues on the field were assumed equal in nutrient value at beginning and end of season.

(6) Nitrogen from other sources such as irrigation water and precipitation were not considered.

Phosphate mass balances averaged much lower than those for nitrogen on a per-acre basis and were more frequently negative. This was particularly true for the top five wheat States, where half to three-fourths of the acreage in most years had a negative balance. Improved nutrient management here would augment phosphate levels to avoid soil-phosphate depletion.

Considerable variation in mass balances occurred from year to year. In most years, this variation appeared due more to changes in nutrient output in the harvested crop (reflecting yield variations as affected by growing conditions) than to changes in nutrient inputs. For example, excessive moisture during 1993 reduced corn yields in Iowa and Nebraska, lowering crop nitrogen uptake and causing nitrogen mass balances to jump considerably above 1992 levels. Such variations make it difficult to determine over just a few years whether nutrient management is improving.

The nutrient mass balance is particularly useful for farmers in managing nutrients on a field-by-field basis. The farmer first estimates the amount of nutrients the crop will need based on a realistic yield estimate. From this projected need, the farmer subtracts the amount of nutrient in the soil at the beginning of the growing season (determined by root zone soil tests), and that supplied by previous legume crops, irrigation water (in areas with high nitrate content in ground water), and animal wastes. The balance indicates the amount of commercial fertilizer nutrients to be applied.

Improving Nutrient Management

Various nutrient management practices can help farmers adjust fertilizer applications to crop needs and reduce losses to the environment. The efficacy of each practice is strongly influenced by field conditions.

Testing Soil, Plant Tissue, and Irrigation Water

Soil and plant tissue tests help farmers estimate the residual nutrients available for plant use in determining fertilizer needs (see box, "Benefits of Soil Nitrogen Testing"). Soil testing before planting includes estimation of nitrogen in the root zone of the crop being planted, which can be 3 feet or more for corn. Plant tissue tests help farmers determine the need for supplemental nitrogen during the crop growing period. After planting, rainy weather often prevents farmers from entering the field to apply nitrogen. In some areas, irrigation water containing

Benefits of Soil Nitrogen Testing

A recent ERS study examined the impact of soil nitrogen (N) testing and N fertilizer use and crop yields in Nebraska corn production (Bosch, Fuglie, and Keim, 1994).

Farmers who N tested were often able to reduce N fertilizer application without affecting crop yields. The impact of N testing was most significant in fields where significant sources of organic N (for example, from livestock manure) were likely. Farmers often have difficulty in properly accounting for organic N because of uncertainty about the quantity of N carried over from the previous season. Soil N testing provided information about carryover N, enabling farmers to reduce N fertilizer rates by up to 25 percent without affecting yields. However, N testing had little, if any, effect in fields without significant carryover N.

The study also evaluated public policy approaches to promoting the use of N testing by farmers. Both regulatory approaches and educational programs are used to encourage improved N fertilizer management in Nebraska. Educational approaches include technical and/or financial assistance to individual farmers. Regulations in target areas were shown to promote high rates of adoption of N testing, but farmers who participated in USDA educational programs appeared to make more effective use of N testing technology than did nonparticipants.

significant levels of nitrogen should be tested and the application of commercial fertilizer reduced accordingly.

Timing Applications to Crop Needs

Timing nitrogen applications to the biological needs of a crop can reduce application rates in crop production by as much as 40 percent without reducing crop yields (Kanwar and others, 1988). Nitrogen is needed only during the plant’s growing season. Nitrogen fertilizer applied before the growing season either in the fall or early spring is more readily lost to the environment. To make up for the nitrogen loss, a larger amount of nitrogen is generally applied. While nitrogen application after planting can minimize the losses and reduce amounts applied, in some areas such a strategy may increase a farmer’s financial risk. For example, a rainy period can prevent farmers from applying nitrogen fertilizer at the time when the plant needs it most, reducing yields and incomes (see box, "Timing Nitrogen Applications"). Also, after-planting nitrogen applications require equipment and labor that may not be available at the time needed or that have a cost exceeding the savings in fertilizer. However, in most areas, especially irrigated cropland, the financial risk of delaying fertilizer application is insignificant.

Changing Application Method

Broadcast applications, because of relatively low field operation costs, are the common practice for applying nitrogen fertilizer before planting. Broadcasted nitrogen, however, is more susceptible to loss to the environment than are banded applications, which place nitrogen fertilizer next to the plant. For ammonia types of fertilizer, leaching and volatilization loss from broadcasting nitrogen on certain soils can be as much as 35 percent of nitrogen fertilizer applied (Achorn and Broder, 1991; Meisinger and Randall, 1991) and can result in yield loss of as much as 15 percent (Mengel, 1986). In contrast, banded applications of anhydrous ammonia injected or knifed into the soil at or after planting can reduce nitrogen loss. While banded applications have relatively high field operation costs compared with broadcast applications, their overall cost (field operation and fertilizer costs) is generally lower. Application of nitrogen through irrigation systems (fertigation) is little used on major field crops, but holds considerable potential for improving fertilizer timing efficiency.

Improving Irrigation

The quantity of water in the soil affects the nutrient concentration in the soil and the rate of nutrient movement to the root (Rhoads, 1991). Too much irrigation water can promote nitrogen leaching, reduce nutrient concentration in soil, and lower plant uptake. Irrigation efficiency can be improved, for example, by switching from gravity irrigation to sprinkler irrigation, by scheduling irrigation according to plant need, and by using improved gravity irrigation practices. The cost of irrigation improvements can be substantial, but the economic benefit from the saving of irrigation water, and in some cases from increased yield, may offset the cost.

Rotating Crops

Crops in rotation with a legume crop (which produces nitrogen) can reduce nitrogen fertilizer needs and use. In addition, crops in rotation reduce soil insect species, improving plant health and increasing nitrogen uptake efficiency (see module 4.2). In some

Timing Nitrogen Applications To Improve Water Quality

Properly timing the application of nitrogen fertilizer can reduce nitrogen losses. A recent ERS study used analytical models to investigate a Mississippi farmer's decision process on the timing of nitrogen fertilizer application in cotton production (Huang, Uri, and Hansen, 1994). Empirical results indicate that (1) the farmer is indifferent between applying nitrogen fertilizer in the fall versus in the spring before planting; (2) splitting nitrogen applications between the spring and the growing season or applying nitrogen only in the growing season is the optimal strategy for the farmers to maximize net farm income; (3) the farmer can save considerable nitrogen fertilizer with a relatively small income loss by applying nitrogen fertilizer only during the growing season rather than before planting; (4) the risk premium for complying with a restriction on applying fertilizer before planting is relatively small; and (5) for areas where nitrate leaching is a main concern, restricting nitrogen fertilizer application before planting is viable.

areas, crop rotations with cover crops can also capture nitrate in the soil and reduce nitrate leaching. Even with these benefits, however, crop rotation is often less profitable than monoculture of crops currently in farm programs.

Using More Stable Fertilizer Products

The various nitrogen fertilizers available each affect the environment differently (Fertilizer Institute, 1976). Nitrogen in ammonia form is more susceptible to volatilization than other forms of nitrogen but less susceptible to nitrogen leaching. For areas where cropland is vulnerable to leaching, ammonia fertilizer can minimize nitrogen loss. For areas where ammonia volatilization is a problem, a nitrate-based fertilizer is preferable.

Nitrogen fertilizer stabilizers or inhibitors in certain types of soil delay the transformation of nitrogen fertilizer from ammonia to nitrate, and help match the timing of nitrate supply with peak plant demand (Nelson and Huber, 1987; Scharf and Alley, 1988). Proper use of nitrogen inhibitors enhances nitrogen efficiency and reduces the potential for loss. Improper use of nitrogen inhibitors, however, can be harmful to the environment by delaying the transformation of nitrogen to nitrate past the potential for plant uptake.

Adoption of Improved Practices

Tables 3.1.8-3.1.10 indicate the extent of nutrient practices on corn, cotton, soybeans, and wheat for 1990-93 for the major crop-growing States. Most crops vary but show an increase in the percentage of acres soil-tested for nitrogen. Corn, spring wheat, and cotton show a reduction in fall application of fertilizer and an increase in after-planting fertilization. Winter, spring, and durum wheat generally show a decrease in broadcasted applications and an increase in banded and injected applications. Because considerable acreage remains to be treated with improved practices, opportunities abound for farmers to increase nutrient efficiency and improve water quality.

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Table 3.1.8—Nutrient management practices on corn and cotton in major producing States, 1990-93[1]

Practice	Corn				Cotton			
	1990	1991	1992	1993	1990	1991	1992	1993
				Percent of acres				
Forms of nutrients applied:								
Livestock manure	17.0	18.6	16.1	17.7	3.9	2.9	2.9	3.5
Chemical fertilizers	97.1	97.2	96.9	97.3	79.8	81.0	80.1	84.8
Fertilizer and manure	16.2	17.6	15.1	16.5	3.3	2.0	2.8	2.9
Lime	5.9	4.4	4.4	3.5	2.2	2.2	1.0	2.9
Sulphur	9.2	9.9	11.1	10.3	22.8	21.3	22.1	23.0
Micro nutrients	11.8	10.6	11.5	10.9	16.6	17.8	17.9	18.3
Nitrogen inhibitor	8.2	9.4	8.4	5.1	4.2	6.0	2.7	2.9
Soil testing/fertilizer amount:								
Soil tested	41.2	41.4	42.0	38.2	27.6	32.3	27.2	28.3
				Percent of soil-tested acres				
Percent testing for nitrogen (N)	61.1	60.3	82.3	77.3	94.5	88.2	97.9	93.6
				Percent of nitrogen-tested acres				
Applied recommended N rate	nr	nr	84.5	86.9	nr	nr	76.2	79.4
Applied more N than rec.	nr	nr	5.2	2.9	nr	nr	12.7	12.1
Applied less N than rec.	nr	nr	10.3	10.2	nr	nr	11.1	8.4
Fertilizer timing:				*Percent of fertilized acres[2]*				
Fall before planting	34.4	34.7	30.1	26.7	36.2	36.0	32.4	34.0
Spring before planting	61.7	57.2	60.5	57.6	45.2	46.4	44.5	49.1
At planting	44.6	43.0	42.7	44.3	7.9	11.3	10.1	8.1
After planting	25.6	28.6	28.2	32.8	50.8	50.6	52.5	53.9
Fertilizer application methods:								
Broadcast (ground)	71.3	72.1	69.4	70.9	55.9	58.2	58.9	54.7
Broadcast (air)	nr	nr	1.4	1.4	nr	nr	4.9	6.0
In irrigation water	1.3	1.7	1.2	0.6	6.5	8.1	6.4	5.8
Banded	43.2	40.6	41.8	42.2	23.5	26.5	24.8	23.8
Foliar	0.7	0.0	0.0	0.0	2.4	3.5	2.8	1.5
Injected (knifed-in)	55.4	52.9	53.9	47.4	44.5	45.0	41.9	45.0

nr = None reported.

[1]For States included, see box, "Cropping Practices Survey."

[2]Percents will add to more than 100 since an acre can be treated more than once.

Source: USDA, ERS, Cropping Practices Survey data.

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Table 3.1.9—Nutrient management practices on soybeans and winter wheat in major producing States, 1990-93[1]

Practice	Soybeans				Winter wheat			
	1990	1991	1992	1993	1990	1991	1992	1993
	Percent of acres							
Forms of nutrients applied:								
Livestock manure	5.7	5.4	6.1	5.5	2.0	3.4	2.5	2.9
Chemical fertilizers	30.7	28.1	29.2	28.7	84.0	84.1	85.0	86.2
Fertilizer and manure	2.0	1.4	1.4	1.0	1.7	2.8	2.2	2.5
Lime	4.1	4.6	5.1	4.5	1.6	1.8	2.0	1.6
Sulphur	1.7	1.2	1.4	1.2	8.8	9.7	11.5	12.6
Micro nutrients	3.1	2.3	1.6	2.0	2.0	1.6	2.2	2.5
Nitrogen inhibitor	0.4	0.9	0.6	0.7	2.6	2.3	1.9	1.3
Soil testing/fertilizer amount:								
Soil tested	26.2	28.1	27.9	27.7	16.5	19.1	22.7	21.6
	Percent of soil-tested acres							
Percent testing for nitrogen (N)	56.8	55.1	72.2	69.	91.9	92.4	95.3	92.5
	Percent of nitrogen-tested acres							
Applied recommended N rate	nr	nr	87.2	86.93	nr	nr	77.2	77.0
Applied more N than rec.	nr	nr	4.2	2.8	nr	nr	6.7	98.4
Applied less N than rec.	nr	nr	8.6	10.3	nr	nr	16.0	14.6
Fertilizer timing:	*Percent of fertilized acres[2]*							
Fall before planting	33.5	35.1	38.6	35.0	70.7	75.2	76.1	74.8
Spring before planting	50.4	46.3	47.4	52.3	4.0	0.3	0.1	0.1
At planting	16.5	16.2	11.7	13.2	22.7	24.5	23.4	25.2
After planting	4.9	6.3	4.9	2.8	42.6	42.8	42.8	41.8
Fertilizer application methods:								
Broadcast (ground)	86.5	85.3	88.9	90.2	64.2	60.9	55.5	54.4
Broadcast (air)	nr	nr	2.6	1.7	nr	nr	5.0	5.2
In irrigation water	nr	nr	0.2	nr	0.3	0.8	1.2	1.3
Banded	14.1	13.8	8.9	9.2	17.2	17.3	20.1	21.2
Foliar	0.1	nr	nr	0.1	2.6	nr	nr	nr
Injected (knifed-in)	2.0	3.8	1.3	0.8	38.2	44.1	47.1	46.7

nr = None reported.

[1]For States included, see box, "Cropping Practices Survey," p. 81.

[2]Percents will add to more than 100 since an acre can be treated more than once.

Source: USDA, ERS, Cropping Practices Survey data.

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Table 3.1.10—Nutrient management practices on spring and durum wheat in major producing States, 1990-93[1]

Practice	Spring wheat				Durum wheat			
	1990	1991	1992	1993	1990	1991	1992	1993
	Percent of acres[2]							
Forms of nutrients applied:								
Livestock manure	5.5	3.2	4.2	3.6	4.6	3.9	4.1	4.9
Chemical fertilizers	69.5	72.7	82.1	87.2	60.3	71.88	73.2	77.9
Fertilizer and manure	4.7	3.2	3.3	3.4	1.5	3.1	0.8	4.1
Lime	nr	nr	0.2	nr	nr	nr	nr	nr
Sulphur	2.7	2.6	2.5	2.0	nr	1.6	1.6	nr
Micro nutrients	1.2	0.7	1.2	nr	nr	0.8	nr	nr
Nitrogen inhibitor	3.3	1.6	0.6	1.6	nr	1.7	1.0	1.0
Soil testing/fertilizer amount:								
Soil tested	31.8	34.0	29.1	33.8	18.3	30.5	21.9	23.8
	Percent of soil-tested acres							
Percent testing for nitrogen (N)	96.8	96.6	97.5	97.2	100.0	94.9	92.6	100.0
	Percent of nitrogen-tested acres							
Applied recommended N rate	nr	nr	79.3	81.5	nr	nr	64.0	82.8
Applied more N than rec.	nr	nr	10.5	9.7	nr	nr	12.0	10.3
Applied less N than rec.	nr	nr	10.1	8.8	nr	nr	24.0	6.9
Fertilizer timing:	*Percent of fertilized acres[2]*							
Fall before planting	39.5	39.0	31.1	33.6	36.7	40.2	30.0	46.3
Spring before planting	34.4	32.3	45.3	38.3	15.2	34.8	45.6	40.0
At planting	62.3	65.2	64.1	73.0	87.3	73.9	71.1	76.8
After planting	2.2	0.3	1.1	3.0	nr	nr	nr	nr
Fertilizer application methods:								
Broadcast (ground)	35.5	34.2	35.6	33.3	12.7	26.1	20.0	14.7
Broadcast (air)	nr	nr	0.3	1.0	nr	nr	nr	nr
In irrigation water	nr	nr	0.3	0.5	nr	nr	1.1	nr
Banded	64.2	62.5	65.4	73.9	81.0	70.6	72.2	76.8
Foliar	1.1	nr	nr	nr	nr	nr	nr	nr
Injected (knifed-in)	40.2	42.5	41.3	45.8	45.6	48.9	52.2	73.7

nr = None reported.

[1]For States included, see box, "Cropping Practices Survey."

[2]Percents will add to more than 100 since an acre can be treated more than once.

Source: USDA, ERS, Cropping Practices Survey data.

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Cropping Practices Survey

The Cropping Practices Surveys collect annual data on fertilizer and pesticide use, tillage systems, crop sequence, and information on other inputs and cultural practices. Fertilizer information has been reported from these surveys since 1964. In the mid-1980's, pesticide use, tillage operations, and prior crop questions were added to the survey. Integrated pest management and nutrient management questions have recently been included.

The 1993 surveys included corn, cotton, soybeans, wheat, and potatoes and represented about 167 million acres. This area includes the acreage in major producing States, which account for about 80 percent of the total U.S. acreage for these crops. Because of priority data needs and available survey funds, the number of crops and States and types of data have varied from year to year. The following crops and States have been included in the recent surveys of fertilizer use:

- Corn: IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI
- Soybeans: Northern: IL, IN, IA, MN, MO, NE, and OH;
Southern: AR, GA, KY, LA, MS, NC, and TN
- Cotton: AR, AZ, CA, LA, MS, and TX
- Winter wheat: CO, ID, IL, KS, MO, MT, NE, OH, OK, OR, SD, TX, and WA.
- Spring wheat: MN, MT, ND, and SD
- Durum wheat: ND
- Fall potatoes: CO, ID, ME, MI, MN, NY, ND, OR, PA, WA, and WI
- Rice: AR and LA.

The sample consists of fields containing a random acre selected through a stratified sampling procedure. Respondents are asked to provide field-level information for the fields containing the sample acre. The operator of the selected sample field is asked to report all fertilizer and nutrient treatments, all tillage operations prior to planting, crops planted in the previous 2 years, and data on other inputs and cultural practices. The operator also identifies whether the field has been designated as highly erodible land (HEL) by the Soil Conservation Service and whether the farm unit participates in Federal price support programs.

Appendix table 3.1.1—Commercial nutrient use by State for years ending June 30, 1992-93[1]

State	1992			1993		
	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
	1,000 nutrient tons					
Maine	13	10	9	12	8	7
New Hampshire	3	1	2	3	1	2
Vermont	6	4	6	5	4	5
Massachusetts	13	6	8	13	6	9
Rhode Island	2	1	1	5	1	1
Connecticut	5	2	3	7	3	4
New York	95	73	95	93	62	83
New Jersey	23	12	16	32	16	22
Pennsylvania	71	55	60	96	73	68
Delaware	22	81	7	20	7	15
Maryland	75	36	49	63	30	45
Northeast	328	208	267	350	211	262
Michigan	257	111	228	240	109	218
Wisconsin	236	115	271	203	107	248
Minnesota	626	242	310	629	259	214
Lake States	1,119	468	809	1,073	474	680
Ohio	331	140	251	377	185	346
Indiana	584	250	395	457	209	342
Illinois	951	391	639	866	377	597
Iowa	969	309	452	840	336	452
Missouri	443	178	250	414	181	252
Corn Belt	3,279	1,269	1,987	2,954	1,288	1,989
North Dakota	383	163	28	497	190	32
South Dakota	169	84	19	205	92	21
Nebraska	755	173	35	729	184	38
Kansas	647	158	40	659	180	42
Northern Plains	1,954	577	123	2,090	646	134
Virginia	119	80	112	108	76	103
West Virginia	10	10	9	10	10	10
North Carolina	218	109	196	219	107	192
Kentucky	208	111	139	208	115	142
Tennessee	164	100	127	161	101	128
Appalachia	718	409	584	705	410	575
South Carolina	78	35	70	80	36	70
Georgia[2]	203	116	163	214	126	276
Florida	248	95	258	253	98	258
Alabama	125	49	66	136	55	76
Southeast	655	295	556	682	314	680
Mississippi	205	62	101	187	54	108
Arkansas	277	67	105	267	73	109
Louisiana	192	50	73	161	45	71
Delta States	674	180	280	615	172	288
Oklahoma	343	77	33	301	92	34
Texas	849	211	113	934	248	133
Southern Plains	1,192	288	146	1,235	340	168
Montana	123	65	14	132	74	16
Idaho	210	90	14	213	93	20
Wyoming	67	13	2	86	23	2
Colorado	130	49	14	174	50	19
New Mexico	33	13	6	36	16	6
Arizona	79	27	1	73	25	1
Utah	20	12	3	28	12	16
Nevada	4	3	1	3	3	1
Mountain	666	270	55	744	296	80
Washington	191	53	36	193	53	38
Oregon	149	44	30	132	41	28
California	490	141	135	554	202	164
Pacific	829	238	201	879	297	230
48 States and DC	11,411	4,202	5,007	4,447	5,086	11,326
Alaska	3	1	1	3	1	0
Hawaii	18	9	18	17	6	13
Puerto Rico	15	6	14	11	4	10
U.S. total	11,447	4,218	5,040	11,358	4,458	5,110

Appendix table 3.1.2—Chemical fertilizer use on corn for grain, major producing States, 1993

State	Acres planted[1]	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P_2O_5	Acres receiving: K_2O	Application rates[2]: N	Application rates[2]: P_2O_5	Application rates[2]: K_2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000		*Percent*				*Pounds/acre*			*Percent*		
Illinois	10,500	738	99	98	81	81	150	76	106	68	3	29
Indiana	5,600	479	99	97	90	79	134	68	114	58	4	38
Iowa	12,000	621	98	98	79	77	114	52	63	76	5	19
Michigan	2,500	308	98	98	93	88	118	53	83	47	1	52
Minnesota	6,300	477	97	97	89	83	103	50	67	82	1	17
Missouri	2,200	247	99	99	76	77	132	53	66	79	8	13
Nebraska[3]	8,100	566	98	98	72	28	136	36	19	52	10	38
Nonirrigated	2,665	181	96	96	66	29	100	29	14	62	13	25
Irrigated	5,435	385	99	99	75	28	153	38	21	48	8	44
Ohio	3,350	465	99	99	95	90	147	71	105	42	2	56
South Dakota	3,400	285	82	82	68	23	70	38	22	83	4	13
Wisconsin	3,400	352	98	97	94	93	80	44	64	75	1	24
Area	57,350	4,538	97	97	82	71	123	56	79	67	4	29

N = nitrogen; P_2O_5 = phosphate; K_2O = potash.

[1] Preliminary.

[2] Average pounds of each nutrient applied to land receiving that nutrient.

[3] Coefficient of variation (CV) for potash (nonir.) greater than 10 percent; for potash (irrigated) greater than 20 percent.

Source: USDA, ERS, Cropping Practices Survey data.

Appendix table 3.1.3—Chemical fertilizer use on upland cotton, major producing States, 1993

State	Acres planted[1]	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P_2O_5	Acres receiving: K_2O	Application rates[2]: N	Application rates[2]: P_2O_5	Application rates[2]: K_2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000		*Percent*				*Pounds/acre*			*Percent*		
Arizona[3]	330	81	98	98	44	10	149	68	5	3	63	34
Arkansas	1,030	131	96	96	76	74	103	48	76	25	7	67
California[4]	1,030	182	98	98	33	6	139	51	149	44	28	28
Louisiana	890	92	86	86	51	52	85	45	66	49	30	20
Mississippi	1,380	159	95	95	43	68	111	57	94	14	13	73
Texas	5,700	506	77	77	58	26	64	43	21	64	15	21
Area	10,360	1,151	85	85	54	36	89	47	58	46	18	36

[1] Preliminary.

[2] Average pounds of each nutrient applied to land receiving that nutrient.

[3] Coefficient of variation (CV) for phosphate greater than 10 percent; for potash greater than 20 percent.

[4] Coefficient of variation (CV) for potash greater than 20 percent.

N = nitrogen; P_2O_5 = phosphate; K_2O = potash.

Source: USDA, ERS, Cropping Practices Survey data.

Appendix table 3.1.4—Chemical fertilizer use on soybeans, major producing States, 1993

State	Acres planted[1]	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P_2O_5	Acres receiving: K_2O	Application rates[2]: N	Application rates[2]: P_2O_5	Application rates[2]: K_2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000		*Percent*				*Pounds/acre*			*Percent*		
Northern:												
Illinois	9,100	535	27	12	20	26	24 *	57	90	98	1	1
Indiana	4,900	356	42	19	29	41	12 *	45	91	95	3	2
Iowa	8,500	441	14	8	11	13	15	51	73	95	5	0
Minnesota	5,600	436	15	11	11	14	17 *	35	62 *	94	5	1
Missouri	4,200	296	22	12	19	21	21**	37	64	98	2	0
Nebraska	2,500	233	20	18	12	5	14 *	32	30**	87	13	0
Ohio	4,200	397	50	14	31	49	17	49	94	98	2	0
Sub-area	39,000	2,694	26	12	18	24	18	47	83	96	3	1
Southern:												
Arkansas	3,500	316	41	14	33	37	42 *	46	68	99	0	1
Georgia	600	136	69	55	63	68	16	35	66	99	1	0
Kentucky	1,200	186	37	27	35	32	21	56	75	97	3	0
Louisiana	1,250	179	12	2	12	12	23**	42	56	95	5	0
Mississippi	2,000	192	21	10	20	21	16 *	39	60	100	0	0
North Carolina	1,300	170	62	54	56	61	19 *	34	80	98	2	0
Tennessee	1,050	176	47	28	42	47	27 *	53	69	100	0	0
Sub-area	10,900	1,355	38	22	34	36	24	44	70	98	1	1
Area	46,900	4,049	29	14	22	27	20	46	79	97	2	1

* = Coefficient of variation (CV) greater than 10 percent; ** = CV greater than 20 percent.

N = nitrogen; P_20_5 = phosphate; K_20 = potash.

[1] Preliminary.

[2] Average pounds of each nutrient applied to land receiving that nutrient.

Source: USDA, ERS, Cropping Practices Survey data.

Appendix table 3.1.5—Chemical fertilizer use on wheat, major producing States, 1993

State	Acres planted[1]	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P_2O_5	Acres receiving: K_2O	Application rates[2]: N	Application rates[2]: P_2O_5	Application rates[2]: K_2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000		*Percent*				*Pounds/acre*			*Percent*		
Winter wheat:												
Colorado	2,550	78	67	67	14	4	50	41 **	22 **	75	19	6
Idaho	850	93	95	95	63	8	102	37	19 **	40	22	38
Illinois	1,550	75	99	99	81	68	87	70	83	13	19	68
Kansas	11,300	52	87	87	51	8	55	30	19 *	62	10	28
Missouri	1,400	67	98	96	77	75	84	52	61	34	22	44
Montana	2,500	93	88	88	84	12	41	29	17 **	79	2	19
Nebraska	2,100	100	75	75	39	12	48	25	10 *	68	13	20
Ohio	1,000	70	99	99	95	95	79	66	74	12	5	84
Oklahoma	5,500	153	96	96	50	10	68	38	22 *	54	11	35
Oregon	860	86	93	93	13	8	62	36 **	31 **	59	12	29
South Dakota	1,400	64	45	45	36	2	36 *	29	9	56	18	25
Texas	3,700	183	77	77	32	5	79	40	16 *	60	19	21
Washington	2,500	139	98	98	38	5	65	22	23 **	81	4	14
Area	37,210	1,453	86	86	49	15	63	37	48	58	12	30
Spring wheat:												
Minnesota	2,500	66	94	94	84	61	97	39	28 *	96	2	2
Montana	2,650	82	65	65	61	13	27	22	9 **	91	0	9
North Dakota	9,700	113	93	92	87	19	67	30	11 *	98	1	1
South Dakota	2,100	58	81	81	71	10	56	24	13	98	0	2
Area	16,950	319	88	88	81	23	66	30	18 *	97	1	2
Durum wheat:												
North Dakota	1,950	122	73	73	60	7	51	26	12 **	100	0	0
All wheat:[3]												
Colorado	2,550	78	67	67	14	4	50	41 **	22 **	75	19	6
Idaho	850	93	95	95	62	8	102	37	19 **	40	22	38
Illinois	1,550	75	99	99	81	68	87	70	83	13	19	68
Kansas	11,300	252	87	87	51	8	55	30	19 *	62	10	28
Minnesota	2,500	66	94	94	83	61	98	39	28 *	97	2	2
Missouri	1,400	67	98	96	77	75	84	52	61	34	22	44
Montana	5,150	175	76	76	72	13	35	26	13 **	84	1	15
Nebraska	2,100	100	75	75	39	12	48	24	10 *	68	13	20
North Dakota	11,650	235	90	90	83	17	66	30	11 *	98	1	1
Ohio	1,000	70	99	99	95	95	79	66	74	12	5	84
Oklahoma	5,500	153	96	96	50	10	68	38	22 *	54	11	35
Oregon	860	86	93	93	13	8	62	36 **	31 **	59	12	29
South Dakota	3,500	122	66	66	57	7	51	25	13	87	5	8
Texas	3,700	183	77	77	32	5	79	40	16 *	60	19	21
Washington	2,500	139	98	98	38	5	65	22 *	23 **	81	4	15
Area	56,110	1,894	87	86	60	17	64	34	35	72	8	20

* = Coefficient of variation (CV) greater than 10 percent; ** = CV greater than 20 percent.

N = nitrogen; P_20_5 = phosphate; K_20 = potash.

[1] Preliminary; acres are harvested for winter wheat and planted for all other crops.

[2] Average pounds of each nutrient applied to land receiving that nutrient.

[3] Does not include winter wheat in MN and ND; spring wheat in CO and WA; or durum wheat in MN, MT, and SD.

Source: USDA, ERS, Cropping Practices Survey data.