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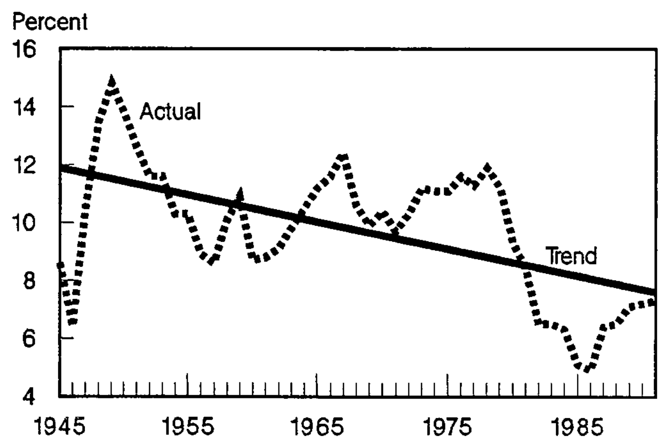

Nominal dollars.
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Coordinators: Harold Taylor & Len Bull

Principal Contributors
(202) 219-0456
Harold Taylor (Fertilizer)
Herman W. Delvo (Pesticides)
Len Bull (Tillage Systems)
Noel Uri, Mohinder Gill (Energy)
Marlow Vesterby (Farm Machinery)
Mohinder Gill (Seeds)

Senior Systems Analyst
Bill Lindamood

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Summary

Fertilizer use in 1991/92 is expected to increase 2 percent and prices to rise 3 to 4 percent above last Spring; while application rates on corn, soybeans, and wheat are anticipated to remain near those of 1990/91. Planted area of corn and wheat, the major fertilizer-using crops, is projected to increase, while planted area for cotton and soybeans to decline slightly. Nitrogen use is forecast at 11.15 million tons, phosphate at 4.33 million, and potash at 5.26 million.

Given current inventories and imports, and increased or stable domestic production, U.S. fertilizer supplies will satisfy greater domestic and export demand at slightly higher prices. Exports during 1991/92 are forecast to rise modestly from a year earlier. Intensified use in developing countries has helped to offset reduced consumption in Central and Eastern Europe and the former USSR. World production also is projected to decline.

Pesticide use on the 10 major field crops in 1992 is projected at 482 million pounds active ingredients (a.i.), up less than 1 percent from 1991. Herbicide use is expected to rise 3.8 million pounds as a result of an estimated expansion in corn acreage. Insecticide and fungicide use is likely to remain stable, but variability in weather and pest infestations will influence final consumption.

Tillage systems used on 1991 crop acreage varied little from 1990. About 30 percent of the corn acreage received conservation tillage methods, 20 percent mulch-till and 10 percent no-till (including ridge-till). Only 15 percent was tilled with the moldboard plow, continuing the trend downward from 20 percent in 1988. The moldboard plow was used on less than 10 percent of the crops produced on highly erodible land, except for cotton (32 percent). The decline in use of the moldboard plow on highly erodible land should continue over the next few years, as farmers implement approved conservation plans.

Soybean production with conservation tillage varied from 35 percent of the acreage in the northern area to 17 percent in the southern area. Greater use of the moldboard plow was made in the northern area, 18 percent compared to 3 percent for the southern area.

Nearly all cotton in the area surveyed was produced with conventional tillage, 21 percent with the moldboard plow and 76 percent without. Over 30 percent of the spring and durum wheat acres utilized mulch tillage and 55 to 60 percent were conventionally tilled without the moldboard plow. Conventional tillage without the moldboard plow was used on about 94 percent of the rice acreage.

U.S. farmers can expect 1992 energy prices to remain at or slightly above 1991 averages due to anticipated steady or slightly higher prices for imported crude oil. For 1991, direct energy expenditures (about 5.9 percent of total cash farm production expenses) are expected to be approximately 3 percent above the preceding year. This rise is attributed to an increase in energy prices and little change in energy use.

Unit tractor sales decreased 12 percent in 1991. Combine sales were down 7 percent. Both tractor and combine sales are forecast to decrease another 7 percent in 1992. Expenditures on tractors and other farm machinery fell from $8.2 billion in 1990 to an estimated $7.6 billion in 1991 and will likely continue to decrease in 1992.

Seed use for last year's eight major crops was 5.9 million tons, down 4 percent from the previous year. Seed use for this year's crops is likely to increase 1 percent above a year earlier as a result of planted acreage gains in wheat, corn, rice, barley, and sorghum.

USDA's prices paid index for seed was nearly unchanged between 1990 and 1991, but the index will likely increase 2-4 percent in 1992. Expected increases in planted acreage are likely to put upward pressure on some spring seed prices. Given the modest increase in the Conservation Reserve Program acreage, 1992 forage seed prices are not likely to increase significantly.

The U.S. net seed trade surplus rose 8 percent to $331 million in the first 9 months of 1991 compared with the same period a year earlier. This increase primarily reflects gains in corn and vegetable seed exports.

Fertilizer

Consumption

Plant nutrient use in the United States is forecast at 20.74 million nutrient tons during fertilizer year 1991/92 (July 1-June 30), up 2 percent from 1990/91. Nitrogen use is forecast at 11.15 million tons, phosphate at 4.33 million, and potash at 5.26 million. During 1990/91, farmers used 11.18 million tons of nitrogen, 4.15 million of phosphate, and 4.98 million of potash.

Fertilizer use in 1991/92 is expected to increase. Planted area of corn and wheat, the major fertilizer-using crops, is expected to increase, while planted area for cotton and soybeans is expected to slightly decline (table 1). Gains in planted area are also expected for rice, barley, and sorghum, but a decrease is anticipated for oats.

Fertilizer application rates on corn, soybeans, and wheat are expected to remain near those of 1991, when rates were a little less than the previous year due to wet soil conditions in some areas that hampered spring fertilizer applications. Cotton rates should also remain close to those of 1991. The 1990/91 application rates may also reflect recommendations from soil testing and farmers' concerns for the environment.

Table 1--Acreage assumptions for 1992 input use forecast

Crop	1991 actual	1992 forecast
	Million planted acres	
Wheat	70.0	72.3 - 75.3
Feed grains	104.4	102.3 - 108.3
Corn	75.9	76.0 - 80.0
Other 1/	28.5	26.3 - 28.3
Soybeans	59.8	56.5 - 59.5
Cotton (all types)	14.1	12.8 - 13.8
Rice	2.9	2.9 - 3.3

1/ Sorghum, barley, and oats.

Spring 1992 fertilizer prices will likely be 3 to 4 percent higher than a year earlier because tightening supplies and increased planted acres will likely put upward pressure on prices.

Exports of fertilizer materials during 1991/92 are projected to rise from a year earlier, due to reduced production in Eastern Europe and the former USSR, as well as from increased demand in developing countries. Overall, nitrogen exports will likely climb 11 percent, assuming trends of the first 5 months continue (table 2). Phosphate exports should increase also if diammonium phosphate shipments to Asia stay strong. Potash exports are expected to decrease over last year by about 2 percent.

Supplies

Domestic supplies of nitrogen fertilizer should be adequate to meet 1992 crop needs because inventories, production, and imports should exceed demand. However, anticipation of increased planted acres and exports should put upward pressure on prices. During the second half of the 1990/91 fertilizer year, higher imports partially offset reduced domestic production and created excess supplies that placed downward pressure on domestic prices.

Reduced production in Central and Eastern Europe tightened supplies, and, in general, strengthened the U.S. market in the first half of the 1991/92 fertilizer year. The forecast is for increased domestic production in anticipation of increased planted acres and slightly reduced nitrogen imports. Domestic phosphate and potash supplies will be ample because of

Table 2--U.S. supply-demand balance for years ending June 30

Item	Nitrogen 1990	Nitrogen 1991	Nitrogen 1992 1/	Phosphate 1990	Phosphate 1991	Phosphate 1992 1/	Potash 1990	Potash 1991	Potash 1992 1/
				Million nutrient tons					
Producers' beginning inventory	1.51	1.14	1.01	0.70	0.52	0.57	0.22	0.34	0.19
Production	13.45	13.89	13.97	3/ 11.78	3/12.22	12.23	1.83	1.83	1.82
Imports	2/ 3.81	2/ 3.42	3.20	0.07	0.05	0.05	4.16	4.61	4.87
Total available supply	4/ 18.77	4/18.44	18.18	12.55	12.78	12.84	6.21	6.79	6.88
Agricultural consumption	11.08	11.18	11.15	4.34	4.15	4.33	5.20	4.98	5.26
Exports	3.14	3.37	3.75	5/ 5.49	5.57	6.93	0.39	0.63	0.62
Total agricultural and export demand	14.21	14.55	14.90	5/ 9.84	9.72	11.26	5.59	5.61	5.88
Producers' ending inventory	1.14	1.01	1.23	0.52	0.57	0.61	0.34	0.19	0.26
Available for non-agricultural use	4/ 3.42	4/ 2.88	2.05	2.20	2.50	0.97	0.27	0.99	0.74

1/ Forecast. 2/ Anhydrous ammonia data is understated since imports from the former USSR are not available.
3/ Does not include phosphate rock. 4/ Significantly understated due to lack of import data for anhydrous ammonia.

Sources: (2, 3, 6, 7, 8).

increased or stable domestic production supplemented by potash imports from Canada.

Transportation difficulties may trigger some regional shortages of fertilizer materials this spring. The U.S. rail system is still plagued by hopper car shortages during peak demand periods, which could trigger spot fertilizer shortages in some areas or higher prices if additional transportation costs are passed on to farmers.

Nitrogen production rates for July-September 1991 were up about 2 percent and indicate that about 96 percent of U.S. anhydrous ammonia capacity was being used (9). Wet-process phosphoric acid facilities, capable of producing almost 12.6 million tons of product a year, operated at 99 percent of capacity through September. During the same period in 1990, anhydrous ammonia and wet-process phosphoric plants operated at about 95 and 103 percent of capacity, respectively.

U.S. potash facilities operated at 81 percent of capacity, producing 0.6 million tons through October 1991. Canadian facilities operated at 52 percent, producing 2.4 million tons. A year earlier, potash plants in the United States and Canada operated at 80 and 55 percent of capacity, respectively.

Nitrogen production is projected to increase about 1 percent in 1991/92 from the previous year. U.S. nitrogen imports are expected to decrease about 6 percent, due to increased domestic production. Shipments will continue to come from Canada, the former USSR, and Trinidad-Tobago, with Canada being the major U.S. supplier (1). During 1990/91, anhydrous ammonia and nitrogen solutions production increased 3 and 5 percent, respectively, to 16.9 and 3.0 million tons (table 3). Decreased production of other nitrogen materials ranged from 1 percent for urea to 3 percent for both ammonium sulfate and ammonium nitrate.

Table 3--U.S. production of selected fertilizer materials for years ending June 30

Material	1990	1991 1/	Annual change
	---1,000 tons---		Percent
Nitrogenous fertilizers: 2/			
Anhydrous ammonia 3/	16,406	16,933	3
Ammonium nitrate, solid	2,179	2,103	-3
Ammonium sulfate	2,443	2,376	-3
Urea 3/	8,073	8,027	-1
Nitrogen solutions	2,880	3,011	5
Phosphate fertilizers: 4/			
Normal and enriched superphosphate	55	52	-6
Triple superphosphate	818	934	14
Diammonium phosphate	6,405	6,641	4
Other ammonium phosphates and other phosphatic fertilizer materials	1,213	1,199	-1
Total 5/	8,491	8,826	4
Wet-process phosphoric acid 6/	11,196	11,748	5
Muriate of potash: 7/			
United States	1,827	1,834	0
Canada	7,466	8,290	11

1/ Preliminary. 2/ Total not listed because nitrogen solutions are in 1,000 tons of N, while other nitrogen products are in 1,000 tons of material. 3/ Includes material for nonfertilizer use. 4/ Reported in 1,000 tons P205. 5/ Totals may not add due to rounding. 6/ Includes merchant acid. 7/ Reported in 1,000 tons of K20.

Sources: (2, 8).

U.S. phosphate production is expected to increase marginally in 1991/92 in response to higher prices. Increased domestic demand and continued strength in the export market is expected. Diammonium phosphate production, which accounts for the largest proportion of U.S. phosphate fertilizer production, rose 4 percent during 1990/91. Production of normal and enriched superphosphate dropped 6 percent in 1990/91 and triple superphosphate production increased about 4 percent.

In 1991/92, domestic potash production will likely decrease by less than 1 percent as a result of higher operating costs. However, U.S. potash imports are expected to increase modestly in response to more planted acres as U.S. suppliers build inventories in anticipation of higher spring demand and price increases.

Farm Prices

Spring 1992 fertilizer prices will likely be 3 to 4 percent above a year earlier. A tightening world demand-supply situation and an anticipated increase in planted acres are putting upward pressure on prices. Higher transportation costs will also contribute to increased fertilizer prices.

Nitrogen prices will likely increase as domestic supplies tighten and production costs of anhydrous ammonia increase. The major production cost of anhydrous ammonia is its feedstock, such as natural gas, fuel oil, or refinery gas, and a modest increase in price is expected. Phosphate and potash prices will also be higher than in the fall as the export market demonstrates continued strength.

Fertilizer prices paid by farmers decreased slightly (less than 1 percent) from October 1989 to April 1990 (table 4). Prices fell again in late spring of 1990 due to excess supplies. Demand and supply were more in balance just prior to the Persian Gulf crisis in August. October 1990 farm prices included the initial shock of the crisis and an increase of 1 to 2 percent from April 1990. Spring 1991 prices were about 3 percent higher than fall 1990. Fall 1991 fertilizer prices were about the same as a year earlier and 3 percent less than spring 1991.

U.S. Fertilizer Trade

Anhydrous ammonia accounts for 35-60 percent of total nitrogen material imports and 25 percent of total nitrogen material exports. During calendar year 1989 the Department of Commerce (DOC) ceased reporting quantity data for anhydrous ammonia trade. The DOC took this action in response to a disclosure petition filed by a fertilizer importer. Al-

Table 4--Average U.S. farm prices for selected fertilizer materials 1/

Year	Anhydrous ammonia (82%)	Urea (44-46%)	Triple superphosphate (44-46%)	Diammonium phosphate (18-46-0%)	Potash (60%)	Mixed fertilizer (6-24-24%)	Prices-paid index
	$/ton						1977=100
1986:							
April	225	174	190	224	111	179	125
October	174	159	182	205	107	173	116
1987:							
April	187	161	194	220	115	176	117
October	180	159	206	231	135	183	121
1988:							
April	208	183	222	251	157	208	132
October	191	188	221	246	157	208	134
1989:							
April	224	212	229	256	163	217	141
October	180	172	204	218	153	196	131
1990:							
April	199	184	201	219	155	198	130
October	191	199	205	228	150	201	132
1991:							
April	210	212	217	235	156	206	136
October	188	203	211	228	148	202	132

1/ Based on a survey of fertilizer dealers conducted by the National Agricultural Statistics Service, USDA.

though data for 1990 and 1991 are now available, the quantity of U.S. fertilizer trade data will be understated since imports from the former USSR are not available.

Fertilizer import volume in 1990/91 increased less than 1 percent from a year earlier while higher prices, exchange rates, and product mix caused value to increase 4 percent (table 5). Imports totaled approximately 14.6 million tons (8.1 million nutrient tons), valued at $1.3 billion. Canada provided a substantial share of U.S. nitrogen imports and almost all potash imports. During July-November of fertilizer year 1991/92, fertilizer import volume increased about 7 percent.

U.S. fertilizer exports totaled 23.5 million tons (9.6 million nutrient tons), about 4 percent less than the previous year (table 6). Asian countries provided the largest markets, followed by Canada and Latin America. China and India received about 21 and 10 percent, respectively, of all U.S. fertilizer exports. South Korea, the Netherlands, Mexico, Japan, France, India, and Canada were the recipients of around 17, 14, 11, 10, 10, 9, and 7 percent, respectively, of phosphate rock exports.

During July-November 1991, exports increased by about 10 percent as purchases by India and China surpassed those of July-November 1990 (table 6). Processed phosphate exports increased about 31 percent, and phosphate rock exports went down 8 percent. Imports of potassium chloride, the major source of potash, increased 24 percent (table 5).

Nitrogen Trade

Imports of all nitrogen materials except urea, sodium nitrate, and other (ammonium sulfates and ammonium nitrates, etc.)

Table 5--U.S. imports of selected fertilizer materials

Material	Fertilizer year 1989/90	Fertilizer year 1990/91	July-November 1990	July-November 1991
	1,000 tons			
Nitrogen:				
Anhydrous ammonia 1/	2,998	2,650	1,161	1,119
Aqua ammonia	41	10	4	2
Urea	1,933	1,980	890	688
Ammonium nitrate	443	408	155	207
Ammonium sulfate	422	317	101	126
Sodium nitrate	141	156	70	54
Calcium nitrate	104	66	33	39
Nitrogen solutions	489	256	108	75
Other	52	72	28	25
Phosphate:				
Ammonium phosphates	15	4	2	3
Crude phosphates	434	553	216	259
Phosphoric acid 2/	2	1	*	1
Normal and triple superphosphate	2	1	1	*
Other	5	2	*	*
Total	458	561	219	263
Potash:				
Potassium chloride	6,703	7,451	2,787	3,466
Potassium sulfate	56	68	27	23
Potassium nitrate 3/	41	34	23	10
Other	354	353	173	77
Total	7,154	7,906	3,010	3,576
Mixed fertilizers	288	193	83	72
Total	14,523	14,575	5,862	6,246
	$ billion			
Total value 4/	1.20	1.25	0.48	0.48

* = Less than 500 tons.

1/ Does not include imports from the former USSR, thus nitrogen imports and domestic supply are significantly understated. 2/ Includes all forms of phosphoric acid. 3/ Includes potassium sodium nitrate. 4/ Value by fertilizer material in appendix table 1.

Source: (7).

Table 6--U.S. exports of selected fertilizer materials 1/

Material	Fertilizer year 1989/90	Fertilizer year 1990/91	July-November 1990	July-November 1991
	1,000 tons			
Nitrogen:				
Anhydrous ammonia	511	853	290	235
Aqua ammonia	15	0	0	0
Urea	1,249	1,050	410	468
Ammonium nitrate	149	26	8	18
Ammonium sulfate	933	994	519	345
Sodium nitrate	2	5	1	2
Nitrogen solutions	429	447	227	157
Other	37	39	14	15
Total	3,325	3,414	1,469	1,240
Processed phosphate:				
Normal superphosphate	22	45	21	11
Triple superphosphate	731	752	277	485
Diammonium phosphate	9,035	9,538	3,435	4,717
Monoammonium and other ammonium phosphates	917	749	284	401
Phosphoric acid--				
Wet-process	729	544	308	260
Super	72	107	93	27
Other	119	105	92	6
Total	11,625	11,840	4,510	5,907
Phosphate rock 2/	8,336	6,607	2,803	2,571
Potash:				
Potassium chloride	423	805	295	318
Potassium sulfate	209	237	104	95
Other	343	336	140	153
Total	975	1,378	539	566
Mixed fertilizers	318	282	105	110
Total	24,579	23,521	9,426	10,394

1/ Declared value of exports not reported after 1985.
2/ Effective January 1984, phosphate rock exports include a small tonnage of miscellaneous fertilizers.

Source: (6).

decreased in 1990/91. Anhydrous ammonia and nitrogen solution imports declined 12 and 48 percent. Ammonium nitrate imports went down 8 percent. Urea imports, which increased from 1.93 to 1.98 million tons, represented 33 percent of all nitrogen material imports during the previous fertilizer year.

In 1990/91, Canada remained the major foreign supplier of nitrogen fertilizer, providing about 42 percent of U.S. import tonnage. On a value basis, Canada was the major source of U.S. anhydrous ammonia imports, earning over 46 percent of anhydrous ammonia import value. Canada also provided most of the imported urea, supplying about 64 percent of the 1.98 million tons of U.S. imports. Trinidad-Tobago and Mexico each shipped another 8 percent.

In 1990/91 the volume of all nitrogen material exports increased from the previous year. Overall nitrogen exports went up 3 percent. Urea exports decreased 16 percent and made up 31 percent of the 3.4 million tons of nitrogen materials exported; ammonium sulfate, 30 percent; nitrogen solutions, 13 percent; anhydrous ammonia, 25 percent; and ammonium nitrate, 1 percent (table 6). Diammonium phosphate (18 percent nitrogen and 46 percent phosphate) accounted for over 51 percent of the 3.4 million nutrient tons of nitrogen exported and 79 percent of the processed phosphate.

Brazil was the largest customer for U.S. ammonium sulfate, purchasing 40 percent of the 0.9 million tons exported. China, France, Chile, and Canada purchased the most urea, importing 46, 9, 15, and 9 percent. Belgium-Luxembourg and France were the largest purchasers of nitrogen solutions, taking 43 percent each.

Phosphate Trade

At 11.8 million tons, U.S. phosphate fertilizer exports in 1990/91 went up 2 percent from the previous year. China and India were the largest purchasers, accounting for 38 and 13 percent of the total. Other important customers were Canada, Chile, Colombia, and Venezuela. Although data on exports of superphosphoric acid to the former USSR are not available, the Soviets buy large amounts of U.S. phosphate fertilizer.

Exports of most phosphate fertilizer materials increased—except for monoammonium and other ammonium phosphates, and wet-process phosphoric acid, which fell 18 and 12 percent. Exports of normal superphosphate, diammonium phosphates, triple superphosphate, and super phosphoric acid went up 105, 6, 3, 49 percent, respectively. India purchased 53 percent of all U.S. super phosphoric acid exports. Chile received about 18 percent (133,000 tons) of concentrated superphosphates. China received 45 percent (4.3 million tons) of diammonium phosphate exports, and Canada imported 34 percent (251,000 tons) of monoammonium phosphate. South Korea purchased the most U.S. phosphate rock, accounting for 17 percent of all exports, while Mexico, the Netherlands, Japan, France, and Canada took 10, 14, 11, 11, and 7 percent.

At 6.6 million tons, U.S. phosphate rock exports declined 21 percent in 1990/91, continuing a trend toward the shipping of processed phosphate fertilizer rather than rock. The phosphate rock of other exporting countries has a higher ore content than that of the United States.

Potash Trade

U.S. exports of potassium fertilizer materials increased about 41 percent in 1990/91. Approximately 1.4 million tons were shipped, with potassium chloride accounting for 58 percent of the total and increasing 90 percent from the previous year (table 6). Brazil and China received 38 and 7 percent of the potassium chloride shipped, respectively. Potassium sulfate exports went up 13 percent, comprising 17 percent of potassium exports with China receiving 50 percent of the total.

U.S. potassium chloride imports increased about 11 percent in 1990/91 to 7.5 million tons (table 5). Potassium chloride accounted for almost all potash imports, with Canada providing 92 percent of the total, down from 94 percent the previous year. Israel and Germany were the only other significant importers, supplying 5 and 2 percent.

Fertilizer Use Estimates

In 1990/91, 46.8 million tons of fertilizer material were used in the United States and Puerto Rico, down 2 percent from the previous year (table 7). Use of plant nutrients of 20.3 million tons represented an decrease of 1.5 percent from the previous year. Nitrogen use increased 1 percent to 11.2 million tons, while phosphate and potash use declined over 4 percent each to 4.2 and 5.0 million tons.

Changes in regional consumption varied (table 8). Plant nutrient use fell as much as 7 percent in the Southeast. In the Southern Plains, it rose as much as 8 percent due to changes in planted acreage and a return to historical application rates for phosphate and potash. Nitrogen use decreased except in the Corn Belt, Northern Plains, and Southern Plains, where it climbed 2, 8, and 9 percent (table 9). Use of phosphate decreased in all regions except the Southern Plains, where it increased 6 percent. Potash use increased 2, 4, 22, and 11

Table 7--U.S. fertilizer consumption 1/

Year ending June 30 2/	Total fertilizer materials	Primary nutrient use				
		N	P205	K20	Total 3/	(1977=100)
	Million tons					Percent
1977	51.6	10.6	5.6	5.8	22.1	100
1980	52.8	11.4	5.4	6.2	23.1	104
1981	54.0	11.9	5.4	6.3	23.7	107
1982	48.7	11.0	4.8	5.6	21.4	97
1983	41.8	9.1	4.1	4.8	18.1	82
1984	50.1	11.1	4.9	5.8	21.8	99
1985	49.1	11.5	4.7	5.6	21.7	98
1986	44.1	10.4	4.2	5.1	19.7	89
1987	43.0	10.2	4.0	4.8	19.1	86
1988	44.5	10.5	4.1	5.0	19.6	89
1989	44.9	10.6	4.1	4.8	19.6	89
1990	47.7	11.1	4.3	5.2	20.6	93
1991	46.8	11.2	4.2	5.0	20.3	92

1/ Includes Puerto Rico. Detailed State data shown in appendix table 2. 2/ Fertilizer use estimates for 1977-84 are based on USDA data; those for 1985-91 are TVA estimates. 3/ Totals may not add due to rounding.

Source: (3).

Table 8--Regional plant nutrient consumption for year ending June 30 1/

Region	1990	1991	Annual change
	1,000 tons		Percent
Northeast	763	756	-1
Lake States	2,583	2,440	-6
Corn Belt	6,681	6,587	-1
Northern Plains	2,434	2,557	5
Appalachia	1,586	1,548	-2
Southeast	1,536	1,427	-7
Delta States	1,060	992	-6
Southern Plains	1,575	1,707	8
Mountain	987	964	-2
Pacific 2/	1,389	1,306	-6
U.S. total 3/	20,595	20,282	-1.5

1/ Includes N, P205, and K20. Totals may not add due to rounding. 2/ Includes Alaska and Hawaii. 3/ Excludes Puerto Rico. Detailed State data shown in appendix table 2.

Table 9--Regional plant nutrient use for year ending June 30 1/

Region	1990	1991	Annual change
	---1,000 tons---		Percent
Nitrogen:			
Northeast	306	299	-2
Lake States	1,134	1,128	-1
Corn Belt	3,215	3,280	2
Northern Plains	1,751	1,890	8
Appalachia	667	646	-3
Southeast	670	628	-6
Delta States	643	609	-5
Southern Plains	1,117	1,223	9
Mountain	642	628	-2
Pacific 2/	921	834	-9
U.S. total 3/	11,065	11,165	0.9
Phosphate:			
Northeast	197	191	-3
Lake States	508	479	-6
Corn Belt	1,334	1,262	-5
Northern Plains	550	541	-2
Appalachia	381	374	-2
Southeast	308	282	-8
Delta States	177	154	-13
Southern Plains	315	334	6
Mountain	279	255	-9
Pacific 2/	289	273	-6
U.S. total 3/	4,339	4,145	-4.5
Potash:			
Northeast	261	266	2
Lake States	941	832	-12
Corn Belt	2,132	2,044	-4
Northern Plains	133	127	-4
Appalachia	538	527	-2
Southeast	559	518	-7
Delta States	240	229	-5
Southern Plains	143	150	4
Mountain	65	80	22
Pacific 2/	179	199	11
U.S. total 3/	5,192	4,972	-4.2

1/ Totals may not add due to rounding. 2/ Includes Alaska and Hawaii. 3/ Excludes Puerto Rico. Detailed State data shown in appendix table 2.

Source: (3).

Table 10--Average annual U.S. fertilizer use 1/

Year ending June 30 4/	Multiple nutrient 2/		Single nutrient 3/	
	Quantity	Share of total	Quantity	Share of total
	Million tons	Percent	Million tons	Percent
1980	23.3	44	29.5	56
1981	23.5	44	30.5	56
1982	20.9	43	27.8	57
1983	18.4	44	23.5	56
1984	21.2	42	28.9	58
1985	20.6	44	26.7	56
1986	17.8	42	24.7	58
1987	17.1	42	24.1	58
1988	17.6	41	25.1	59
1989	17.6	41	25.2	59
1990	18.4	41	26.9	59
1991	17.6	40	26.6	60

1/ Includes Puerto Rico. 2/ Fertilizer materials that contain more than one primary nutrient. 3/ Materials that contain only one nutrient. 4/ Fertilizer use estimates for 1980-84 are based on USDA data; those for 1985-91 are TVA estimates.

Source: (3).

percent in the Northeast, Southern Plains, Mountain, and Pacific regions.

The proportion of fertilizers applied as single nutrient materials increased slightly, constituting 60 percent of U.S. fertilizer use in 1990/91 (table 10). Farmers continued to use more concentrated materials to meet plant nutrient needs.

Corn for Grain

Fertilizer was applied to 97 percent of the corn acres in 1990/91 (table 11). The proportion of acres fertilized with nitrogen remained unchanged, while the proportion fertilized with phosphate and potash decreased. Application rates of nitrogen and potash decreased slightly from a year earlier to 128 and 81 pounds per acre while phosphate rates remained at 60.

Cotton

The proportion of acres receiving some fertilizer in 1990/91 increased to 81 percent, up from 80 in 1989/90. The proportion of acres receiving nitrogen, phosphate, and potash increased to 81, 52, and 34, respectively. Application rates for nitrogen, phosphate, and potash increased to 91, 47, and 48 pounds per acre, up from 86, 44, and 47 in 1989/90.

Rice

Fertilizer was applied on 99 percent of the rice acreage in 1990/91. The proportion of acres treated with the various nutrients ranged from 99 percent for nitrogen to 30 percent for phosphate. The application rate for nitrogen, at 127 pounds per acre, was reduced last year because of heavy spring rains and flooding, but remained near earlier year levels. Rates for phosphate increased a pound per acre to 46 pounds, while potash rates decreased to 47 pounds.

Table 11--Fertilizer use on selected U.S. field crops 1/

Crop, year	Acres receiving: Any fertilizer	N	P205	K20	Application rates: N	P205	K20
	Percent				Pounds/acre		
Corn for grain:							
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
Cotton:							
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
Rice:							
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
Soybeans:							
1985	32	17	28	30	15	43	72
1986	33	18	29	31	15	43	71
1987	30	15	25	28	20	47	75
1988	32	16	26	31	22	48	79
1989	34	17	28	32	18	46	74
Northern area	30	14	23	28	16	48	77
Southern area	44	24	42	44	21	43	67
1990	31	17	24	29	24	47	81
Northern area	27	14	20	25	22	47	87
Southern area	41	26	38	39	28	47	70
1991	28	16	22	25	25	48	77
Northern area	26	14	19	22	24	49	80
Southern area	37	21	33	35	28	45	70
All wheat:							
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

1/ Detailed data for selected States by crop shown in appendix tables 3-7.

Soybeans

Some fertilizer was applied to 28 percent of soybean acres planted in 1990/91. This was down from 31 percent the previous year, as the proportion of acres fertilized declined for nitrogen, phosphate, and potash. However, application rates for nitrogen and phosphate increased from the preceding year while potash decreased. Application rates were the highest for potash at 77 pounds per acre, followed by phosphate at 48 pounds, and nitrogen at 25 pounds. There were some differences in application rates between the northern and southern regions, with the North applying less nitrogen per acre and more phosphate and potash.

Wheat

The share of wheat acres fertilized increased from 79 percent in 1989/90 to 80 percent in 1990/91. The proportion of acres treated with nitrogen increased to 80 percent, and the proportion treated with phosphate increased to 54 percent. Potash-treated acres increased to 20 percent. Potash application rates decreased to 43 pounds per acre, while phosphate remained the same. The rate for nitrogen went up to 62 pounds.

World Fertilizer Review and Prospects

World plant nutrient production and use increased in 1987/88 but likely decreased in 1989/90 and 1990/91. Fertilizer production and consumption rose significantly in developing market economies (Asia, Africa, and Latin America), but only slightly in developed market economies. However, changes in Central and Eastern Europe, and the former USSR, the crisis in the Persian Gulf, and other world developments reduced production and consumption, resulting in lower overall estimates.

World Supplies

In 1989/90, world plant nutrient supplies probably have decreased more than 3 percent to 143.7 million metric tons (table 12). Nitrogen supplies decreased 1 percent to 80.1 million tons, and phosphate supplies went down 5 percent to 37.5 million metric tons. Potash supplies decreased 8 percent to 26.1 million metric tons. World supplies likely declined another 2 percent during fertilizer year 1990/91. Reduced production in Central and Eastern Europe and the former USSR reduced world supplies in the short term and put upward pressure on world prices.

Consumption

World plant nutrient consumption in 1989/90 decreased less than 2 percent from a year earlier to about 143.3 million metric tons (table 12). Nitrogen use dropped less than 1 percent, while phosphate and potash use fell less than 2 and 4 percent, respectively. Nitrogen, phosphate, and potash consumption decreased to about 79, 37, and 27 million metric tons. In 1990/91, world plant nutrient use went down an estimated 2 to 3 percent due to decreased demand in Central and Eastern Europe and the former USSR. Demand in the developing market economies of Latin America and Asia is still strong.

Table 12--World plant nutrient supply and consumption for years ending June 30

Plant nutrient	1989	1990 1/	1991 1/
	Million metric tons		
Available supply: 2/			
Nitrogen	80.8	80.1	77.7
Phosphate	39.2	37.5	37.3
Potash	28.5	26.1	25.2
Total 3/	148.5	143.7	140.3
Consumption:			
Nitrogen	79.7	79.1	77.8
Phosphate	38.0	37.4	36.4
Potash	28.1	26.9	25.5
Total 3/	145.7	143.3	139.7

1/ Projected. 2/ Production less industrial uses and losses in transportation, storage, and handling. 3/ Totals may not add due to rounding.

Source: (4, 5).

World Trade Developments

Existing nitrogen trade patterns should continue. Canada, Eastern Europe and the former USSR will continue to supply nitrogen fertilizer to the United States, Western Europe, and Asia. Additional nitrogen fertilizer production in Canada and Trinidad-Tobago will compete for a share of the already-crowded North American, West European, and Mediterranean markets. Surplus nitrogen from the Near East will probably move to Asian markets.

Phosphate production is expected to grow in most regions. Although U.S. consumption is stabilizing, world consumption will increase, tightening the supply-demand balance. Asia should have the most active trade, because countries in that region are expected to produce only a small share of the phosphate they need. The African and U.S. phosphate industries will compete for this growing market.

Canada, Germany, Israel, and the former USSR are the major potash exporters. Canadian exports are expected to outdistance those of other major exporters by further penetrating the large Indian and Chinese markets and continuing shipments to the United States.

World Fertilizer Prices

Intensified use of fertilizer in developing countries has temporarily helped to offset reduced consumption in Central and Eastern Europe and the former USSR. Further, projected world production also is expected to decline. World consumption dropped about 1.6 percent in 1989/90, while available supply decreased 3.2 percent. The tighter supply-demand situation should raise world prices in 1991/92 over fall 1991 prices. The long-awaited resumption of Chinese and Indian demand, as well as strong U.S. import demand, will fuel upward price movement in the future.

Global Projections to 1996

According to 1991 forecasts of the Food and Agriculture Organization/United Nations Industrial Development Organization/World Bank/Industry Working Group, world fertilizer consumption of nitrogen, phosphate, and potash is expected to grow 10, 9, and 6 percent during 1991-96 (table 13). Fertilizer production and use are projected to grow fastest in developing countries in South America and Asia, and the developing market and centrally planned economies of Asia.

By 1996, consumption in Western Europe is expected to decline from 4 to 9 percent, depending on the nutrient. This is down from earlier projections of over 10-percent growth. The slower rate of growth in U.S. consumption assumes continuation of acreage set-aside programs. Stable demand in Western Europe will also slow growth in world fertilizer use and curb nitrogen and phosphate production rates. North American potash exports to South America are expected to rise, supporting growth in U.S. and Canadian potash production. Smaller potash production increases in Eastern Europe and the former USSR could reduce those countries' exports.

Table 13--Projected 1991-96 change in world fertilizer supply and consumption 1/

World regions	Nitrogen	Phosphate	Potash
	Percent increase		
Supply potential:			
Africa	28	17	0
America:	5	3	11
North America	5	3	11
Central America	3	0	0
South America	18	8	2/
Asia:	19	16	10
West Asia	41	35	7
South Asia	30	19	0
East Asia	11	11	2/
Europe:	5	4	-12
East Europe	11	9	0
West Europe	2	-0	-12
Former USSR	3	1	5
Oceania	0	11	0
Total	11	7	3
Consumption:			
Africa	15	13	16
America:	5	7	6
North America	1	-5	2
Central America	14	17	0
South America	18	32	16
Asia:	17	14	21
West Asia	14	21	16
South Asia	22	16	22
East Asia	15	11	20
Europe:	-3	5	-3
East Europe	14	31	5
West Europe	-9	-4	-7
Former USSR	5	5	7
Oceania	36	29	10
Total	10	9	6

1/ Detailed data in appendix table 8. 2/ Production scheduled.

Source: (4).

In the developing countries of Africa, Central and South America, and Asia the supply potential for nitrogen, phosphate, and potash is expected to climb as much as 41 percent by 1996. Consumption will rise up to 32 percent. The rapid rise in consumption can be attributed to the goal of many developing countries to become self-sufficient in food and fertilizer production.

Nitrogen demand growth in Western Europe and the United States is uncertain. Plants that closed during the past several months may reopen in anticipation of higher prices resulting from tighter world supplies and the situation in Central and Eastern Europe and the former USSR. Nitrogen and phosphate production in the developed countries is expected to increase during the next 5 years, while potash production will decline slightly. Most of the nitrogen increase will come from greater Canadian production. Higher phosphate fertilizer production in the United States will depend heavily on phosphate export potential.

New and more efficient ammonia plants are scheduled to be completed during the next few years in Canada, Trinidad-Tobago, the United Kingdom, and Belgium. New urea plants are planned for Saudi Arabia, Indonesia, Bangladesh, India, Pakistan, Java, and China. Nitrogen production is expected to increase near natural gas reserves in Indonesia, India, Saudi Arabia, Mexico, and Trinidad-Tobago. Among centrally planned economies in Asia, greater nitrogen production capacity will be limited mainly to those plants built in China.

This surplus of nitrogen production capacity will likely provide sufficient supplies until the year 1996. However, the world will then need more production capacity. Therefore, prices will have to increase to make it profitable to expand production to meet demand.

Africa, Asia, Oceania, South America, and Western Europe are projected to have nitrogen deficits through 1996. North and South America, Eastern Europe, the former USSR, and West Asia will have surpluses because countries like these, with plentiful natural gas resources, produce nitrogen fertilizer for export.

Phosphate production will center primarily in the United States, the former USSR, and Morocco during 1991-96. About 33 percent of the phosphoric acid supply capability will be located in the United States, 20 percent in the former USSR, and 10 percent in Morocco. Increased phosphate production in India, China, Mexico, Tunisia, and Brazil will also add to world supplies.

The developed countries and Africa are projected to have surpluses of phosphate fertilizer. The former USSR, Asia, and Eastern Europe will be deficit areas, with Asia having the most acute shortage.

Worldwide, phosphate rock capacity will be more than adequate to meet demand, with the main surplus areas being North America and Africa. Jordan and Morocco are major phosphate producers and have large capacity additions planned for the next 5 years. The former USSR and India are forecast to be the world's largest importers of phosphoric acid, accounting for an estimated 45 percent of world trade. China, Brazil, Mexico, and India will also remain significant importers of processed phosphates through the early 1990's, because the excavation of new phosphate mines in those countries will take a long time and their phosphate rock processing facilities have not been fully developed.

Potash supply capability should be adequate into the next decade. World potash production potential is expected to increase about 3 percent. The greatest surplus is forecast for North America, due to heightened Canadian production. Israel, Jordan, Brazil, Thailand, and China will add to worldwide capacity. Potash capacity in Western Europe may decline as mines close in Germany and France. Nor is any significant development expected for the next few years in Chile, Ethiopia, Thailand, or Tunisia.

Eastern Europe and the former USSR will have major potash surpluses even though production has been reduced more than 1 million tons during the reunification of Germany. Reduced production is also anticipated in the former USSR during the next 2 years. Western Europe, Asia, Africa, and Latin America are projected to be deficit areas.

Projected regional shares of world fertilizer supply and demand indicate a continued shift in production and use from the developed to the developing countries (table 14). The centrally planned countries' and the former USSR share of world production will remain relatively constant through 1996 at around 46 percent for nitrogen, 33 percent for phosphate, and 41 percent for potash. Their consumption of each nutrient will also remain about the same—35 to 44 percent.

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4. The World Bank/FAO/UNIDO/Industry Fertilizer Working Group. *World and Regional Supply and Demand Balances for Nitrogen, Phosphate, and Potash, 1989/90 - 1995/96.* World Bank Technical Paper Number 144, Washington, D.C., 1991.

Table 14--Projected regional shares of world fertilizer supply potential and demand for years ending June 30

World regions	Nitrogen		Phosphate		Potash	
	1991	1996	1991	1996	1991	1996
	Percent					
Supply potential:						
Africa	2.5	2.8	13.2	14.4	0.0	0.0
America:	20.2	19.2	30.3	29.1	35.3	38.2
North America	14.1	13.3	25.7	24.7	35.3	37.9
Central America	4.2	3.9	1.8	1.7	0.0	0.0
South America	1.8	2.0	2.7	2.7	0.0	0.3
Asia:	38.5	41.4	18.4	19.9	7.1	7.6
West Asia	38.5	5.4	3.3	4.1	7.0	7.3
South Asia	4.2	12.1	2.4	2.7	0.0	0.0
East Asia	10.3	24.0	12.7	13.1	0.1	0.3
Europe:	18.0	17.0	17.4	16.7	27.1	23.1
East Europe	6.6	6.6	7.6	7.7	0.0	0.0
West Europe	11.4	10.5	9.8	9.1	27.1	23.1
Former USSR	20.4	19.0	18.1	17.1	30.5	31.1
Oceania	0.5	0.5	2.7	2.8	0.0	0.0
Consumption:						
Africa	2.9	3.1	3.3	3.4	2.0	2.2
America:	19.5	18.7	18.9	18.5	28.7	28.5
North America	14.3	13.2	12.1	10.5	20.0	19.2
Central America	2.8	2.9	1.6	1.8	1.4	1.3
South America	2.5	2.6	5.1	6.2	7.3	8.0
Asia:	48.0	51.1	36.5	38.0	18.4	20.9
West Asia	3.4	3.6	4.3	4.7	0.6	0.7
South Asia	13.0	14.4	10.8	11.5	5.3	6.1
East Asia	31.5	33.1	21.4	21.8	12.5	14.1
Europe:	17.9	15.8	18.1	17.3	28.6	26.0
East Europe	4.5	4.7	4.4	5.3	7.8	7.7
West Europe	13.4	11.1	13.7	12.0	20.8	18.2
Former USSR	11.1	10.5	21.3	20.5	21.2	21.4
Oceania	0.6	0.8	1.9	2.3	1.0	1.1

Source: (4).Number of characters across: 57.

5. United Nations. *1990 Fertilizer Yearbook*, Rome, 1991.

6. U.S. Department of Commerce, Bureau of the Census. *U.S. Exports, Commodity and Country*, FT-410. October 1991 and earlier issues.

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Pesticides

Consumption

Pesticide use on the major field crops is projected at 482 million pounds active ingredients (a.i.) in 1992, up less than 1 percent from a year earlier (table 15). Planted area for corn and wheat is expected to increase, while for cotton and soybeans it is expected to decline. Area planted to other crops is expected to be up slightly from 1991.

Herbicides account for 84 percent of total pesticide use, while insecticides make up 14 percent. The 3.8-million-pound a.i. rise in herbicide use expected in 1992 can largely be attributed to the projected expansion in corn acreage. Corn accounts for 57 percent of herbicide use.

Insecticide use in 1992 is expected to remain unchanged from the year earlier. Fungicide use on major field crops is expected to remain stable, with most being used in peanut production.

Table 15--Projected pesticide use on major U.S. field crops, 1992

Crops 1/	Herbicides	Insecticides	Fungicides
	Million pounds (a.i.)		
Row crops:			
Corn	231.9	28.7	0.07
Cotton	20.1	19.6	0.21
Grain sorghum	10.8	1.8	0.00
Peanuts	7.4	1.6	7.30
Soybeans	102.4	9.0	0.06
Tobacco	1.2	2.9	0.39
Total	373.8	63.6	8.03
Small grains:			
Barley and oats	4.3	0.1	0.00
Rice	13.0	0.5	0.08
Wheat	15.4	2.1	0.85
Total	32.7	2.7	0.93
1992 total	406.5	66.3	8.96
1991 total	402.7	66.5	8.85

1/ See table 1 for crop acreage.

1991 Pesticide Use

Corn

Herbicides were used on 95 percent of the surveyed corn acreage in 1991 (table 16). South Dakota farmers treated the fewest acres for weed control at 89 percent.

In the 10 surveyed States, an average of 1.4 herbicide treatments were made to control weeds. A single herbicide treatment was used on 62 percent of the acreage and 2 treatments on 31 percent. Iowa and Minnesota, with 41 percent, had the highest proportion of corn acreage treated twice.

Atrazine used alone or in combination with other active ingredients was the most commonly used herbicide. Atrazine + alachlor and atrazine + metolachlor were the most commonly used combination mixes, each accounting for 10 percent of the acre-treatments. These active ingredients control a large number of broadleaf and grass weeds, and when applied in combination the control spectrum is broadened. Metolachlor was the most commonly used single material, with 11 percent of the acre-treatments, followed by alachlor and atrazine. Metolachlor and alachlor are from the same chemical family.

EPTC accounted for 14 percent of the acre-treatments in South Dakota and 8 percent in Minnesota. EPTC controls many annual grasses, especially wild proso millet, a major problem in the northern Corn Belt. It is also more biologically active at low soil temperatures than many other preplant herbicide materials.

Much of the corn acreage in the upper Midwest is treated with dicamba, 2,4-D, or a combination of dicamba + 2,4-D. These materials are applied postemergence for broadleaf weed control.

Nicosulfuron registered in 1990 accounted for 2 percent of corn herbicide acre-treatments. It is applied postemergence and controls a variety of broadleaf and grass weeds.

Insecticides were used on 32 percent of the corn acreage in 1991 (table 17). Insecticide use was greatest in Nebraska, where 64 percent of the corn acreage was treated. In contrast, Minnesota and South Dakota farmers treated only 13 percent of their corn acreage and Ohio farmers, 14 percent. In Nebraska, corn rootworm larvae can be a problem because about two-thirds of the corn acreage is irrigated and a high proportion is planted to corn every year, allowing a buildup of the pest. In Minnesota, Ohio, and South Dakota, more corn acreage is rotated with other crops, including small grains, thus reducing corn rootworm problems.

Table 16--Selected herbicides used in corn production, 1991

Item	IL	IN	IA	MI	MN	MO	NE	OH	SD	WI	Area
1,000 acres planted 1/	11300	5800	12200	2600	6600	2200	8300	3800	3750	3800	60350
1,000 acres treated with herbicides	11085	5619	11902	2436	6347	2108	7614	3618	3343	3484	57556
Percent of acres treated:	98	97	98	94	96	96	92	95	89	92	95
With 1 treatment	59	77	55	75	51	76	66	69	57	68	62
With 2 treatments	38	18	41	18	41	16	24	24	29	23	31
With 3 or more	1	2	2	1	4	4	2	2	3	1	2
Average acre-treatments	1.41	1.23	1.45	1.22	1.51	1.25	1.31	1.29	1.41	1.27	1.37
1,000 acre-treatments	15641	6895	17289	2963	9582	2640	10005	4659	4703	4411	78788
Acre-treatments by active ingredient: 2/						Percent					
Single materials--											
Alachlor	8	5	9	1	12	3	10	3	22	6	9
Atrazine	8	9	3	8	2	21	11	7	2	16	7
Bromoxynil	2	nr	3	2	4	2	1	nr	4	1	2
Cyanazine	1	1	1	3	2	3	4	2	2	6	2
Dicamba	3	2	2	2	9	1	2	7	12	5	4
EPTC	2	1	4	*	8	nr	1	nr	14	1	3
Metolachlor	13	4	19	6	15	4	2	5	6	9	11
Nicosulfuron	2	1	2	1	5	1	2	nr	1	1	2
2,4-D	3	1	6	3	6	3	4	4	6	8	4
Other	3	5	2	5	3	4	5	2	12	9	5
Combination mixes--											
2,4-D + dicamba	*	*	1	1	2	nr	1	3	3	1	1
Atrazine + alachlor	10	26	6	15	2	16	18	16	2	4	10
Atrazine + bromoxynil	2	nr	8	1	5	1	1	nr	2	nr	3
Atrazine + butylate	1	5	*	*	nr	3	1	1	nr	nr	1
Atrazine + cyanazine	10	8	9	5	*	13	11	7	2	3	7
Atrazine + dicamba	9	6	3	3	3	1	2	4	4	3	5
Atrazine + metolachlor	11	17	6	19	1	17	14	19	nr	4	10
Atrazine + others	6	2	3	7	2	1	1	2	1	3	3
Other 2-way mixes	1	1	6	7	11	3	3	4	4	14	5
3-way mixes	4	6	6	10	7	2	5	13	3	14	6
Total	100	100	100	100	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Table 17--Selected insecticides used in corn production, 1991

Item	IL	IN	IA	MI	MN	MO	NE	OH	SD	WI	Area
1,000 acres planted 1/	11300	5800	12200	2600	6600	2200	8300	3800	3750	3800	60350
1,000 acres treated with insecticides	3336	1930	4301	665	879	525	5305	540	483	1324	19288
Percent of acres treated:	30	33	35	26	13	24	64	14	13	35	32
With 1 treatment	28	33	34	25	13	24	38	14	13	35	28
With 2 treatments	2	0	1	1	0	0	19	0	0	0	3
With 3 treatments	0	0	0	0	0	0	7	0	0	0	1
Average acre-treatments	1.06	1.00	1.03	1.03	1.02	1.01	1.39	1.00	1.00	1.00	1.13
1,000 acre-treatments	3551	1930	4429	682	900	532	7399	540	483	1324	21770
Acre-treatments by active ingredient: 2/						Percent					
Carbofuran	3	15	1	3	4	8	12	13	13	10	8
Chlorpyrifos	35	24	32	46	29	40	22	37	16	23	28
Fonofos	15	15	17	19	3	1	7	17	21	11	12
Permethrin	12	4	4	nr	11	24	4	6	3	nr	6
Phorate	2	5	5	1	19	nr	1	3	8	20	4
Tefluthrin	9	12	4	1	10	5	7	1	13	5	7
Terbufos	21	23	35	23	18	3	20	18	26	30	24
Other	4	2	2	8	4	19	25	6	nr	1	11
Total	100	100	100	100	100	100	100	100	100	100	100

nr = None reported.

1/ Preliminary. 2/ Spot treatments not included.

Table 18--Selected herbicides used in northern soybean production, 1991

Item	IL	IN	IA	MN	MO	NE	OH	Area
1,000 acres planted 1/	9200	4450	8800	5500	4500	2500	3900	38850
1,000 acres treated with herbicides	9069	4244	8678	5227	4143	2412	3756	37529
Percent of acres treated:	99	95	99	95	92	96	96	97
With 1 treatment	50	64	51	52	65	65	75	58
With 2 treatments	43	27	44	40	22	28	19	35
With 3 or more	6	4	4	3	5	3	2	4
Average acre-treatments	1.56	1.38	1.55	1.50	1.36	1.36	1.24	1.46
1,000 acre-treatments	14117	5857	13424	7840	5638	3271	4663	54810
Acre-treatments by active ingredient: 2/					Percent			
Single materials--								
Alachlor	1	5	1	2	4	4	2	2
Bentazon	8	2	5	4	1	3	2	4
Chlorimuron	2	2	3	*	5	1	2	2
Clomazone	2	2	*	nr	4	2	3	1
Ethalfluralin	3	1	2	3	*	1	nr	2
Fluazifop-P-butyl	1	3	1	1	2	2	1	1
Glyphosate	1	2	3	2	1	2	2	2
Imazaquin	1	1	*	*	3	1	1	1
Imazethapyr	12	8	16	32	8	14	11	15
Metolachlor	4	4	1	2	3	*	2	2
Metribuzin	1	1	1	1	4	2	1	1
Pendimethalin	7	1	3	4	4	4	2	4
Quizalofop-ethyl	1	*	2	1	1	nr	1	1
Sethoxydim	5	3	2	3	1	2	1	3
Trifluralin	9	4	22	23	11	19	2	14
Other	2	6	4	3	4	2	6	3
Combination mixes--								
Acifluorfen + bentazon	4	4	2	3	2	1	1	3
Fluazifop-P-butyl + imazethapyr	*	*	2	2	*	*	nr	1
Linuron + alachlor	*	3	*	1	nr	nr	3	1
Metribuzin + alachlor	nr	1	*	nr	1	2	3	1
Metribuzin + chlorimuron	4	2	1	nr	1	1	2	2
Metribuzin + metolachlor	nr	1	*	*	nr	*	6	1
Pendimethalin + imazaquin	5	6	nr	nr	11	1	5	4
Pendimethalin + imazethapyr	4	2	7	2	1	9	2	4
Trifluralin + alachlor	3	1	3	4	1	1	nr	2
Trifluralin + clomazone	2	1	4	*	1	4	nr	2
Trifluralin + imazaquin	2	3	nr	nr	4	2	*	1
Trifluralin + metribuzin	*	*	2	1	nr	1	*	1
Thifensulfuron + chlorimuron	2	1	3	*	1	2	2	2
Other 2-way mixes	7	9	6	5	7	5	11	7
Other combinations	7	22	6	2	14	11	27	10
Total	100	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

Insecticides are generally applied at planting for corn rootworm larvae control. Insecticides are also used to control cutworms and European corn borers. Chlorpyrifos (28 percent) and terbufos (24 percent) were the most commonly used insecticides.

Soybeans

In 1991, 97 percent of the northern and 93 percent of southern soybean acreage in the surveyed States were treated with herbicides (table 18 and 19). In the northern soybean region, farmers applied 1.5 treatments per acre, compared with 1.6 treatments in the southern region. Normally, the difference between the two regions is larger, but this past year frequent rains disrupted weed control programs in the southern region, resulting in fewer herbicide treatments.

In the northern region, Illinois and Iowa had the highest number of treatments per acre at 1.6. Farmers in these States typically use a preemergence herbicide and follow it with a postemergence application, if additional weed problems arise. In the southern region, Georgia and North Carolina had the fewest treatments per acre at 1.3. In these States, a large proportion of soybean acreage is double-cropped with winter wheat. Because soybeans are planted directly into the wheat stubble, less soil is disturbed and the leaf canopy is rapidly established, shading the ground and thereby inhibiting weed seed germination.

In the northern soybean region, imazethapyr and trifluralin, applied alone or in combination with other herbicides, were the most commonly used materials. Imazethapyr, registered in 1989, accounted for 15 percent of the herbicide acre-treatments in 1991, up from 9 percent in 1990. It controls a variety of broadleaf and grass weeds and may be applied

Table 19--Selected herbicides used in southern soybean production, 1991

Item	AR	GA	KY	LA	MS	NC	TN	Area
1,000 acres planted 1/	3200	650	1150	1450	1900	1350	1100	10800
1,000 acres treated with herbicides	3014	579	1124	1192	1716	1276	1094	9995
Percent of acres treated:	94	89	98	82	90	95	99	93
With 1 treatment	50	64	58	44	41	67	30	51
With 2 treatments	39	22	30	23	40	23	59	35
With 3 or more	5	3	10	15	9	5	10	7
Average acre-treatments	1.51	1.32	1.51	1.72	1.67	1.36	1.83	1.57
1,000 acre-treatments	4565	762	1693	2051	2865	1736	2004	15676
Acre-treatments by active ingredient: 2/					Percent			
Single materials--								
Acifluorfen	4	nr	nr	4	1	3	1	2
Alachlor	2	9	1	nr	nr	11	*	3
Bentazon	1	1	2	3	2	*	2	2
Chlorimuron	3	7	3	2	5	7	3	4
Clomazone	1	nr	nr	2	1	2	*	1
Fluazifop-P-butyl	*	nr	9	4	3	1	9	3
Fomesafen	1	nr	1	7	4	*	2	2
Glyphosate	2	2	6	10	6	1	2	4
Imazaquin	7	nr	*	4	4	nr	7	4
Imazethapyr	nr	nr	6	nr	nr	2	5	1
Metolachlor	5	nr	1	2	2	3	2	3
Metribuzin	3	17	nr	2	4	*	1	3
Pendimethalin	3	18	1	1	2	1	4	3
Sethoxydim	3	1	1	3	2	*	*	2
Trifluralin	22	12	7	10	19	6	17	15
Other	4	3	4	8	4	3	3	4
Combination mixes--								
Acifluorfen + bentazon	5	1	1	2	6	3	8	4
Acifluorfen + imazaquin	5	nr	3	2	2	*	2	3
Alachlor + glyphosate	nr	nr	3	nr	*	2	*	1
Fluazifop-P-butyl + fomesafen	*	nr	3	1	1	1	*	1
Imazaquin + pendimethalin	2	5	*	4	7	12	7	5
Imazaquin + trifluralin	4	1	11	4	3	1	2	4
Metribuzin + chlorimuron	2	3	4	5	4	5	2	3
Metribuzin + pendimethalin	2	5	nr	nr	2	nr	nr	1
Metribuzin + trifluralin	3	2	nr	nr	3	*	2	2
Other 2-way mixes	7	3	15	8	8	24	11	10
Other combinations	8	11	17	11	5	9	8	9
Total	100	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

preplant, preemergence, or postemergence. Its mode of action involves uptake by weed roots and/or foliage. Therefore, it controls existing weeds as well as germinating weeds. Trifluralin is applied preplant soil-incorporated and controls many broadleaf and grass weeds as they germinate.

Trifluralin, applied as a single active ingredient, was the most commonly used material in the southern region, accounting for 15 percent of the acre-treatments. Fourteen other active ingredients were applied alone, with none garnering more than 4 percent of the acre-treatments. Several combination mixes were used but none dominated.

Cotton

Herbicides were used on 91 percent of the cotton acreage in 1991, ranging from 100 percent in Mississippi to 81 percent in California (table 20). On average, cotton farmers applied 2.2 herbicide treatments per acre. Treatment frequency ranged from 3.3 to 4.7 in the Delta States to 1.4 in California and Texas. The severe weed pressure in the Delta is demonstrated by the large proportion of cotton acreage receiving 3 or more herbicide treatments per season. In Texas and the irrigated West, 1 or 2 herbicide treatments are the norm.

Of the herbicides applied as single ingredients, trifluralin was the most commonly used (30 percent). Fluometuron was used extensively in the Delta and pendimethalin and prometryn in Texas and the West, which indicates varying weed problems among regions. Combination mixes accounted for 25 percent of the acre-treatments, but no single combination accounted for more than 3 percent. MSMA was included in many of the combination mixes and was applied as a postemergence-directed spray. With directed sprays, drop nozzles are used to place the herbicide material under the leaf canopy in the crop row.

Spring Wheat and Durum

In States producing spring wheat and durum, herbicide use ranged from a low of 86 percent in South Dakota to a high of 97 percent in Minnesota (table 21). Generally spring wheat

Table 20--Selected herbicides used in cotton production, 1991

Item	AR	LA	MS	TX	AZ	CA	Area
1,000 acres planted 1/	990	800	1250	6500	370	950	10860
1,000 acres treated with herbicides	866	774	1250	5952	311	766	9919
Percent of acres treated:	87	97	100	92	84	81	91
With 1 treatment	8	13	1	58	44	49	42
With 2 treatments	20	10	10	30	26	31	25
With 3 treatments	33	20	15	3	9	1	9
With 4 treatments	6	15	24	1	5	0	5
With 5 treatments	8	13	28	0	0	0	5
With 6 or more	12	26	22	0	0	0	5
Average acre-treatments	3.31	4.29	4.67	1.42	1.69	1.43	2.23
1,000 acre-treatments	2867	3318	5839	8447	525	1092	22088
Acre-treatments by active ingredient: 2/					Percent		
Single materials--							
Cyanazine	9	8	8	nr	5	9	5
Diuron	nr	6	2	2	4	nr	2
DSMA	4	nr	1	*	2	nr	1
Fluazifop-P-butyl	1	6	4	2	1	5	3
Fluometuron	15	17	13	2	2	nr	9
Glyphosate	*	1	1	2	nr	8	1
Methazole	1	3	2	nr	nr	nr	1
MSMA	6	4	4	1	2	4	3
Norflurazon	4	7	3	nr	nr	nr	2
Pendimethalin	1	2	1	11	20	16	7
Prometryn	5	4	5	13	26	6	8
Trifluralin	11	7	7	60	15	40	30
Other	4	8	4	2	3	6	4
Combination mixes--							
MSMA + cyanazine	8	3	7	nr	nr	nr	3
MSMA + fluometuron	4	4	6	nr	nr	nr	3
MSMA + methazole	2	3	4	nr	nr	nr	2
MSMA + prometryn	1	4	3	nr	nr	nr	2
Norflurazon + fluometuron	6	1	5	nr	nr	nr	2
Norflurazon + pendimethalin	4	1	3	nr	nr	nr	2
Trifluralin + norflurazon	2	2	5	nr	nr	nr	2
Trifluralin + prometryn	nr	nr	nr	0	15	3	1
Other 2-way mixes	8	11	10	4	5	3	7
3-way mixes	4	*	1	nr	1	nr	1
Total	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

growers apply herbicides once, but in Minnesota and North Dakota about 20 percent of the acreage received two treatments. In durum wheat production over 40 percent of the acreage in North Dakota received two herbicide treatments. The number of treatments needed for effective weed control decreases from East to West because weeds are more of a problem in higher rainfall areas.

The most commonly used herbicides on both crops were 2,4-D, MCPA, and a combination of 2,4-D + dicamba. These materials are applied postemergence and control a wide range of broadleaf weeds. Trifluralin was used extensively in durum wheat production for foxtail control.

Rice

In 1991, herbicides were used on 95 percent of the rice acreage in the surveyed States—Arkansas and Louisiana (table 22). About one-third of the rice acreage received one herbicide treatment and 44 percent two treatments. Propanil was the most commonly used herbicide in rice production, either alone or in combination mixes with other materials. Fenoxaprop and molinate ranked second in importance. Propanil and molinate are used primarily to control barnyardgrass and a variety of other grass and broadleaf weeds. Fenoxaprop does not control broadleaf weeds or sedges.

Insecticides were used on 16 percent of the rice acreage in 1991 (table 23). Methyl parathion, the most commonly used insecticide, controls rice stink bugs and grasshoppers. Carbofuran is used to control the rice water weevil.

Fungicides were used on 24 percent of the rice acreage (table 24). Sheath blight, caused by a soil-borne organism, poses the gravest disease problem in rice production. It kills the foliage, thereby reducing yields. Fungicides are only partially effective, they can slow development of sheath blight, not control it.

Regulatory Issues

Atrazine may become a regulatory issue due to human health concerns, but the Environmental Protection Agency (EPA)

Table 21--Selected herbicides used in spring wheat production, 1991

Item	Spring wheat MN	Spring wheat MT	Spring wheat ND	Spring wheat SD	Spring wheat Area	Durum ND
1,000 acres planted 1/	2100	2600	7000	1800	13500	3000
1,000 acres treated with herbicides	2039	2261	6570	1552	12422	2813
Percent of acres treated:	97	87	94	86	92	94
With 1 treatment	71	84	75	71	75	50
With 2 treatments	22	3	19	14	16	41
With 3 or more	4	0	0	0	1	3
Average acre-treatments	1.32	1.03	1.21	1.16	1.19	1.51
1,000 acre-treatments	2682	2336	7921	1800	14739	4242
Acre-treatments by active ingredient: 2/						
Single materials--						
2,4-D	8	26	21	43	22	18
Dicamba	2	2	1	14	3	3
Diclofop-methyl	6	nr	1	nr	1	1
Imazamethabenz	5	nr	1	nr	1	nr
MCPA	15	3	10	7	10	8
Metsulfuron	nr	2	nr	2	*	3
Triallate	3	3	2	nr	2	4
Tribenuron	nr	nr	2	2	1	1
Trifluralin	2	nr	9	nr	5	16
Other	5	nr	3	nr	3	1
Combination mixes--						
2,4-D + clopyralid	3	nr	nr	3	1	nr
2,4-D + dicamba	1	35	9	7	12	10
2,4-D + metsulfuron	nr	8	nr	2	1	3
2,4-D + tribenuron	1	2	4	nr	2	8
MCPA + bromoxynil	17	3	2	2	5	1
MCPA + dicamba	2	8	7	7	6	8
MCPA + tribenuron	1	nr	5	nr	3	nr
Thifensulfuron + tribenuron	5	nr	3	3	3	nr
Triallate + trifluralin	nr	nr	nr	nr	nr	8
Other 2-way mixes	6	6	3	3	4	5
2,4-D + thifensulfuron + tribenuron	10	nr	5	nr	4	nr
2.4-D + Fenoxaprop-ethyl + MCPA	1	nr	4	3	3	nr
MCPA + thifensulfuron + tribenuron	3	nr	3	nr	2	nr
Other combinations	4	2	7	2	5	1
Total	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

has not yet issued any position document or taken any regulatory action. It is the most widely used herbicide in U.S. corn production. In 1990, 58 million pounds a.i. were applied to 48 million corn acres. The per acre application rate for the 1990 crop year was 1.22 pounds a.i. down from 1.46 pounds in 1982. Atrazine accounted for 49 percent of the herbicide acre-treatments on corn in 1988, 43 percent in 1989, 45 percent in 1990, and 46 percent in 1991.

Atrazine is viewed as a potential health hazard, because it is reported to cause tumors in a sensitive strain of rats. The risk to humans could come from ingestion in food or water. Atrazine has been found in both ground and surface water throughout the Midwest. After late spring and early summer rainfall, atrazine levels in some raw water samples exceeded the maximum contaminant level for drinking water. By harvest time, concentrations returned to near preplanting levels.

EPA has issued a preliminary determination to cancel the use of arsenic acid on cotton, because it is classified as a known human carcinogen. Arsenic acid is used to desiccate cotton prior to stripper harvesting, especially in Oklahoma and Texas. Experts say that there are no good alternatives to arsenic acid in those States, so producers may be forced to take major production losses or change harvesting methods. USDA's 1989 cotton pesticide survey estimated that 1.2 million pounds a.i. were applied to 3 percent of U.S. cotton acreage. Use is variable from year to year, because the occurrence of killing frosts can make a desiccant unnecessary. Experts estimate that 25-30 percent of Oklahoma and Texas acreage (13 percent of U.S. cotton acreage) may need to be treated.

EBDC (ethylene bisdithiocarbamate) fungicides (maneb, mancozeb, and metiram) are used on a variety of fruit, nut, vegetable, and grain crops and are suspected of causing birth defects and tumors. In December 1989, the U.S. Environ-

Table 22--Selected herbicides used in rice production, 1991

Item	AR	LA	Area
1,000 acres planted 1/	1350	530	1880
1,000 acres treated with herbicides	1301	482	1783
Percent of acres treated:	96	91	95
With 1 treatment	29	48	34
With 2 treatments	46	36	44
With 3 or more	21	7	17
Average acre-treatments	1.95	1.56	1.84
1,000 acre-treatments	2538	750	3288
Acre-treatments by active ingredient: 2/			
Single materials--			
2,4-D	3	11	5
Acifluorfen	2	nr	2
Bentazon	1	2	1
Fenoxaprop-ethyl	9	16	10
Glyphosate	2	1	2
Molinate	9	18	11
Pendimethalin	2	nr	1
Propanil	41	18	36
Thiobencarb	3	4	3
Other	2	4	2
Combination mixes--			
Propanil + bromoxynil	3	1	3
Propanil + molinate	11	15	12
Propanil + pendimethalin	3	nr	2
Propanil + thiobencarb	6	4	6
Other	5	6	5
Total	100	100	100

nr = None reported.

1/ Preliminary. 2/ Spot treatments not included.

Table 23--Selected insecticides used in rice production, 1991

Item	AR	LA	Area
1,000 acres planted 1/	1350	530	1880
1,000 acres treated with insecticides	142	160	301
Percent of acres treated:	11	30	16
With 1 treatment	10	24	14
With 2 treatments	*	6	2
Average acre-treatments	1.03	1.18	1.11
1,000 acre-treatments	146	188	334
Acre-treatments by active ingredient: 2/			
Single materials--			
Carbofuran	9	70	43
Methyl parathion	85	30	54
Other	6	nr	3
Total	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

mental Protection Agency (EPA) proposed canceling 45 of 55 registered uses. Earlier that year, four major registrants withdrew 42 of the 45 uses from their product labels.

According to a News Release of February 13, 1992, EPA announced the intent to maintain registration of EBDC's for 45 food crops. EPA specified certain protective measures including decreasing application rates, decreasing frequency of application, increasing intervals between application and harvest, requiring protective clothing, and providing warning labels that must be followed. At the same time, EPA announced they would cancel uses on 11 crops where "the long term risks of using EBDC's... outweigh the benefits." The 11 crops for which use is canceled are apricots, carrots, celery, collards, mustard greens, nectarines, peaches, rhubarb, spinach, succulent beans, and turnips. This action was taken following the provision of residue data to EPA by the registrants of the EBDC's.

Table 24--Selected fungicides used in rice production, 1991

Item	AR	LA	Area
1,000 acres planted 1/	1350	530	1880
1,000 acres treated with fungicides	319	138	457
Percent of acres treated:	24	26	24
With 1 treatment	18	24	20
With 2 treatments	5	2	4
With 3 treatments	1	0	*
Average acre-treatments	1.29	1.06	1.22
1,000 acre-treatments	411	146	557
Acre-treatments by active ingredient: 2/			
Single materials--			
Benomyl	64	56	62
Iprodione	17	25	19
Propiconazole	19	19	19
Total	100	100	100

* = Less than 1 percent.

1/ Preliminary. 2/ Spot treatments not included.

EPA amended its cancellation order on ethyl parathion. EPA will allow use of existing stocks of the wettable powder formulation until July 31, 1992, on crops where the registration was canceled. Under the previous order, use was banned after December 31, 1991. Emulsifiable concentrate formulations are not affected by the amendment. Under the original notice, use was allowed on alfalfa, barley, corn, cotton, sorghum, soybeans, sunflowers, and wheat. Use on canola might be available, if a residue tolerance is set.

On February 3, 1992, the manufacturer announced an agreement with EPA on the use of aldicarb on citrus, potatoes, sweet potatoes, and bananas. Aldicarb use in orange and grapefruit groves will continue, but use rates will be reduced to 5 pounds active ingredient per acre. In addition, the company will expand a stewardship program under which applications are restricted to technologically advanced, highly accurate equipment and will field-monitor treated acreages to determine if modifications of use practices are warranted. The current voluntary and temporary withdrawal from use in potato production will continue while field research is conducted. A decision on the potato registration is to be completed by January 31, 1994. Use of aldicarb on sweet potatoes will continue, while research trials are conducted. Finally, EPA intends to revoke the import tolerance on bananas.

Tillage Systems

Tillage operations and amount of previous crop residue on the soil surface after planting are important indicators of soil erosion potential. The conservation compliance provisions of the 1985 Food Security Act (FSA) require farmers to implement conservation practices on highly erodible land (HEL) by 1995 or become ineligible for farm program benefits. To meet these requirements on HEL, farmers must make a change in crop rotation, use a different tillage system, add a cropping practice (such as contouring), and/or install permanent structures (such as terraces). The USDA has developed soil conservation plans for 135 million acres of highly erodible U. S. cropland, including 100 million acres of conservation tillage.

In terms of controlling water erosion, a conservation tillage system is defined as one that leaves 30 percent or more of the soil surface covered with previous crop residue after planting. If less than 30 percent residue is left, the system is called conventional tillage. Because the various tillage systems leave significantly different amounts of residue, the type of system used directly affects erosion potential and water quality. In general, conventional tillage systems without the moldboard plow leave less than one-half as much residue after planting as mulch-till systems.

Of the acreage planted to major crops, currently 3-18 percent is conventional tilled with a moldboard plow. The highest residue conservation tillage system, no-tillage, is used on 11 percent or less, depending on the crop. Most of the acreage is cropped with conventional tillage without the moldboard plow, a system that leaves less than 30 percent residue on the soil surface after planting.

The tillage system employed influences the types and levels of other input use. Labor hours spent in tilling the soil are determined by the number of times the farmer goes over the field, as well as implement size and tractor speed. Labor and fuel are normally reduced with tillage systems that require fewer trips over the field. On the other hand, a no-till system used on sod might need an extra trip for a nonselective herbicide application. In 1991, conventional tillage without a moldboard plow required an average of 3.4 passes over the field for corn and 6.2 for cotton. The number of hours per

Table 25--Tillage systems used in corn production, 1991

Category	IL	IN	IA	MI	MN	MO	NE 1/	NE 2/	OH	SD	WI	Area
Planted acres (1,000) 3/	11,300	5,800	12,200	2,600	6,600	2,200	2,747	5,553	3,800	3,750	3,800	60,350
	% of acres 4/											
Tillage system:												
Conv/w mbd plow 5/	6	17	8	29	25	13	5	4	31	11	41	15
Conv/wo mbd plow 6/	67	57	57	44	58	60	36	48	40	69	43	55
Mulch-till 7/	15	15	29	18	14	18	36	25	11	17	15	20
No-till 8/	12	11	6	9	3	9	23	23	18	3	1	10
	% of soil surface covered											
Residue remaining after planting:												
Conv/w mbd plow	2	2	2	2	2	2	2	3	2	3	2	2
Conv/wo mbd plow	15	16	18	16	15	15	19	19	15	16	18	17
Mulch-till	37	38	37	38	37	38	39	41	37	39	38	38
No-till	65	65	58	73	47	68	68	64	69	59	71	65
Average	24	23	25	21	16	22	37	34	23	20	15	24
	Number											
Hours per acre:												
Conv/w mbd plow	.6	.6	.6	.9	.8	.8	.6	.4	.9	.6	.9	.8
Conv/wo mbd plow	.4	.4	.4	.5	.4	.4	.4	.4	.5	.4	.6	.4
Mulch-till	.2	.3	.2	.4	.3	.3	.3	.3	.4	.3	.5	.3
No-till	.1	.1	.1	.2	.2	.1	.1	.2	.2	.1	.2	.2
Average	.3	.4	.3	.6	.5	.4	.3	.3	.6	.4	.7	.4
Times over field:												
Conv/w mbd plow	4.2	3.8	4.1	3.8	4.0	3.8	3.3	3.4	3.9	3.7	4.0	3.9
Conv/wo mbd plow	3.3	3.4	3.3	3.4	3.4	3.5	2.9	3.6	3.5	3.3	3.6	3.4
Mulch-till	2.4	2.5	2.4	2.8	2.9	2.7	2.5	2.5	2.7	2.6	3.1	2.6
No-till	1.0	1.1	1.0	1.0	1.2	1.0	1.0	1.8	1.0	1.0	1.0	1.2
Average	3.0	3.1	3.0	3.2	3.5	3.2	2.3	2.9	3.1	3.2	3.7	3.1

1/ Nonirrigated. 2/ Irrigated. 3/ Preliminary. 4/ May not add to 100 due to rounding. 5/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 6/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 7/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 8/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

acre averaged 0.4 and 0.7, respectively. These numbers have changed very little over the past 4 years.

Tillage system designations were determined from the estimates of residue remaining after planting and the use of specific implements (1). To obtain the residue estimate, the percentage of residue remaining from the previous crop was estimated, and then reduced by the residue-incorporation rate of each tillage and planting implement used. For this report, the percentage of residue was assumed to be evenly distributed over the soil surface.

Corn

Tillage practices used in 1991 corn production varied widely among the 10 major producing States (table 25). Wisconsin had the highest use of the moldboard plow (41 percent) to accommodate the corn/alfalfa rotations needed to support dairy farming. In Nebraska, the moldboard plow was used on only about 5 percent of the total corn acres. Nebraska does not have a preponderance of wet/heavy soils which require fall plowing. Furthermore, it has a more serious wind erosion problem than the other corn producing States. In the area surveyed, a moldboard plow was used on 15 percent of 1991 corn acres, down from 20 percent in 1988.

Among the surveyed States, no-till systems were used on only 10 percent of the corn acreage. Corn acreage in Nebraska had the highest proportion of acres under no-till (23 percent), a figure which may reflect concern with wind erosion. Nebraska had the highest State-average residue level, due to the prevalence of nonmoldboard plow tillage systems and extensive continuous corn production. Ohio, at 18 percent, had the next highest acreage proportion under no-till. Ohio has traditionally had a high proportion of no-till acreage because of the emphasis placed on such systems by its agricultural agencies. Nebraska and Ohio have consistently been among the highest users of no-till in corn production.

Soybeans

The 14 major soybean producing States were divided into the northern and southern areas. The northern area reported 18 percent of its 1991 acres using conventional tillage with a moldboard plow, compared with only 3 percent in the southern area (tables 26 and 27). This was a decrease from 28 percent in 1988 for the northern area, while the southern area showed little change. In contrast, 80 percent of southern-area acreage used conventional tillage without the moldboard plow, compared with 48 percent of the northern area.

Mulch tillage was more predominant in the northern than the southern area (25 vs. 6 percent), while no-tillage was about the same in both areas (11 percent in the southern area and 10 in the northern). Kentucky reported a high usage of no-till (39 percent) and is recognized as a leader in the advocacy and adoption of no-till systems.

A reason for some differences between the two areas is found in the examination of rotation data. In the southern area, 50-90 percent of the previous acreage use consisted of soybeans or a fallow period (leaving fragile and limited resi-

Table 26--Tillage systems used in northern soybean production, 1991

Category	IL	IN	IA	MN	MO	NE	OH	Area
Planted acres (1,000) 1/	9,200	4,450	8,800	5,500	4,500	2,500	3,900	38,850
	% of acres 2/							
Tillage system:								
Conv/w mbd plow 3/	13	22	13	38	4	2	34	18
Conv/wo mbd plow 4/	51	39	52	36	64	49	38	48
Mulch-till 5/	22	20	31	23	25	43	13	25
No-till 6/	14	19	4	4	7	6	16	10
	% of soil surface covered							
Residue remaining after planting:								
Conv/w mbd plow	2	3	3	3	2	3	2	3
Conv/wo mbd plow	17	18	18	18	15	21	15	17
Mulch-till	40	40	38	38	37	38	37	39
No-till	73	71	73	62	75	69	72	72
Average	28	29	25	19	24	31	22	25
	Number							
Hours per acre:								
Conv/w mbd plow	.6	.6	.6	.6	.7	.6	.8	.6
Conv/wo mbd plow	.5	.5	.5	.5	.5	.4	.6	.5
Mulch-till	.3	.4	.4	.4	.3	.3	.4	.4
No-till	.1	.1	.1	.1	.2	.2	.2	.1
Average	.4	.4	.4	.5	.4	.4	.5	.4
Times over field:								
Conv/w mbd plow	4.3	4.1	4.4	4.5	4.2	3.8	4.1	4.3
Conv/wo mbd plow	4.1	3.7	4.4	4.6	3.8	3.5	3.8	4.1
Mulch-till	3.2	2.9	3.6	3.5	2.8	2.9	3.1	3.2
No-till	1.0	1.1	1.1	1.4	1.1	1.3	1.0	1.1
Average	3.5	3.1	4.0	4.2	3.4	3.1	3.4	3.6

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Table 27--Tillage systems used in southern soybean production, 1991

Category	AR	GA	KY	LA	MS	NC	TN	Area
Planted acres (1,000) 1/	3,200	650	1,150	1,450	1,900	1,350	1,100	10,800
	% of acres 2/							
Tillage system:								
Conv/w mbd plow 3/	nr	8	9	nr	nr	8	4	3
Conv/wo mbd plow 4/	95	75	46	82	86	76	73	80
Mulch-till 5/	3	16	6	3	9	6	5	6
No-till 6/	2	1	39	15	6	10	18	11
	% of soil surface covered							
Residue remaining after planting:								
Conv/w mbd plow	nr	1	2	nr	nr	1	1	1
Conv/wo mbd plow	6	10	16	7	8	8	8	8
Mulch-till	38	43	40	58	43	40	44	43
No-till	74	id	77	59	60	78	79	72
Average	9	15	40	16	14	17	23	17
	Number							
Hours per acre:								
Conv/w mbd plow	nr	1.3	.6	nr	nr	1.3	.9	1.0
Conv/wo mbd plow	.5	.6	.5	.4	.5	.7	.6	.5
Mulch-till	.2	.3	.3	.2	.2	.2	.3	.2
No-till	.1	.1	.1	.1	.1	.2	.1	.1
Average	.4	.5	.3	.4	.4	.7	.5	.5
Times over field:								
Conv/w mbd plow	nr	4.6	4.1	nr	nr	4.6	4.9	4.5
Conv/wo mbd plow	5.3	3.5	3.5	4.8	4.3	4.2	4.6	4.6
Mulch-till	2.9	2.2	2.3	1.8	2.6	2.1	2.0	2.4
No-till	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Average	5.2	3.3	2.5	4.1	4.0	3.8	3.8	4.1

nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

dues). In the northern area, over 60 percent of the previous crop residue was corn, which leaves a hardier and heavier residue.

The residue remaining under conventional tillage was higher in the northern area, while mulch-tillage residue was higher in the southern area. Again, no-tillage was very similar for both areas. The hours per acre averaged 0.6 in the northern area and 1.0 in the southern area for conventional tillage with the moldboard plow, and the number of passes over the field were slightly higher for the southern area. For mulch tillage, the northern area averaged nearly one more trip over the field than the southern area. These numbers have changed very little since 1988.

Cotton

Nearly all cotton is produced using conventional tillage methods in the six major cotton States (table 28). Use of the moldboard plow has fluctuated over the years. The 1991 level of 21 percent is less than the 1988 level (28 percent) but greater than the 1990 level of 14 percent.

Use of the moldboard plow was minimal in four of the States (table 28). The plow was used most extensively in Arizona (56 percent of the acreage) and Texas (31 percent). This was an increase from 37 percent in 1990 for Arizona. Arizona, California, and parts of Texas have State "plow-down" laws requiring that the cotton plant be disposed of to eliminate the food source for bollworms and boll weevils. Some producers have misinterpreted these laws to mean that the previous crop must be plowed with a moldboard plow. California producers mainly use multiple passes with a heavy disk. In some areas of Texas, the moldboard plow is also used to bring up subsoil clay to cover the soil surface with clods which helps control wind erosion.

The large number of tillage trips across the field (averaging 6.1) leaves very little residue, even without use of the moldboard plow. Research is being conducted in a number of cotton producing States on the use of mulch-till and no-till systems and the use of cover crops.

Wheat

Minnesota reported greater-than-average use of the moldboard plow in producing spring wheat (table 29). This probably results from a greater incidence of heavier soils and less wind erosion. In the surveyed area, the use of the moldboard has declined from 16 percent in 1988 to 7 percent in 1991. The percentage of residue remaining after planting in most spring-wheat States came fairly close to the average for the area surveyed.

Wheat acreage under conventional tillage without the moldboard plow required more trips over the field than with the plow. Much of the wheat produced in the Great Plains and the Western States is produced after a fallow period. All implement passes made during the fallow year were included in determining residue levels, hours per acre, and trips over the field. Normal fallow procedure starts with chisel plowing and other noninversion tillage operations in the fall instead

Table 28--Tillage systems used in cotton production, 1991

Category	AZ	AR	CA	LA	MS	TX	Area
Planted acres (1000) 1/	370	990	950	800	1,250	6,500	10,860
				% of acres 2/			
Tillage system:							
Conv/w mbd plow 3/	56	nr	id	7	nr	31	21
Conv/wo mbd plow 4/	44	100	98	93	97	65	76
Mulch-till 5/	nr	nr	nr	nr	nr	3	1
No-till 6/	nr	nr	id	nr	3	1	1
Residue remaining after planting:			% of soil surface covered				
Conv/w mbd plow	0	nr	id	0	nr	0	0
Conv/wo mbd plow	0	2	1	2	2	4	3
Mulch-till	nr	nr	nr	nr	nr	51	51
No-till	nr	nr	id	nr	30	66	54
Average	0	2	1	2	3	4	3
				Number			
Hours per acre:							
Conv/w mbd plow	1.9	nr	id	.7	nr	.8	.8
Conv/wo mbd plow	.8	.6	1.2	.6	.7	.6	.7
Mulch-till	nr	nr	nr	nr	nr	.4	.4
No-till	nr	nr	id	nr	.1	.1	.1
Average	1.4	.6	1.2	.6	.7	.7	.7
Times over field:							
Conv/w mbd plow	8.1	nr	id	6.0	nr	6.2	6.4
Conv/wo mbd plow	7.3	6.4	7.8	5.9	6.1	5.8	6.2
Mulch-till	nr	nr	nr	nr	nr	2.8	2.8
No-till	nr	nr	id	nr	1.0	1.0	1.0
Average	7.7	6.4	7.8	5.9	5.9	5.8	6.1

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Table 29--Tillage systems used in spring and durum wheat production, 1991

Category	Spring wheat MN	MT	ND	SD	Area	Durum wheat ND
Planted acres (1,000) 1/	2,100	2,600	7,000	1,800	13,500	3,000
		% of acres 2/				
Tillage system:						
Conv/w mbd plow 3/	16	nr	7	9	7	5
Conv/wo mbd plow 4/	76	62	54	66	60	55
Mulch-till 5/	8	36	36	22	30	37
No-till 6/	nr	id	4	3	3	3
Residue remaining after planting:		% of soil surface covered				
Conv/w mbd plow	3	nr	3	2	3	4
Conv/wo mbd plow	15	15	15	16	15	18
Mulch-till	39	43	44	39	43	39
No-till	nr	id	64	id	65	40
Average	15	26	26	22	24	26
			Number			
Hours per acre:						
Conv/w mbd plow	.5	nr	.4	.5	.5	.2
Conv/wo mbd plow	.3	.3	.4	.3	.3	.3
Mulch-till	.3	.2	.2	.2	.2	.2
No-till	nr	id	.1	id	.1	.1
Average	.3	.3	.3	.3	.3	.3
Times over field:						
Conv/w mbd plow	4.2	nr	3.5	3.2	3.7	2.7
Conv/wo mbd plow	3.7	5.0	4.0	2.8	4.0	4.4
Mulch-till	3.2	2.9	2.3	2.1	2.5	2.9
No-till	nr	id	1.0	id	1.0	1.0
Average	3.7	4.2	3.3	2.6	3.4	3.7

id = Insufficient data. nr = none reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

of a pass with the moldboard plow. For these States, therefore, the tables reflect more trips over the field under conventional tillage without the moldboard plow. North Dakota durum-wheat acreage also shows this pattern because much of the durum wheat is planted after a fallow period.

Rice

Most of the rice acreage in Arkansas and Louisiana is produced under conventional tillage without the moldboard plow (table 30), consistently about 95 percent since 1988. Erosion is not a problem in rice production because most rice is planted on flat, heavy-textured soils and then flooded. Most rice seedbeds are nearly residue free, partly because residue is perceived to harbor the disease organism that causes stem rot at the water line.

Highly Erodible Land

Corn production utilized the largest amount of HEL acreage in 1991, even though winter wheat had a higher percentage of crop acres designated as HEL (table 31). Winter wheat, corn, and northern soybeans showed significantly less use of a moldboard plow on land designated HEL than on land designated non-HEL. On the other hand, the plow was used more extensively on cotton land designated as HEL.

With the exception of northern soybeans (55 percent), more than 60 percent of the 1991 cropland designated HEL (for the surveyed States and crops) utilized conventional tillage methods. There has been a steady decrease in the proportion using the moldboard plow since 1989 and this should continue over the next few years, as USDA-approved conservation plans are implemented.

References:

1. Bull, Len. "Residue and Tillage Systems in 1987 Corn Production," *Agricultural Resources: Inputs Situation and Outlook*, AR-13, ERS, USDA, February 1989.

Table 30--Tillage systems used in rice production, 1991

Category	AR	LA	Area
Planted acres (1,000) 1/	1,350	530	1,880
		% of acres 2/	
Tillage system:			
Conv/w mbd plow 3/	nr	nr	nr
Conv/wo mbd plow 4/	94	94	94
Mulch-till 5/	4	2	4
No-till 6/	2	4	2
Residue remaining after planting:	% of soil surface covered		
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	4	4	4
Mulch-till	39	37	38
No-till	65	60	63
Average	7	6	7
		Number	
Hours per acre:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	.5	.3	.5
Mulch-till	.3	id	.3
No-till	id	id	.1
Average	.5	.3	.5
Times over field:			
Conv/w mbd plow	nr	nr	nr
Conv/wo mbd plow	6.1	5.5	5.9
Mulch-till	3.1	3.0	3.1
No-till	1.0	1.0	1.0
Average	5.9	5.2	5.7

id = Insufficient data. nr = none reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Table 31--Erodibility distribution of crop acreage and tillage systems, 1991

Category	Winter wheat 1/	Corn	Northern soybeans	Southern soybeans	Cotton	Spring wheat	Durum wheat	Rice
Planted acres (1,000) 2/	34,180	60,350	38,850	10,800	10,860	13,500	3,000	1,880
Highly erodible land (%)	30	22	19	10	22	17	16	5
Land not highly erodible (%)	64	74	77	81	70	80	78	89
Land not designated (%)	6	4	4	9	8	3	6	6
Highly erodible land:								
Planted acres (1,000) 2/	10,185	13,300	7,230	1,060	2,355	2,330	470	90
				Percent				
Tillage system:								
Conv/w mbd plow 3/	8	9	5	3	32	5	5	nr
Conv/wo mbd plow 4/	74	51	50	66	61	55	70	95
Mulch-till 5/	14	26	30	3	3	38	25	5
No-till 6/	4	14	15	28	4	2	nr	nr
Land not highly erodible:								
Planted acres (1,000) 2/	21,940	44,480	29,930	8,810	7,590	10,800	2,345	1,680
				Percent				
Tillage system:								
Conv/w mbd plow 3/	14	15	20	2	17	7	5	nr
Conv/wo mbd plow 4/	72	58	48	84	82	61	53	95
Mulch-till 5/	12	18	23	6	1	29	38	3
No-till 6/	2	9	9	8	nr	3	4	2
Land not designated								
Planted acres (1,000) 2/	2,055	2,570	1,690	930	915	370	185	110
				Percent				
Tillage system:								
Conv/w mbd plow 3/	11	33	27	4	30	13	nr	nr
Conv/wo mbd plow 4/	69	46	39	68	68	79	50	87
Mulch-till 5/	16	17	26	8	1	8	50	9
No-till 6/	4	4	8	20	1	nr	nr	4

nr = None reported.

1/ Harvested acres for winter wheat only. 2/ Preliminary. 3/ Conventional tillage with moldboard plow--Any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 4/ Conventional tillage without moldboard plow--Any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; allows passes of nontillage implements, such as stalk choppers.

Energy

U.S. farmers can expect 1992 energy prices to remain at or slightly above 1991 averages due to likely steady or slightly higher prices for imported crude oil. For 1991, direct energy expenditures (about 5.9 percent of total cash farm production expenses) are expected to be approximately 3 percent above their level in the preceding year. This rise is attributed to the increase in energy prices coupled with little change in energy use.

The World Crude Oil Price

After the Persian Gulf War, the world price of crude oil settled back to the pre-war level of around $20 per barrel. Over the past few months, it has fallen to $17 to $18 per barrel. This reduction is expected to be short-lived, lasting only through the first quarter of 1992. It has been driven by the increased production of crude oil by Saudi Arabia. Saudi production grew from 5.4 million barrels per day before the Iraqi invasion of Kuwait to about 8.5 million barrels currently, but it is expected to sink back to its pre-invasion level.

World crude oil prices over the next few years will evolve from a number of inherent uncertainties. These include the oil production of the Organization of Petroleum Exporting Countries (OPEC), excess petroleum stocks relative to petroleum demand (as measured in days of forward consumption), and exports from the former USSR.

The OPEC crude oil production capacity will depend on the speed with which Iraq and Kuwait restore oil production facilities. While Kuwait will probably increase production as capacity is restored, Iraqi production will be affected by other factors. These include whether Iraq will accept the United Nations' oil export plan and agree on the time frame and production level allotted. Also, how quickly Iraqi oil export facilities are repaired will affect production. Aggregate OPEC production will also be affected by other OPEC member countries restraining their production, if necessary, to accommodate increased exports from Iraq and Kuwait.

There is also uncertainty about the excess petroleum stocks available relative to demand. Abnormally high petroleum stocks would be useful this winter because they would offset, at least partially, the upward pressure on the world oil price from the low level of excess OPEC oil production capacity. This low level precludes OPEC from expanding production much beyond its current level in the short run.

Oil exports from the former USSR will be determined by the political stability in the oil producing regions and by the relative decline of oil production and consumption, all of which are extremely uncertain at this time.

In addition, two other uncertainties affecting the world oil price are the severity of winter weather and the magnitude of economic growth, especially in the United States and in the other countries that comprise the Organization for Economic Cooperation and Development (OECD).

Given these uncertainties, the world price of crude oil is forecast by the Department of Energy to increase between 0 and 15 percent through the end of 1992, with the most probable increase being around 4 percent.

Domestic Petroleum Consumption and Production

The Department of Energy has analyzed the consumption and production of refined petroleum products, assuming an average world price of crude oil of $20 per barrel through 1992 (table 32). With a higher world crude oil price and a sluggish, though rebounding, economy, U.S. petroleum demand is expected to increase. At a world price of $20 per barrel, the demand for all refined petroleum products in 1992 is expected to be 16.92 million barrels per day, a 1.6 percent increase from 1991.

On the supply side, the $20-per-barrel price is expected to slow, but not reverse, the rate of decline in domestic crude oil production in 1992. Net crude oil and petroleum imports are expected to reverse their direction from a decrease of 6.6 percent for 1991 to a 9.4 percent increase for 1992, as a result of reduced domestic production and increased domestic consumption.

In the $20-per-barrel-world-oil case, the price of crude oil is assumed to increase by nearly $1 per barrel (2.4 cents per gallon) from the fourth quarter of 1991 to the fourth quarter of 1992. Most refined petroleum product prices would increase by about 3 cents per gallon during this period, indicating that the refiner margin would change little.

At $20 per barrel, the consumption of most refined petroleum products is expected to increase slightly in 1992. In the transportation sector, continued slow economic growth and moderately higher prices for gasoline and diesel fuel are expected to dampen travel demand. Growth in motor vehicle-miles traveled is expected to be more than offset by the continued improvements in vehicle efficiency that reduce gasoline and diesel fuel use. Higher fuel costs are expected to result in higher airline ticket prices, which in turn is expected to keep commercial jet fuel demand weak in 1992.

Table 32--U.S. petroleum consumption-supply balance

Item	1988	1989	1990	1991	Forecast 1992
	Million barrels/day				
Consumption:					
Motor gasoline	7.34	7.33	7.23	7.21	7.19
Distillate fuel	3.12	3.16	3.02	2.97	3.12
Residual fuel	1.38	1.37	1.23	1.14	1.13
Other petroleum 1/	5.45	5.47	5.51	5.33	5.48
Total	17.29	17.33	16.99	16.65	16.92
Supply:					
Production 2/	10.51	9.91	9.70	9.78	9.50
Net crude oil and petroleum imports (includes SPR) 3/	6.59	7.20	7.17	6.70	7.33
Net stock withdrawals	0.19	0.21	0.12	0.16	0.09
Total	17.29	17.32	16.99	16.64	16.92
	Percent				
Net imports as a share of total supply	38.11	41.57	42.20	40.26	43.32
	Percent change from previous year				
Consumption		0.23	-1.96	-2.00	1.62
Domestic production		-5.71	-2.12	0.82	-2.86
Imports		9.26	-0.42	-6.56	9.40

1/ Includes crude oil product supplied, natural gas liquid (NGL), other hydrocarbons and alcohol, and jet fuel. 2/ Includes domestic oil production, NGL, and other domestic processing gains (i.e., volumetric gain in refinery cracking and distillation process). 3/ Includes both crude oil and refined products. SPR denotes Strategic Petroleum Reserves.

Source: U.S. Department of Energy, Energy Information Administration. Short-Term Energy Outlook. DOE/EIA-0202(91/3Q), August 1991.

The slightly higher energy prices are expected to have minimal effect on domestic production of crude oil in 1992. In a $20-per-barrel oil price scenario, domestic crude oil output is projected to decline in 1992 by 280,000 barrels per day from 1991. This compares to an average increase of 80,000 barrels per day in 1991 but a decline of 210,000 barrels per day in 1990. Higher oil prices are expected to further slow the rate of decline in domestic crude oil production by the end of 1992.

At $20 per barrel, net imports of crude oil are anticipated to increase by 630,000 barrels per day to 7.33 million barrels in 1992, compared to a decline of 470,000 barrels in 1991. The expected 1992 increase largely reflects the reduced import rates during the first quarter of 1991, giving a lower base level of imports.

End-of-year crude oil inventories are projected to remain almost unchanged in 1992. The sizeable stock drawdown during the first half of 1991, brought about by the disruption of normal supply patterns, is projected to be reversed. Inventories should return to normal levels. Refined petroleum product inventories, however, are expected to increase slightly in 1992 over 1991.

Energy in the Farm Sector

The U.S. agricultural sector's energy supply and price expectations reflect world crude oil market conditions. Current world oil supplies are adequate and expected to continue through 1992. Fuel prices in the farm sector increased in 1990 over 1989, but are likely to stabilize in 1992 at or slightly above 1991 levels. Farmers can expect plentiful supplies of gasoline, diesel fuel, and liquefied petroleum (LP) gas this year.

Little shift is expected in the input mix (e.g., fuel choice) over the next year. If crude oil prices go higher, however, farmers will likely substitute relatively less expensive energy (e.g., natural gas) for refined petroleum products where possible.

Farm Fuel Use

Agricultural consumption of refined petroleum products such as diesel fuel, gasoline, and liquefied petroleum gas declined steadily between 1978 and 1989. Since then, aggregate energy consumption has remained relatively constant. Although the number of acres planted influences energy use, so do weather and other factors. For example, switching from gasoline to diesel-powered engines, adopting conservation tillage practices, changing to larger, multifunction machines, and creating new methods of crop drying and irrigation contributed to the earlier decline. (See "Energy Efficiency, Technological Change and the Dieselization of Agriculture in the United States" in this issue.) While no-till and mulch-till farming practices have not been widely adopted, they are as prevalent as conventional tillage practices in some parts of the United States.

With only a minimal variation in total acres planted and harvested, few significant changes in cropping practices, and somewhat higher average energy prices, 1991 farm energy consumption probably remained near its 1990 level.

Energy Prices Rose in 1990 and Were Mixed in 1991

Crude oil prices (especially imported crude, since it is the marginal supply in most instances) heavily influence the prices farmers pay for refined petroleum products. Historically, each 1 percent increase in the U.S. price of imported crude oil has translated into about a 0.7 percent rise in the price of gasoline and diesel fuel paid by farmers. In 1990, average gasoline prices increased by 11.4 percent and diesel fuel prices rose by 25 percent over their 1989 levels (table 33). For 1991, gasoline prices were 1.7 percent above their 1990 average while diesel fuel prices fell by 8.4 percent.

More revealing than average energy prices between 1990 and 1991 are the price changes between July and October of 1990 and January, April, July, and October of 1991. Recall that the Persian Gulf War began on August 2, 1990. Thus, between July and October 1990, when the impact of the conflict on the world crude oil market was most severely felt, the price of gasoline, diesel fuel, and LP gas jumped by 28.1 percent, 65.9 percent, and 44.6 percent, respectively. As surge production from oil producing countries replaced that lost from Iraq and Kuwait, the world price decline resulted in a fall in average U.S. farm fuel prices (table 33). After the cessation of hostilities in February 1991, the price of gasoline stabilized slightly above pre-war levels, while prices of diesel fuel and LP gas approached their pre-war level.

Table 33--Average U.S. farm fuel prices 1/

Time Frame	Gasoline	Diesel	LP gas
		$/gallon 2/	
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.89	0.71	0.67
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.94	0.83
1991	1.19	0.87	0.75
Jan 1990	1.09	1.01	1.06
April 1990	1.08	0.81	0.67
July 1990	1.10	0.74	0.65
Oct 1990	1.41	1.22	0.94
Jan 1991	1.26	1.05	0.88
April 1991	1.16	0.82	0.72
July 1991	1.16	0.77	0.68
Oct 1991	1.16	0.85	0.73

1/ Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service, USDA. 2/ Bulk delivered.

Energy Expenditures Up in 1990

In 1990, farm energy expenditures on gasoline, diesel fuel, LP gas, electricity, natural gas, and lubricants totaled $7.47 billion, up 10.2 percent from a year earlier (table 34). This rise reflects a 16.2 percent jump in fuel and lubricant expenditures and about a 1.3 percent decrease in electricity expenditures. Higher energy prices and yields and a very slight fall in acres planted and harvested in 1990 over 1989 accounted for these increases. For 1991, a moderate change in planted acreage and relatively higher energy prices during the planting season likely held the rise in farm energy expenditures to 3.3 percent.

Farm Machinery

Economic conditions affecting the general economy also adversely impacted the farm machinery industry. Farmers purchased fewer tractors, trucks, combines, and other farm

Table 34--Farm energy expenditures

Item	1987	1988	1989	1990	Expected 1991
	$ billion				
Fuels and lubricants:					
Gasoline	1.37	1.42	1.44	1.65	1.62
Diesel	2.13	2.12	2.12	2.42	2.57
LP gas	0.38	0.38	0.38	0.53	0.56
Other	0.47	0.53	0.51	0.57	0.60
Electricity:					
Excluding irrigation	2.03	2.17	1.69	1.65	1.70
For irrigation	0.43	0.48	0.64	0.65	0.67
Total	6.81	7.10	6.78	7.47	7.72
Percent change from preceding year		4.25	-4.51	10.18	3.35

Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Farm Production Expenditures, 1987, 1988, 1989, and 1990 summaries.

equipment in 1991 than in 1990, and the downward trend will likely extend into 1992 if the recession continues.

While the recession is not affecting income in the farm sector as much as in nonfarm sectors, it does impact farmers' decisions to invest in capital equipment. Farmers may delay capital investments pending a brighter economic outlook, as do investors in nonfarm sectors. While many farm inputs, such as seed, fertilizer, and pesticides must be bought annually, farm machinery purchases can be delayed, sometimes several years.

Unit Sales

There were lower sales in all categories of tractors and combines in 1991 (table 35). Four-wheel-drive tractors fell the most, from 5,100 to 4,100 units (20 percent). Combine sales fell the least, 7 percent.

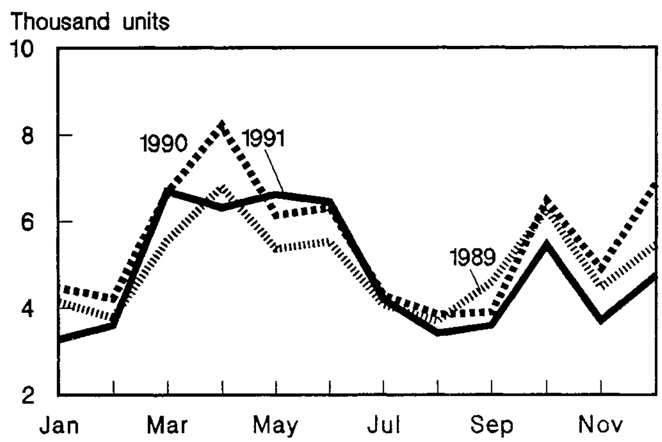
In March, May, and June 1991, tractor sales were above the same months of the preceding two years. However, 1991 sales were below those for 1989 and 1990 for eight months of the year (figure 1). From August through December, 1991 sales were below every corresponding month of both 1989 and 1990. Although tractor sales rose from the August low of 3400 units, year-end sales were still well below those for the same period last year.

Tractor sales are forecast to continue declining through 1992, by as much as 11 percent for the 40-99 horsepower category. Two-wheel-drive tractors 100 horsepower and over are forecast to decrease the least, by 2 percent.

Factors Affecting Sales

Several economic variables are correlated with farm machinery sales. These include cash receipts, government payments, net income, commodity exports, assets, debt, and interest rates (table 36). Knowledge of trends in these variables can provide insight about trends in farm machinery sales which affect farmers, equipment dealers, wholesalers, and manufacturers. Farm machinery demand is also affected

Figure 1
Farm Tractor Sales



Wheel tractors 40 horsepower and above.
Source: Equipment Manufacturers Institute.

Table 35--Domestic farm machinery unit sales

Machinery category	1985	1986	1987	1988	1989	1990	1991P	1992F	Change 90-91	Change 91-92
	Units								Percent	
Tractors:										
Two-wheel-drive										
40-99 hp	37,800	30,800	30,700	33,200	34,900	38,400	33,900	30,200	-12	-11
100-139 hp 1/	7,300	5,100	5,100	4,300	5,200					
Over 139 hp 1/	10,400	9,100	10,800	11,800	15,400					
Total over 99 hp	17,700	14,300	15,900	16,100	20,600	22,800	20,100	19,800	-12	-2
Four-wheel-drive	2,900	2,000	1,700	2,700	4,200	5,100	4,100	3,800	-20	-7
Grain and forage harvesting equipment:										
Self-propelled combines	8,400	7,700	7,200	6,000	9,100	10,400	9,700	9,000	-7	-7
Forage harvesters 1/2/	2,500	2,200	2,300	2,400	2,800					
Haying equipment:										
Mower conditions 1/	11,200	10,900	11,200	11,000	13,200					

1/ Discontinued after 1989. 2/ Shear bar type.

Source: Equipment Manufacturers Institute (EMI). All 1992 values are ERS forecasts.

Table 36--Trends in U.S. farm investment expenditures and factors affecting farm investment demand

Item	1985	1986	1987	1988	1989	1990	1991F	1992F
				$ billion				
Capital expenditures:								
Tractors	1.94	1.51	2.10	2.48	2.76	2.87	2.8	2.7-2.9
Other farm machinery	3.23	3.09	4.30	4.15	4.92	5.32	4.8	4.5-4.8
Total	5.17	4.60	6.40	6.63	7.68	8.19	7.6	7.2-7.7
Tractor and machinery repairs	3.44	3.43	3.51	3.56	3.93	3.73	3.9	3.7-4.1
Trucks and autos	1.76	1.71	2.17	2.33	2.50	2.52	2.7	2.4-2.8
Farm buildings 1/	2.26	2.14	2.60	2.35	2.45	2.67	2.3	2.1-2.4
Factors affecting demand:								
Interest expenses	18.6	17.1	15.0	14.7	14.7	14.7	14	12-15
Total production expenses	132.4	125.5	128.7	133.9	140.2	144.3	146	146-154
Outstanding farm debt 2/ 3/	188	167	153.7	148.5	146.0	145.1	146	145-151
Farm real estate assets 2/	757	613	658.6	687.0	692.7	702.6	713	715-725
Farm nonreal estate assets 2/	235.8	234.9	252.8	269.8	283.3	293.6	297	300
Agricultural exports 4/	31.2	26.3	27.9	35.4	39.6	40.1	38	39
Cash receipts	144.1	135.2	141.8	151.1	160.9	170.1	168	163-171
Net farm income	31.0	31.0	39.7	41.6	50.1	50.8	44	40-46
Net cash income	47.9	46.7	55.3	57.4	59.4	61.8	58	52-57
Direct government payments	7.7	11.8	16.7	14.5	10.9	9.3	9	8-11
				Million acres				
Idled acres 5/	30.7	48.1	76.2	77.7	60.8	61.6	63.3	na
				Percent				
Real prime rate 6/ 7/	6.2	5.7	5.0	5.4	6.6	5.8	4.7	na
Nominal farm machinery and equipment loan rate 7/	13.7	12.2	11.5	11.7	12.8	12.3	11.3	na
Real farm machinery and equipment loan rate 6/	9.6	9.4	8.0	7.5	8.2	7.8	7.3	na
Debt-asset ratio 8/	21.0	19.6	16.9	15.5	15.0	14.6	14-15	na

1/ Includes service buildings, structures, and land improvements. 2/ Calculated using nominal dollar balance sheet data, including farm households for December 31 of each year. 3/ Excludes CCC loans. 4/ Fiscal year. 5/ Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program. 1991-preliminary.
6/ Deflated by the GDP deflator. 7/ Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System.
8/ Outstanding farm debt divided by the sum of farm real and nonreal estate asset values.
F-forecast, subject to change

Source: Agricultural Income and Finance, Situation and Outlook Report AFO-42, ERS; and other ERS sources.

by the number of planted acres (more machinery is needed to farm more land). However, the number of planted acres has a greater effect on inputs that are purchased annually, such as fertilizer and pesticides.

General economic indicators also correlate with the sales of farm machinery. These include the Consumer Price Index, the Producer Price Index, and changes in the Gross National Product. Economic factors that affect these indexes also affect the farm sector.

Cash Receipts

Cash receipts were up for crops, but down for livestock. The net result was a 1 percent decline in total cash receipts in 1991. Cash receipts are positively correlated with purchases of farm machinery—when cash receipts are down farmers have less money to buy tractors and farm machinery. Cash receipts are forecast to be steady or slightly lower in 1992.

Government Payments

Government payments are positively correlated with sales of farm machinery. When government payments increase farmers have more financial resources available for capital investment. Government payments were down in 1991, but are forecast to remain about the same through 1992. Government payments have been nearly stable at $9-11 billion since 1989. This is after reaching an 8-year high of $16.7 in 1987.

Income

Both net cash income and net farm income decreased from 1990 to 1991. Net farm income fell by 13 percent and net cash by 6 percent. Net cash income is composed of cash receipts minus cash expenses. Net farm income includes inventory adjustments, farm-related income and other factors associated with the farm enterprise. While 1991 net farm income was down, it was at an all-time high in 1990. Both net cash and farm incomes are forecast to decrease again in 1992, but not as much as 1991.

Commodity Exports

The value of commodity exports decreased from $40.1 to $38 billion from 1990 to 1991. However, exports are expected to increase through 1992. An increase in wheat and soybean exports will likely more than offset a decline in coarse grain exports. Increases in farm machinery sales are positively related to exports since increased exports mean more farm income that can be used for capital investments.

Assets, Debts, and the Debt-Asset Ratio

Farm machinery sales usually rise when the value of farm assets increase. Higher debt has a negative affect on the sales of farm machinery. The debt-asset ratio, representing the relative indebtedness of the farm business, also has a negative effect on machinery sales: as the debt-asset ratio increases, machinery sales decrease.

Both farm real estate and nonreal estate asset values rose in 1991, continuing a 5-year rise in asset values. Asset values will likely experience a moderate rise again in 1992.

Outstanding farm debt also rose in 1991, by $900 million. This rise follows 5 years of decreasing debt, from $188 billion in 1985 to $145 billion in 1990. The net effect of an increase in asset value and an increase in debt resulted in the debt-asset ratio holding constant through 1991. However, a moderate increase in debt accompanied by only a slight increase in the value of assets could increase the debt-asset ratio in 1992.

Interest Rates

Interest rates were lower in 1991, both real and nominal. Interest rates are negatively correlated with sales of farm machinery, that is, as interest rates fall, the demand for tractors, combines, and other farm equipment increases. The nominal interest rate for farm machinery fell to 11.3 percent in 1991 from 12.3 percent in 1990.

Real interest rates are now deflated with the new Gross Domestic Product (GDP) deflator instead of Gross National Product (GNP). The United States started using GDP to have a measure more comparable to the United Nation's System of National Accounts (SNA) for easier international comparisons. The GDP measures the value of goods and services produced in the United States, whatever the nationality of producers. The GNP measures the value of goods and services produced by U.S. nationals, no matter where located.

While there is little annual difference in the deflator using GDP or GNP, quarterly differences can be significant. Since 1977 the real GNP growth averaged about 2.4 percent per year and real GDP growth averaged about 2.5 percent.

Prices

The index of prices paid for tractors and self-propelled machinery increased 3.8 percent from October 1990 to October 1991 (table 37). Prices of trucks and autos for farm use rose by 6.4 percent. Other machinery and implement prices rose 4.5 percent. For comparison, inflation rates, measured by the Consumer Price Index, were 5.4 for 1990, 4.2 for 1991.

Farm Equipment Expenditures as a Percent of Total Expenses

Capital expenditures on tractors, trucks, and other farm machinery as a percent of total production expenses reached a 40 year low in 1986, but by 1991 had nearly returned to the longrun trend (figure 2). From 1946 to 1949, the proportion of farm equipment expenditures increased to a high of 14.8 percent as farmers bought new machinery unavailable during WWII. From 1952-78 the annual proportion ranged between 8.6 and 12.4 percent.

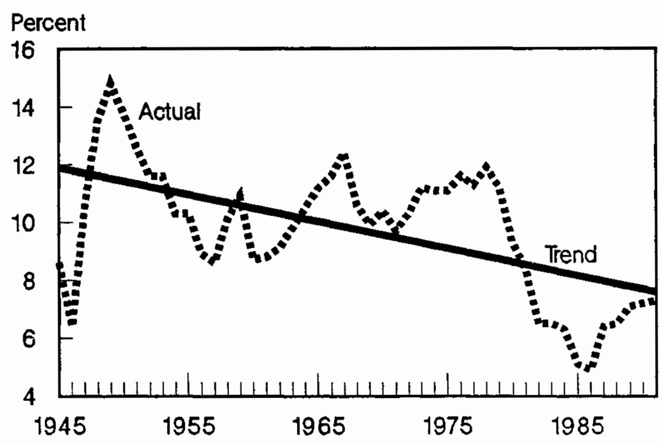
From 1978 to 1986, equipment purchases as a percent of total expenditures decreased markedly, and hit a 40 year low of 4.9 percent in 1986. The 1978-86 low was caused by several factors, but was primarily due to depressed farm incomes resulting from drought, reduced exports, and low commodity

Table 37--Prices paid for trucks, tractors, and other farm machinery

Year	Trucks and autos	Tractors and self-propelled machinery	Other machinery and implements
		1977 = 100	
1980	123	136	132
1981	143	152	146
1982	159	165	160
1983	170	174	171
1984	182	181	180
1985	193	178	183
1986	198	174	182
1987	208	174	185
1988	215	181	197
1989	223	193	208
1990	231	202	216
1991	244	211	226

Source: National Agricultural Statistics Service, USDA.

Figure 2
Machinery Portion of Production Expenses



Nominal dollars.
ERS National Financial Summary, 1990.

prices. Depressed real estate values and high debt also contributed to the downturn by reducing farmers' collateral for farm machinery loans. Capital equipment expenditures increased through 1989, but slowed in 1990-91.

The difference in expenditures on capital equipment relative to total input probably results from several factors. The prices or quantities of noncapital inputs might be rising more rapidly than equipment inputs. Or in some years, economic conditions may be less favorable for the purchase of trucks, tractors, and other farm machinery. For example, the proportion of equipment expenditures rose to the 1978 high when cash receipts were up, interest rates were down, the debt-asset ratio was low, and farm income was up. However, these same economic conditions turned around, contributing to the 1986 low in equipment expenditures.

Also, the farm sector could be tending toward less capital investment relative to total production expenses. For example, shifts toward no-till and mulch-till require fewer field operations and less machinery because some chemicals can be substituted for mechanical weed control.

The longrun trend line in figure 2 will not likely continue at the same rate. The decrease was largely the result of the 1978-86 drop. If the longrun trend is plotted from 1945-80 it is nearly horizontal at 10.6 percent. Economic factors contributing to the decline will likely change, causing the longrun trend to rise.

Trade

Imports of farm wheel tractors (40 horsepower and greater) totaled $1.2 billion in 1990. Exports were $0.7 billion. About one-half of 1990 imports came from Germany and the United Kingdom, and another 18 percent came from Japan. About 26 percent of U.S. tractor exports went to Canada. Australia was the next largest importer of U.S. tractors in 1990, taking about 11 percent.

From October 1990 to October 1991, imports of farm wheel tractors decreased from $1 billion to $0.8 billion, a decrease of 20 percent. Decreases occurred for every major trading country except Italy and Brazil, which increased exports to the U.S. by 26 and 111 percent, respectively. These were primarily in the 60 to 80 horsepower categories.

From October 1990 to October 1991, exports of farm tractors increased from $0.6 to $0.7 billion. Significant increases occurred to Mexico, Germany, Saudi Arabia, Netherlands, United Arab Emirates, Venezuela, New Zealand, and Israel. The value of exports decreased for most other trading partners.

All farm machinery exports totaled $2.9 billion in 1991, a decrease of $300 million from 1990. Imports also decreased, $361 million to $2.2 billion in 1991. According to the 1992 U.S. Industrial Outlook, published by the U.S. Department of Commerce, exports of farm machinery have exceeded imports 3 years in a row and are forecast to exceed imports again in 1992.

Seeds

Consumption

In the 1990/91 crop year, seed use for eight major field crops was close to 5.9 million tons, down 4 percent from the previous year. For the 1991/92 crop year, seed use is expected to increase 1 percent as a result of gains in wheat, corn, rice, barley, and sorghum planted acreage. However, a slight decline is expected in the planted acreage of cotton and soybeans (table 38).

Prices

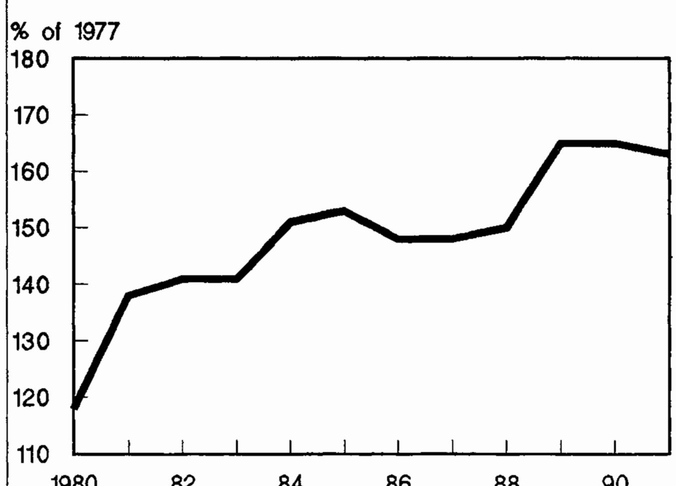
In 1991, higher corn, grain sorghum, cotton, and soybean seed prices were offset by generally lower prices for small grains, forage seeds, and seed potatoes. As a result, USDA's prices-paid index for all seeds at 163, was 2 points lower than in 1990 (figure 3).

Table 38--Seed use for major U.S. field crops 1/

Crops	1988/89	1989/90	1990/91 2/	1991/92 3/	90/91-91/92
	1,000 tons				%
Corn	515	529	540	556	3
Sorghum	42	31	36	37	2
Soybeans	1,751	1,664	1,722	1,670	-3
Barley	360	320	350	357	2
Oats	433	361	306	275	-10
Wheat	3,090	3,000	2,670	2,804	5
Rice	150	160	168	174	9
Cotton 4/	112	94	108	102	-6
Total	6,453	6,159	5,892	5,975	1

1/ Crop marketing year. 2/ Preliminary. 3/ Projected based on table 1 acreage. 4/ Upland cotton.

Figure 3
Seed Price Index



In 1992, prices-paid index for seed is likely to remain steady to slightly higher. This is because seed supplies did not change enough to have a noticeable effect on prices, planted acreage increases are modest for spring, and commodity price movement is small, as non-hybrid seed prices tend to follow commodity prices. However, if planted row crop acreage, especially corn, increase significantly more than anticipated, the seed price index could increase 2-4 percent.

Forage seed prices were lower last year as demand declined due to slow growth of Conservation Reserve Program (CRP) acreage and abundant seed supplies. In 1992, 1.12 million acres are expected to be retired compared to 550,000 acres in 1991. Although newly enrolled CRP acreage this year will grow slightly, the requirement that 18 percent be planted to trees compared to 6 percent in previous years (1985-90) will be a factor in reducing grass seed demand. This year CRP-related grass seed demand is, therefore, expected to increase modestly and is likely to generate limited upward pressure on forage seed prices. Moreover, forage seed supplies will likely be plentiful in 1992.

Seeding Rates and Seed Costs Per Acre

Seeding rates and seed prices are the two major factors which determine seed cost per acre. Costs vary substantially by State and by crop. Seeding rates also vary among States depending upon moisture during the growing season. Areas where crops are generally irrigated (as in California) or where rain is normally abundant (as in the eastern Corn Belt) support heavier seeding rates, thereby raising seed costs per acre.

Corn

The average seeding rate for the 10 leading corn producing States in 1991 was 24,900 kernels per acre, only 200 kernels higher than a year earlier. The average seed cost per acre was $20.79, slightly higher than 1990, reflecting higher corn seeding rates. The average plant population per acre for these States increased nearly 5 percent in 1991 because of moisture availability (table 39).

Minnesota and Ohio had the highest seeding costs due to greater seeding rates. South Dakota, on the other hand, had the lowest seeding rate and, consequently, the least seed cost per acre.

Soybeans

In 1991, the average seeding rate for the 14 major soybean producing States was 64 pounds per acre, up 3 percent from 1990. The average seed cost per acre was $15.07, up 6 percent, reflecting higher seed prices and greater seeding rates (table 40). Most of the northern soybean growing States, which have higher seeding rates and yields, have greater seed cost per acre. Most of the southern States, on the other hand, have lower seeding rates and, consequently, less seed cost per acre.

Farmers in the surveyed States used purchased rather than homegrown seed on 73 percent of the 1991 soybean acres. It was 71 percent in 1990. The share of 1991 acres planted with purchased seed varied widely among States, ranging from 55 percent in Arkansas and Tennessee to 95 percent in Louisiana. Differences in seed cost and yield often determine the choice between purchased and homegrown seed.

Spring and Durum Wheat

In 1991, the average spring wheat seeding rate was 89 pounds per acre, 1 percent higher than 1990. The average seed cost per acre was $6.52, down 22 percent from a year earlier. The 22 percent decline in average spring wheat seed price contributed to the lower seed cost per acre in 1991

Table 39--Corn for grain seeding rates, plant population, and seed cost per acre, 1991 1/

States	Acres planted 2/	Rate per acre	Plant population per acre	Cost per acre
	Thousand	Kernels	Number	Dollars
Illinois	11,300	25,511	23,700	21.09
Indiana	5,800	25,027	22,400	20.26
Iowa	12,200	25,285	22,800	21.62
Michigan	2,600	24,279	21,800	20.49
Minnesota	6,600	26,602	23,900	22.98
Missouri	2,200	22,575	19,900	19.87
Nebraska	8,300	24,501	22,200	20.21
Non-irrigated	2,747	18,648	nr	15.64
Irrigated	5,553	27,397	nr	22.47
Ohio	3,800	26,442	23,200	22.51
South Dakota	3,750	19,111	17,500	16.03
Wisconsin	3,800	25,611	23,400	19.16
1991 average	60,350	24,906	22,080	20.79
1990 average	58,800	24,700	21,040	20.50
1989 average	57,900	24,100	20,760	20.40

nr = Not reported.

1/ States planted 80 percent of U.S. corn acres in 1991.
2/ Preliminary for 1991.

Table 40--Soybean seeding rates, seed cost per acre, and percent seed purchased, 1991 1/

Region/States	Acres planted	Rate per acre	Cost per acre 3/	Acres with purchased seed
	Thousand	Pounds	Dollars	Percent
Northern:				
Illinois	9,200	66	16.44	73
Indiana	4,450	67	15.85	82
Iowa	8,800	61	16.35	81
Minnesota	5,500	68	14.65	74
Missouri	4,500	65	15.20	61
Nebraska	2,500	61	15.80	78
Ohio	3,900	77	16.26	69
Southern:				
Arkansas	3,200	58	11.74	55
Georgia	650	49	10.24	81
Kentucky	1,150	61	13.54	64
Louisiana	1,450	52	12.12	95
Mississippi	1,900	53	10.38	78
North Carolina	1,350	65	14.09	73
Tennessee	1,100	53	10.07	55
1991 average 2/	49,650	64	15.07	73
1990 average	48,250	62	14.20	71
1989 average	51,130	60	15.50	68

1/ States planted 83 percent of U.S. soybean acres in 1991. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

(table 41). The average seeding rate did not increase enough to offset the decline in average spring wheat seed price. Variations in seed prices and seeding rates resulted in per acre costs ranging from $4.86 in Montana to $8.03 in Minnesota. Farmers planted most of the spring wheat acres with homegrown seed. The Share of acres which used purchased seed was 32 percent, compared to 39 percent in 1990.

For the 1991 crop, the average seed cost for durum wheat was $6.66, down 11 percent, reflecting lower seed prices (table 41). Only 27 percent of the durum wheat acres used purchased seed. The remaining acres were planted with homegrown seed.

Rice

Arkansas and Louisiana are the two major rice producing States. These States accounted for 65 percent of total U.S. rice acres planted in 1991. In 1991, the seeding rate in Arkansas was 125 pounds per acre, while it was 129 pounds in Louisiana, similar to last year when the two state average seeding rate was 126 pounds. Louisiana had a higher seed cost per acre — $21.85, because of the higher seeding rate. Arkansas, on the other hand, had a lower seeding rate and, consequently, lower seeding cost of $19.29 per acre (table 42).

Farmers in both States used purchased rather than homegrown rice seed. The average share of the rice acreage planted with purchased seed in 1991 was 81 percent.

Cotton

In 1991, the average seeding rate for cotton was 17 pounds per acre, the same as last year. The average seed cost was $8.11 per acre, 4 percent higher than a year earlier, because of higher cottonseed prices in 1991 (table 43).

Seeding rates and seed costs for cotton varied among surveyed States. California had the highest seed cost per acre, while Texas had the highest seeding rate. Although California had a lower seeding rate compared to Texas, its seeding cost was greater because of higher seed prices. The situation in Texas is the opposite—a higher seeding rate but lower seed cost because of lower seed prices. In Texas, the competition among suppliers is intense, due to the large number of cottonseed varieties. Farmers in the surveyed States used purchased seed on 66 percent of 1991 cotton acres, the same as 1989, but lower than 1990.

U.S. Seed Exports and Imports

Corn Seed Exports

The volume of U.S. field corn seed exports to the 12 leading countries rose to 47,260 metric tons in the first 9 months of 1991, an increase of 18 percent over the corresponding pe-

Table 41--Spring and durum wheat seeding rates, seed cost per acre, and percent of seed purchased, 1991 1/

States	Area Planted	Rate per acre	Cost per acre 3/	Acres with purchased seed
	Thousand	Pounds	Dollars	Percent
Spring:				
Minnesota	2,100	108	8.03	39
Montana	2,600	64	4.86	28
North Dakota	7,000	91	6.46	33
South Dakota	1,800	94	6.74	26
1991 average 2/	13,500	89	6.52	32
1990 average	15,800	88	8.40	39
1989 average	16,580	89	8.82	40
Durum:				
North Dakota	3,000	100	6.66	27
1991 average 2/	3,000	100	6.66	27
1990 average	3,100	97	7.50	27
1989 average	3,000	99	10.10	47

1/ States planted 87 percent of U.S. spring wheat and 89 percent of U.S. durum wheat acres in 1991. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

Table 42--Rice seeding rates, seed cost per acre, and percent of seed purchased, 1991 1/

States	Acres planted	Rate per acre	Cost per acre 3/	Acres with purchased seed
	Thousand	Pounds	Dollars	Percent
Arkansas	1,350	125	19.29	76
Louisiana	530	129	21.85	93
1991 average 2/	1,880	126	20.13	81
1990 average	1,800	126	20.80	84
1989 average	2,085	134	19.87	83

1/ States planted 65 percent of U.S. rice acres in 1991. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

Table 43--Cotton seeding rates, seed cost per acre, and percent seed purchased, 1991 1/

States	Acres planted	Rate per acre	Cost per acre 3/	Acres with purchased seed
	Thousand	Pound	Dollars	Percent
Arizona	370	14	7.65	94
Arkansas	990	14	7.65	96
California	950	17	11.23	89
Louisiana	800	11	7.26	90
Mississippi	1,250	13	7.84	98
Texas	6,500	19	7.74	47
1991 average 2/	10,860	17	8.11	66
1990 average	9,730	17	7.80	70
1989 average	8,444	18	8.17	67

1/ States planted 78 percent of U.S. upland cotton acres in 1991. 2/ Preliminary. 3/ Based on data from farmers who used purchased seed.

riod a year earlier (table 44). These countries accounted for nearly 83 percent of U.S. total corn seed exports during this period in 1991. Total volume of U.S. corn seed exports was up 18 percent. Increased corn seed exports reflect plentiful supplies in the United States and strong demand abroad.

Although exports to Mexico, Spain, and Italy fell 14, 54, and 31 percent respectively, sharp increases in exports to Canada, France, Unified Germany, Netherlands, Greece, Japan, Romania, and the former USSR more than offset these declines.

Table 44--U.S. corn seed exports by volume

Country	1988	1989	1990	January-September 1990	January-September 1991	Change 90-91
	Metric tons			Metric tons		Percent
Canada	2,582	1,548	4,076	3,290	3,850	17
Mexico	3,312	10,205	10,329	8,167	7,056	-14
France	2,453	2,873	9,666	2,571	4,164	62
Germany	62	522	1796	116	8,150	6926
Spain	4,134	1,836	4,132	2,893	1,332	-54
Italy	8,741	12,168	20,889	16,018	11,004	-31
Netherlands	1,061	351	2,437	1,128	1,973	75
Greece	2,251	1,999	1,828	1,731	2,814	63
Romania	2,424	107	1,050	1,050	2,530	141
Union of Soviet Socialist Rp.	15	0	2,459	2,459	3,569	45
Turkey	1,101	245	59	59	171	190
Japan	1,322	1,051	1,431	496	647	30
Subtotal	29,458	32,905	60,152	39,978	47,260	18
Total all countries	33,732	36,859	70,366	48,441	57,138	18

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Corn Seed Imports

Because of larger domestic seed stocks, corn seed imports totaled 8,323 metric tons in the first 9 months of 1991, a 27 percent decline over the same period a year earlier (table 45).

Canada, Argentina, Chile, and Hungary are the major suppliers of corn seed imports. In 1988, 1989, and 1990 these 4 countries supplied 95, 92, and 99 percent of the total U.S. corn seed imports. However, corn seed imports constitute a very small component of total U.S. consumption. For example, in 1990, the share was only 0.2 percent of the total seed consumption.

Table 45--U.S. corn seed imports by volume

Country	1988	1989	1990	January-September 1990	January-September 1991	Change 90-91
	Metric tons			Metric tons		Percent
Canada	3,935	7,753	8,010	5,368	4,337	-19
Argentina	0	2,457	511	511	138	-73
Chile	2,055	7,000	4,509	4,509	3,367	-25
Hungary	1,327	3,708	881	881	0	-100
Subtotal	7,317	20,918	13,911	11,269	7,842	-30
Total all countries	7,909	22,672	13,996	11,354	8,323	-27

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Soybean Seed Exports

The bulk of the U.S. soybean seed is exported to 6 countries — Italy, France, Japan, Mexico, Turkey, and Canada. In 1990, 96 percent of U.S. soybean seeds were shipped to these countries; in the first 9 months of 1991 their share was 93 percent. The volume of soybean seed exports to these countries was 72,390 metric tons, a decline of 14 percent compared with the corresponding period in 1990. Overall volume, however, declined 11 percent (table 46).

Although exports to Italy, France, and Japan increased sharply in the first 9 months of 1991 compared with the corresponding period of 1990; these gains were overshadowed by 88 and 35 percent declines in exports to Mexico and Turkey, respectively. The result was a 14 percent decline in U.S. soybean seed exports. Increased soybean seed exports to Japan appear to be related to the growing popularity of tofu food, which requires high quality U.S. soybean seeds.

U.S. exports to Mexico in 1989 were a record high following the 1988 drought. In 1990, exports to Mexico fell sharply but were still well above usual quantities. Then, because of adequate supplies resulting from favorable weather conditions, exports to Mexico fell further in the first 9 months of

Table 46--U.S. soybean seed exports by volume

Country	1988	1989	1990	January-September 1990	January-September 1991	Change 90-91
	Metric tons			Metric tons		Percent
Canada	293	390	449	449	425	-5
Mexico	8,922	100,380	36,731	36,473	4,542	-88
France	2,187	1,698	4,827	2,689	3,948	47
Italy	27,833	20,185	55,937	40,422	56,757	40
Turkey	3,798	2,777	2,835	2,835	1,838	-35
Japan	5,277	1,608	2,325	1,724	4,880	183
Subtotal	48,310	127,038	103,104	84,592	72,390	-14
Total all countries	53,730	128,582	106,991	88,348	78,259	-11

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

1991. Once the volume of soybean seed exports to Mexico returns to normal, declines may change into gains.

Total Exports

The value of total seed exports increased 9 percent to $453 million in the first 9 months of 1991 compared with the same period a year earlier. This increase primarily reflects gains in vegetable, corn, and sugarbeet seed exports. These gains, however, were partly offset by 3, 11, and 12 percent declines in forage, flower, and other seed exports (table 47).

Total Imports

The value of total seed imports rose 10 percent to $122 million in the first 9 months of 1991 compared with the corresponding period of 1990 (table 47). This increase largely reflects 32, 6, and 57 percent increases in vegetable, flower, and other seed imports. U.S. net seed trade balance rose 8 percent to $331 million in the first 9 months of 1991 compared with the same period a year earlier.

Table 47--Exports and imports of U.S. seed for planting 1/

Item	1988	1989	1990	January-September 1990	January-September 1991	Change 90-91
	$ million					Percent
Exports:						
Forage	94	96	104	73	71	-3
Vegetable	167	153	176	116	142	22
Flower	9	11	13	9	8	-11
Corn 2/	67	68	138	89	109	22
Grain sorghum	29	55	27	22	22	0
Soybean	26	54	45	36	36	0
Tree/shrub	3	4	2	1	1	0
Sugarbeet	2	1	2	2	3	50
Other	27	68	81	68	60	-12
Total	424	510	588	417	453	9
Imports:						
Forage	52	44	35	28	24	-14
Vegetable	58	56	60	44	58	32
Flower	21	24	23	16	17	6
Corn 3/	10	37	18	15	11	-27
Tree/shrub	2	2	2	1	1	0
Other	4	6	7	7	11	57
Total	147	169	145	111	122	10
Trade balance	277	341	443	306	331	8

1/ Totals may not add due to rounding. 2/ Not sweet, not food aid. 3/ Certified.

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Forecasting the Prices Paid for Farm Inputs

Noel D. Uri*

Abstract: Forecasting models for the prices paid by farmers for seed, fertilizer, agricultural chemicals, and fuels are developed. The models are econometric in nature. Forecasts for 1992 indicate that prices paid for seed and fertilizer will increase at slightly less than 4 percent, while fuel and agricultural chemical prices paid will increase somewhat less than 3 percent.

Keywords: Agricultural chemicals, energy, fertilizer, forecasting, prices paid, seed

Introduction

Forecasting the prices paid for farm inputs using econometric models can be an elusive proposition. Problems arise from a variety of sources, including difficulty in identifying underlying relationships and specifying their functional forms, lack of requisite data, or incorrect data used for estimation, shortcomings in the estimating technique(s), and limitations in forecasting the exogenous or explanatory variables.

Confronted with these potential problems, the forecaster must be prudent in developing the requisite structural models on which the forecasts are based. Various empirical tests, coupled with a justifiable theoretical basis for the forecasting models, will mitigate the impact that these enumerated problems can have. In developing forecasting models and ultimately forecasts for the prices paid for seed, fertilizer, agricultural chemicals, and fuels at the national level, both conventional microeconomic theory and sound empirical techniques will be combined.

Theoretical Considerations

The demands for factors used in the production of agricultural commodities — including seed, fertilizer, agricultural chemicals, and fuels — are derived demands. That is, the demands for the factors of production are not based on any intrinsic desire for the factors themselves, but on the need to use these factors to produce a product to sell. (Stigler (7) explores the nature of derived demand.) This means that the demand for such factors as seed, fertilizer, agricultural chemicals, and fuels is determined in the final market(s) by the supply and demand for the agricultural commodities being produced.

This, in turn, implies that the derived demand is indirectly based on the elements which generate the supply and demand for the final commodities. This latter general relationship is the footing on which the requisite forecasting relationships for the prices paid for the factor inputs will be based.

Before developing these relationships, however, one further consideration is needed. Typically, when the derived demand for a factor of production is considered, the quantity demanded is specified to be a function of a set of explanatory factors, including the price of that factor of production and elements determining the supply and demand for the final commodity(ies) that the factor is used to produce.

An equally useful relationship is the one whereby the price of the factor of production is specified to be a function of the quantity of the factor of production demanded, plus a set of final supply and demand determining elements. This latter demand relationship is commonly referred to as the inverse demand function. (Deaton (5) provides an overview of the properties of an inverse demand function.) It is this relationship that will be employed here.

That is, in developing the forecasting relationships, the price of the factor inputs; i.e., the prices paid by producers for the various factors of production, are specified to depend on the quantities of the respective inputs demanded and a set of explanatory variables that determine the supply and demand for the final commodities.

Specifying the Forecasting Models

One of the justifications for using an econometric approach to forecasting prices paid rather than using a simpler univariate approach (e.g., the Box-Jenkins (2) times series method) is that during periods when widely fluctuating economic factors are affecting the prices paid, there will be considerable volatility in the prices paid (as occurred, for example, during the 1970's where there was considerable variation in the level of economic activity, the rate of inflation, and energy prices).

* The author is an economist with the Commodity Economics Division, Economic Research Service, USDA.

Explicitly reflecting the movements in these economic factors in the structural models will lead to more reliable forecasts. This holds true, of course, only if more reliable forecasts of the set of explanatory variables are available or can be developed, relative to those obtained using only the series of interest in generating the forecast.

Given this, the explanatory variables considered must account for not only the price levels, but movements in the prices of the factors of production of interest as well. Furthermore, the explanatory variables must be theoretically consistent and they should have reliable forecasts available (or they should be capable of being independently forecast).

Given these criteria for developing forecasting models, the requisite models for the prices paid for seed, fertilizer, agricultural chemicals, and fuels are developed. Because of the nature of the prices-paid data available — these data are compiled and reported as indexes by the National Agricultural Statistics Service — the actual specifications are in terms of price indexes and not average prices per se for the specific factors of production. The specifications are as follows.

Seed

The seed prices-paid index in a given period is specified to be a function of the prices-paid index in the previous period and the number of acres planted in the current period. The number-of-acres-planted variable captures demand-side considerations for agricultural commodities in general, while the lagged seed price reflects ongoing dynamics in the seed market. Both of these variables should be positively related to the seed prices paid.

Preliminary analyses of the data did not detect the explicit impact of any supply-side considerations. A number of different measures were considered, including the wage rate for farm workers, the price of energy, and the level of irrigation. Finally, the quantity of seeds demanded in the current period was omitted from the specification because reliable forecasts of this factor could not be independently obtained.

Fertilizer

The fertilizer prices-paid index in the current period is very much influenced by the price of natural gas in the current period. This occurs because anhydrous ammonia is synthesized through a chemical process that combined atmospheric nitrogen with hydrogen (typically derived from natural gas) and is the source of nearly all nitrogen fertilizer used in the United States (**11**). Thus, it is necessary to forecast the price of natural gas. To accomplish this, natural gas price in the current period is specified to be a function of a set of variables including the price of crude oil in the current period, as crude oil is a substitute for natural gas in many industrial and commercial uses (**10**). Additionally, the price of natural gas in the current period is specified to be a function of its price in the previous period, thus allowing energy market dynamics to be adequately reflected. Note that there should be a positive relation between the price of natural gas and the prices-paid index for fertilizer.

In addition to the price of natural gas influencing the fertilizer prices-paid index, the number of acres planted in the current period also affects the current-period price because of its effect on the demand for fertilizer. Consequently, this variable is included in the specification for fertilizer prices paid. Its impact is expected to be positive.

Agricultural Chemicals

The agricultural chemicals input category is a very heterogeneous factor. To properly forecast the prices-paid index would require considerably more detail on the components of the agricultural chemicals category than is currently available. Consequently, a second best approach is adopted. This is done by specifying the amorphous prices-paid index for agricultural chemicals to be a function of general factors affecting agricultural chemicals supply and use.

This translates into specifying the index to be a function of the average energy price and the prices-paid index for agricultural chemicals in the previous period. Both of these variables should be positively related to the prices-paid index.

A large number of other potential explanatory variables were considered in preliminary analyses, including the wage rate for farm workers and the number of acres planted, but none proved to have a measurable impact. Also, the quantity of agricultural chemicals demanded was omitted from the specification because reliable forecasts are not independently available.

In the specification, an average energy price is introduced to reflect the effect that energy prices in the aggregate have on the price of agricultural chemicals. Thus, the average price of energy must be forecast. To accomplish this, the average price of energy in the current period is specified to be a function of the price of "crude oil to be refined" in the current period. A positive relationship should be observed. This specification is consistent with the earlier natural gas price/crude oil to be refined price relationship, because crude oil (or more properly its refined derivatives) is substitutable in many uses, not only for natural gas but other types of energy as well (**10**).

Fuels

The primary type of energy consumed on farms is refined petroleum products, specifically diesel fuel and gasoline. But, in the context of aggregate U. S. energy consumption, agriculture is a relatively insignificant consumer of these refined petroleum products. As a result, its behavior will have little impact on the energy market and hence the price of energy. In fact, changes in the quantity of fuels demanded by the agricultural sector did not have a statistically significant (at the 95-percent level) impact on the prices-paid index for fuels.

Therefore, the prices-paid index for fuels in the current period is simply specified to be a function of the price of crude oil to be refined in the current period in the United States. This price of refined crude oil is heavily influenced by the world price of crude oil. The world price of crude oil has a positive effect on the price of crude oil to be refined in the current period, which, in turn, has a positive effect on the prices-paid index for fuels. Based on preliminary analyses, other factors potentially affecting the price farmers pay for fuels, including planted acreage and irrigation levels, did not register any measurable impact.

Forecasting Model Estimation

Turn now to the actual estimation of the forecasting models. A variety of sources were used to secure the data needed to estimate the model parameters. The data on the prices paid indexes for seed, fertilizer, agricultural chemicals, and fuels were obtained from various issues of *Agricultural Prices*, published by the National Agricultural Statistics Service, USDA. Data on the total number of acres planted in major field crops were taken from *Agricultural Statistics, 1990*, U.S. Department of Agriculture (8).

The energy price data, including the composite refiner acquisition cost, the world price of crude oil, the industrial price of natural gas, and the average energy price were taken from various issues of the *Monthly Energy Review* (U.S. Department of Energy). All of the data are national aggregates and annual averages. The data cover the period 1965 - 1990 (26 observations). Given the assumption of the absence of any money illusion (a common assumption in economics, (6), all of the nominal terms were deflated by the Gross National Product implicit price deflator.

In deciding on the exact functional specifications to be employed, a number of specifications were considered in preliminary analyses, including a simple linear specification, semi-logarithmic specifications, and a double logarithmic specification. Based on the results of the Davidson and MacKinnon (4) J-test, the double logarithmic specification, where all of the variables — both the dependent and the explanatory — are transformed logarithmically was preferred. The logarithmic transformation are in terms of natural logarithms.

Also, all of the equations estimated were subjected to regression diagnostics (1). Regression diagnostics investigates whether a subset of the data has a disproportionate influence on the estimated parameters. This is of concern because it is quite possible that coefficient estimates in the models are generated primarily by this subset of the data rather than by all of the data equally. This can be disastrous in a forecasting setting if the future never emulates the past behavior of this subset of data. Only in the case of the seed prices-paid forecasting equation was there a problem. Finally, the forecasting models' coefficients were estimated via classical least squares with correction for first order serial correlation which was present in each of the estimated relationships.

The estimated models are given below. The coefficient estimates in every instance have signs consistent with prior expectations.

Seed

$$\begin{aligned}\log(PP_{seed})_t = & -1.7005 + 0.5611 \log(PP_{seed})_{t-1} \\ & \ (0.8319) \quad (0.1067) \\ & + 0.6621 \log(ACRES)_t \\ & \ (0.1963) \\ & + 0.1428\, D74_t + 0.1018\, D75_t \\ & \ (0.0393) \qquad (0.0492) \quad R^2 = 0.9631\end{aligned}$$

where PP_{seed} denotes the prices-paid index for seed, ACRES denotes the number of acres planted, log denotes that the variable was logarithmically transformed, t denotes the time period, and R^2 is the coefficient of determination. The standard errors of the estimates are in parentheses below the coefficient estimates. The variables D74 and D75 are defined as qualitative (0-1) variables and were introduced because the regression diagnostics revealed that data for the years 1974 and 1975 had a disproportionate impact on the coefficient estimates.

Fertilizer

$$\begin{aligned}\log(PP_{fert})_t = & -3.6138 + 0.3169 \log(P_{ng})_t \\ & \ (0.0469) \quad (0.1654) \\ & + 0.6366 \log(ACRES)_t \\ & \ (0.2332) \qquad R^2 = 0.9924\end{aligned}$$

where PP_{fert} denotes the prices-paid index for fertilizer, P_{ng} denotes the price of natural gas, and the other variables are as previously defined.

Agricultural Chemicals

$$\begin{aligned}\log(PP_{chem})_t = & \ 2.0596 + 0.4562 \log(PP_{chem})_{t-1} \\ & \ (0.5363) \quad (0.1350) \\ & + 0.1174 \log(P_{energy})_t \\ & \ (0.0336) \qquad R^2 = 0.9988\end{aligned}$$

where PP_{chem} denotes the prices-paid index for agricultural chemicals, P_{energy} denotes the average price of energy, and the other variables are as previously defined.

Fuels

$$\log (PP_{fuel})_t = \underset{(0.0959)}{3.9983} + \underset{(0.0339)}{0.3745} \log (CRAC)_t \qquad R^2 = 0.992$$

where PP_{fuel} denotes the prices-paid index for fuel, CRAC denotes the composite refiner's acquisition cost for crude oil, and the other variables are as previously defined.

Three other estimated relationships are required to make the forecasting system complete. First, a relationship between the composite refiner's acquisition cost — which is the average price refiners in the United States pay for crude oil to be refined — and the world price of crude oil is needed. This is given as:

$$\log (CRAC)_t = \underset{(0.0933)}{0.1894} + \underset{(0.0549)}{0.9081} \log (WOP)_t \qquad R^2 = 0.9621$$

where WOP is the world price of crude oil and the other terms are as previously defined.

A second relationship is one relating the price of natural gas and the refiner's acquisition cost. This is given as:

$$\log (P_{ng})_t = \underset{(0.1091)}{-0.5303} + \underset{(0.0452)}{0.7527} \log (P_{ng})_{t-1} + \underset{(0.0451)}{0.2625} \log (CRAC)_t \qquad R^2 = 0.9726$$

where all of the terms are as previously defined.

The final necessary relationship is one for the average energy price. It is given as:

$$\log (P_{energy})_t = \underset{(0.1165)}{2.6665} + \underset{(0.0335)}{0.5046} \log (CRAC)_t \qquad R^2 = 0.9799$$

where all of the terms are as previously defined.

Forecasting the Prices Paid

Before actually using the estimated relationships to forecast, it is important to examine their integrity by generating out-of-sample forecasts over a known horizon. To accomplish this, the equations were re-estimated based on 1965-1989 data, and the 1990 prices-paid indexes were forecast where the values of the explanatory variables (e.g., the number of acres planted and the price of energy) were forecast using simple first order autoregressive models. These forecasts are given in Table A-1.

Table A1. Forecasts of prices paid

Factor	1990 Actual	1990 Forecast	Error	1992 Forecast	1992 Increase 1/
	1977=100		Percent	1977=100	Percent
Seed	165	165	0.0	169	3.68
Fertilizer	131	134	2.29	139	3.73
Agricultural chemicals	139	136	-2.16	154	2.67
Fuels	204	201	-1.47	208	2.46

1/ The percent increase is based on 1991 prices paid indexes for the respective factor inputs.

The forecast errors are very small indicating the general acceptability of the forecasting relationships. Keep in mind, however, that nothing especially dramatic happened during the important planting and growing seasons to adversely impact the prices-paid indexes. The effects of the Persian Gulf Crisis on energy prices occurred late in the crop year and, consequently, only incidentally impacted prices paid. These effects, however, to the extent they affected the prices-paid indexes, were nicely picked up by the forecasting relationships.

To use the estimated relationships in a true forecasting setting for 1992, it is necessary to have forecasts of (1) the world price of oil, (2) the number of acres to be planted in major field crops, and (3) the rate of inflation (which is measured by the Gross National Product implicit price deflator). The world oil price forecast is taken from the Energy Information Administration (3). The planted acreage is independently forecast by assuming that planted acreage follows a random walk with a mean zero error term, and the rate of inflation is forecast assuming that inflation follows a first order autoregressive process.

The forecasts derived from the estimated relationships for the 1992 prices-paid indexes for seed, fertilizer, agricultural chemicals, and fuels are given in Table A1. Seed and fertilizer prices paid are forecast to increase at slightly less than four percent while fuels prices paid are forecast to increase somewhat less than 3 percent. Each of these increases is the result of an assumed increase in the world price of crude oil, coupled with a moderate rate of inflation. Agricultural chemical prices are forecast to increase at approximately a 2 1/2 percent annual rate in 1992, being minimally affected by inflation and the price of crude oil.[1]

[1] The forecasts presented here are slightly different from forecasts found in other U.S. Department of Agriculture publications. These differences arise naturally because of the data and forecasts of explanatory variables used. The forecasts presented here, however, are consistent with those found in other portions of this report.

factors behave in an unanticipated fashion, then the increase in the prices paid can be more, or less, than expected.

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Energy Efficiency, Technological Change, and the Dieselization of U.S. Agriculture

Noel D. Uri and Kelly Day*

Abstract: This study focuses on the increase in the relative importance of diesel fuel consumption on farms in the United States during 1971-1989. Four factors are identified as being central to the observed trend. These include the relative efficiency of diesel-powered equipment versus gasoline-powered equipment, technological changes that have affected energy efficiency, the trend towards larger farms, and the enhanced energy conservation by farmers as a result of adopting reduced-tillage practices.

Keywords: Efficiency, energy conservation, farm size, fuel consumption, tractors.

Introduction

While agriculture's share of total U.S. energy consumption has remained essentially constant over the past 20 years, consumption of specific refined petroleum products has not.[1] A variety of energy use trends have been observed on U.S. farms. One of the most significant is the increase in diesel fuel consumption. For example, in 1971 diesel fuel accounted for about 30 percent of the total energy consumed on farms. By 1980, diesel fuel accounted for 50 percent of energy consumption and, in 1989, it was responsible for slightly more than 60 percent (**1, 2**). The explanation of this trend helps to understand how U.S. farming has changed over the past two decades.

Trends in Farm Energy Consumption

The major energy-using activities on U.S. farms relate to cropping operations. Thus, tasks such as preplanting, planting, cultivating, disking, irrigating, harvesting, and applying fertilizer and pesticides account for roughly 90 percent of the energy consumed. Prior to the early 1970's, gasoline was the dominant energy type. In 1971, for example, gasoline was responsible for 60 percent of aggregate farm energy consumption. This dominance has given way to diesel fuel, so by 1989, gasoline accounted for only 22 percent of farm energy consumption.[2]

* The authors are economists with the Economic Research Service, USDA, Washington, DC.

[1] Currently, the agricultural sector directly accounts for approximately 2.5 percent of total U.S. energy consumption. In terms of refined petroleum products, it consumes approximately 1.4 percent of gasoline and 6.1 percent of diesel fuel sold.

[2] Other energy types consumed on farms include liquefied petroleum gas (approximately 8 percent of aggregate energy consumption per year), natural gas (nearly 4 percent per year), and electrical energy (3-6 percent per year). The liquefied petroleum gas and natural gas shares have remained fairly constant over the period 1971-1989, while the electrical energy share has about doubled.

The trends in gasoline and diesel fuel consumption can be clearly seen in figure B-1. Until 1975, gasoline consumption exhibited no definitive trend. Use was a function of normal economic influences such as gasoline price, the number of acres planted and government programs (**25**). Since the mid-1970's, however, there has been a pronounced downward drift of 6.3 percent per year in the quantity of gasoline consumed. Diesel fuel consumption, on the other hand, grew at a hefty 6.7 percent annual rate between 1971 and 1978. Since 1978, this has turned into a modest decline of 1.4 percent per year, even though it has continued to increase in relative importance.

Explaining these observed trends has been the subject of considerable debate. One argument for diesel-powered farm equipment over gasoline-powered equipment is that gasoline was relatively more expensive than diesel fuel (**9**). Gasoline prices historically have been higher than diesel fuel prices, although this differential narrowed considerably in the mid- to late- 1970's and early 1980's (see figure B-2). This narrowing of the price differential had no apparent, measurable ef-

Figure B-1
Gasoline and Diesel Fuel Consumption on U.S. Farms

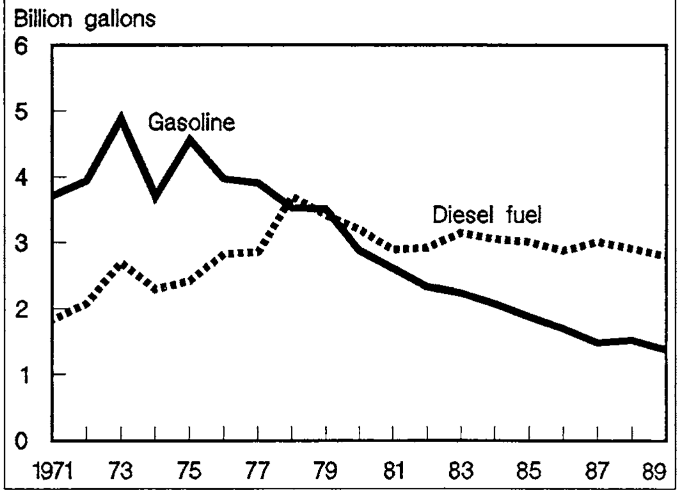
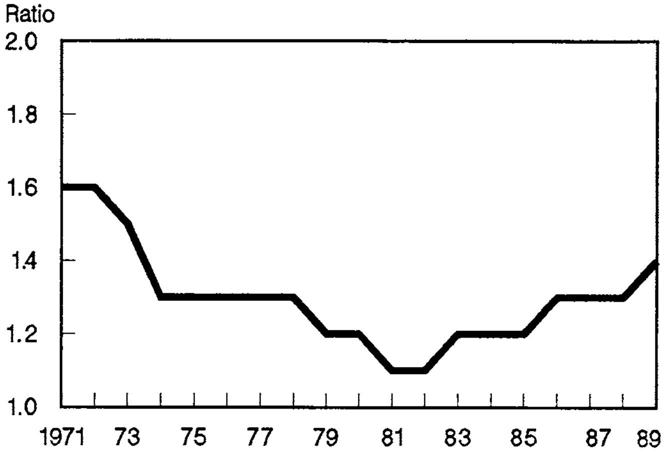


Figure B-2
Fuel Prices Paid by U.S. Farmers: Gasoline Relative to Diesel



Price of gasoline/price of diesel fuel.

fect on the trend toward dieselization. That is, there is no identifiable discontinuity in diesel fuel consumption corresponding to this period (25).

Another reason suggested for the increasing importance of diesel fuel is that farmers had become concerned about the security of the supply of gasoline during the first Arab Oil Embargo in 1973-1974 (3). This argument makes little sense because both gasoline and diesel fuel are components of crude oil and it was the crude oil supply that was problematic, not the gasoline supply. Moreover, the increase in diesel fuel consumption began well before the 1973-1974 period.

A third reason introduced to explain the increasing importance of diesel fuel is the greater relative energy efficiency of diesel-powered equipment. This, however, has been the case over time, and it did not lead to diesel-powered equipment replacing gasoline-powered equipment at some earlier period.

For example, in 1965 there were 13 new diesel-fuel tractors introduced by various manufacturers with a horsepower rating in the 40-59 category. These tractors had a combined average energy efficiency rating of 15.2 horsepower hours per gallon of diesel fuel. In the same year, there were seven new gasoline-powered tractors in the 40-59 horsepower category. These tractors had a combined average energy efficiency rating of 11.2 horsepower hours per gallon of gasoline.

Thus, there was a 26.3 percent differential in relative energy efficiency between comparable sized diesel fuel and gasoline-powered tractors. But in 1965, diesel-powered tractors in this horsepower category accounted for only 38 percent of total sales. (Gasoline-powered tractor sales accounted for 60 percent, and the remaining sales were attributed to liquefied petroleum-powered tractor sales.) Similar patterns are observed for other years prior to 1972 for other horsepower categories (see below).[3] Clearly, the relative difference in energy efficiency between diesel-powered equipment and gasoline-powered equipment did not, in and of itself, precipitate the trend toward dieselization (i.e., the situation where diesel fuel is the dominant energy type consumed on the farm), although, as discussed below, it contributed to it.

These and similar arguments do not adequately address the underlying forces that have led towards dieselization. In the subsequent section, a more comprehensive view of these forces will be provided.

Factors Affecting the Trend in Dieselization

Four factors are central to both the observed increase in the relative importance of diesel fuel in terms of aggregate farm energy consumption over the 1971-1989 period and the decline in the absolute quantity of diesel fuel consumed over the 1978-1989 period. These factors include the relative efficiency of diesel-powered equipment versus gasoline-powered equipment, the technological changes in diesel-powered equipment that have improved energy efficiency, the trend towards larger farms, and enhanced energy conservation by farmers as a result of changes in their cropping practices.

Relative Energy Efficiency

The relatively greater energy efficiency of diesel-powered equipment versus gasoline-powered equipment was briefly discussed above. Depending on the horsepower rating, diesel-powered equipment is 20 to 25 percent more energy efficient than comparable gasoline-powered equipment. For example, for all tractors introduced between 1956 and 1972,[4] diesel-fuel-powered tractors under 40 horsepower were 23.7 percent more energy efficient than comparable gasoline-powered tractors.[5] Diesel-fuel-powered tractors in the 40-59 and 60-79 horsepower categories were, respectively, 24.8 and 21.1 percent more energy efficient than comparable gasoline-powered tractors over the 1956 to 1972 period.[6]

[3] The data on tractors and their horsepower ratings were taken from National Farm and Power Equipment Dealers Association (19). These data are based on the official Nebraska Tractor Tests conducted by the University of Nebraska. The horsepower ratings represent those observed on the power take-off (PTO). The data on tractor sales were obtained from the Farm and Industrial Equipment Institute (FIEI). They represent nearly all manufacturers.

[4] There was only one new gasoline-powered tractor introduced after 1972, that was a 34.4 horsepower tractor in 1977.

[5] Tractors with less than 40 horsepower are specialty tractors designed for mowing, loading, landscaping, and similar sorts of small-scale efforts and they are not typically used for the extensive production of crops. Such tractors account for 20 to 25 percent of new tractor sales annually.

[6] There were too few new, gasoline-powered tractors in the 80-89 horsepower category to draw any meaningful comparison with comparable diesel-fuel-powered tractors. There were no gasoline-powered tractors introduced over the relevant time period with a horsepower rating of greater than 90.

This differential in relative energy efficiency remained fairly constant over the 1956 to 1972 period. Use of the Mann-Kendall test for the detection of a trend (**17, 16**) revealed no discernable pattern in the energy efficiency of either diesel-fuel-powered or gasoline-powered tractors across horsepower categories over the time period.[7] This, however, was not the case after 1975.

Improvement in Energy Efficiency

Beginning in 1975, there is an identifiable improvement in the energy efficiency of diesel-fuel-powered equipment. Using annual data on the energy efficiency of new tractors introduced between 1975 and 1989, taken from the Nebraska Tractor Tests (**19**), significant trends in energy efficiency across horsepower categories are apparent.[8] Thus, for new tractors of less than 40 horsepower, energy efficiency increased an average of 1.68 percent per year.

Larger horsepower tractors experienced analogous efficiency increases. Thus, for example, new tractors in the 40-59 horsepower category, the 60 to 79 horsepower category, the 80 to 99 horsepower category, the 100 to 139 horsepower category, and the greater than 140 horsepower category experienced annual energy efficiency improvements of, respectively, 1.12, 1.41, 1.56, 1.53, and 1.58 percent.

Why were these energy-efficiency improvements observed beginning in 1975 and not before? There are several reasons. First, the Energy Policy and Conservation Act of 1975 mandated corporate average fuel economy standards for all automobile manufacturers. These standards applied to all automobiles whether powered by a gasoline or diesel engine, and required a 74.2-percent increase in energy efficiency between 1975 and 1985.[9] Because diesel-fuel-powered vehicles account for approximately 3 percent of domestic vehicle sales (based on data provided by the Motor Vehicle Manufacturers Association), any improvement in energy efficiency would be averaged in with that of gasoline-powered vehicles when measuring the corporate average fuel economy. Thus, manufacturers had an incentive to improve the energy efficiency of diesel engines as they endeavored to meet the mandated requirements.[10] These improvements were readily adaptable to diesel engines used on farm equipment.

The technological improvements leading to energy efficiency enhancements occurred in a variety of forms, some the direct result of changes in diesel fuel engines used on motor vehicles and some the result of changes specific to farm equipment. In the former category, the engine compression was boosted, fuel injection was introduced to increase the consistent flow of fuel, air-to-fuel ratios were raised, and the air flow was enhanced through the redesign of ports and valves. Farm-machinery-specific energy efficiency improvements involved changes not only in the diesel engines such as a redesign of the crankshaft, installation of turbo chargers on larger engines, improvement of the engine cooling system, but also more efficient constant mesh transmissions, heat dissipating clutches, and better traction through redesign of the differential.

Accompanying these changes was the installation of performance monitoring equipment on larger horsepower equipment (generally greater than 100 horsepower). Based on data from the Nebraska Tractor Tests covering the 1975 to 1989 period (**19**), energy efficiency at full power take off (PTO) is about 30 percent higher than at 50 percent PTO. However, when the engine load is not high, energy efficiency can be improved by reduced throttle operation using a higher gear. Microcomputers were installed on the equipment beginning in the mid-1970's and designed to assist farmers in selecting the requisite gears for optimal energy efficiency (**8**).

Changing Farm Size

A third factor leading to the greater importance of diesel fuel has been the increase in the average size of U.S. farms. Accompanying this change has been an increase in average horsepower of the equipment (figure B-3). Data on the average number of farm acres were taken from *Agricultural Statistics* (**22**) and data on the average horsepower of all tractors shipped by manufacturers were taken from *Tractors (Except Garden Tractors)* (**24**).[11]

Coincident with the increase in the average horsepower of farm tractors has been a slight increase in energy efficiency. Thus, based on data from the Nebraska Tractor Tests for full

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[7] The Mann-Kendall test was used instead of the more conventional econometric approach because there are missing observations for various years. That is, at least one new tractor in each horsepower category was not introduced in each year between 1956 and 1972. Complete test results are available from the authors upon request.

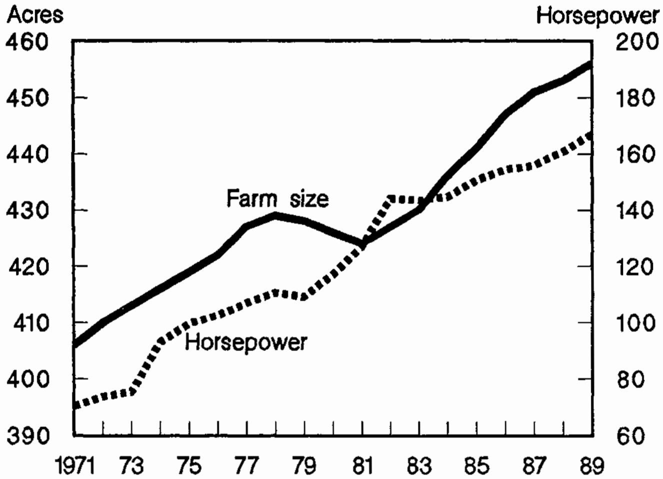
[8] The data represent the average of the energy efficiency of all new tractors introduced in a given year across all manufacturers. Because there is considerable variability, however, in the energy efficiency of manufacturers' equipment (that is, heteroscedasticity is present in the data), it is necessary to correct for this in the econometric estimation. This was done by correcting each observation by the inverse of the square root of the variance for each sample for each year. See Judge, et al. (**15**) for a discussion of the problem and its solution.

[9] In 1975 the average energy efficiency was 15.79 miles per gallon. The 1985 target was 27.5 miles per gallon. See Heavenrich (**14**) for more details.

[10] The fact that the corporate average fuel economy standards were subsequently relaxed is a political issue that will not be addressed here. The reader interested in this issue is referred to Gillis (**11**).

[11] Note that there is no implied direction of causation here. That is, it is not suggested that the trend towards larger farms was brought about by larger size tractors or vice versa. The conventional Granger-Weiner test for causality (**18**) revealed an absence of any directional causality. Rather, these trends occurred coincidentally and were brought about by other, not necessarily mutually exclusive factors, such as a wide range of technological improvements in farming operations, government programs affecting farmers decisions, etc.

Figure B-3
Average U.S. Farm Size and Tractor Horsepower



power take off covering the 1975 to 1989 period (**19**), tractors in the 40-59 horsepower category are about 1.8 percent more energy efficient than tractors in the less-than-40-horsepower category (this difference is statistically significant at the 95-percent level). Tractors in the 60-to-79-horsepower category are about 2.5 percent more efficient than those in the 40-to-59-horsepower category (likewise, this difference is statistically significant at the 95-percent level). There is no apparent (statistically significant) difference in the energy efficiency between tractors in horsepower categories greater than 60 to 79.

Given these differences in relative energy efficiency across the lower horsepower categories, a proportionate increase in sales of tractors in the 60-to-79 horsepower category and a reduction in sales of tractors in the 40-to-59 horsepower category is consistent with the observed trends. This is precisely what happened. Based on sales data from the Farm and Industrial Equipment Institute, in 1971 tractors in the 40-to-59 horsepower category accounted for 27.2 percent of the sales of new tractors, while tractors in the 60-to-79 horsepower category accounted for 16.4 percent of sales. By 1980, tractors in the 40-to-59 horsepower category accounted for 18.8 percent of sales and by 1989, they represented only 14.9 percent. Tractors in the 60-to-79 horsepower category, on the other hand, accounted for 17.5 percent of sales in 1980 and 18.6 percent in 1989. Throughout this time period, the total number of new tractors sold annually remained roughly constant when the impact of normal economic effects are taken into account

Changes in Cropping Practices

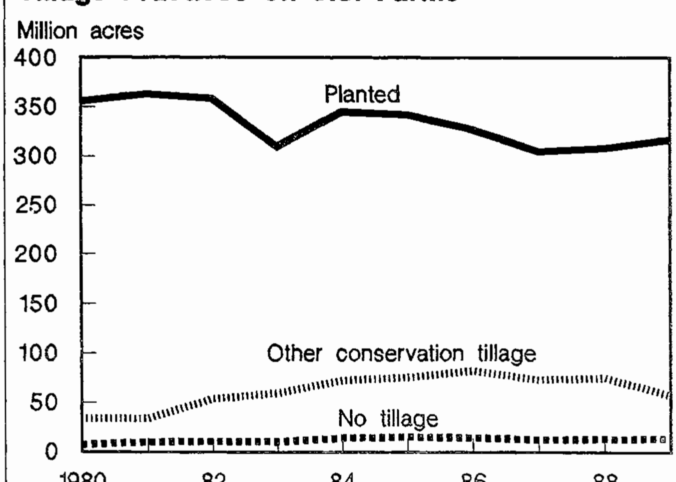
The final important identifiable factor resulting in the trend in diesel fuel consumption is the adoption by some farmers of alternative cropping practices that are more energy efficient than those previously employed. Alternative cropping practices that reduce diesel fuel energy consumption are principally related to reduced tillage. It has been suggested that the 1970's were peak years in tillage, while the 1980's were a readjustment to reduced tillage operations (**10**).

Reduced-tillage systems are frequently termed minimum tillage or conservation tillage. They are the least amount of tillage required to create suitable soil conditions for seed germination yet leave sufficient residue to minimize soil erosion. With reduced-tillage systems, energy savings result from fewer tillage operations.

There is little data on the extent of reduced tillage prior to 1980, as it was not a common practice and, therefore, was not of significant concern. Beginning in 1980, data became available from the Conservation Technology Information Center (**7**) on the number of acres receiving no-tillage and those receiving other conservation tillage practices (figure B-4). Since 1980, the use of no-tillage has remained fairly constant at around 4.0 to 4.4 percent of the total number of acres planted each year. Conservation tillage practices other than no-tillage, on the other hand, exhibit an upward trend in the early 1980's and then level off to 20 to 25 percent of the acres planted annually. This upward trend accounts for some of the reduction in diesel fuel consumption in the early 1980's.

The four factors that have been discussed in the foregoing are principally responsible for the observed trend in diesel fuel consumption on farms in the United States. Due to the nature of the data available on the stock of U.S. farm equipment on farms and because the impacts of some of the factors considered occur over a period of several years, it is not possible to measure precisely the extent to which each contributed to the trend.

Figure B-4
Acres Planted and Incidence of Reduced Tillage Practices on U.S. Farms



Thus, while the shift in sales from the mix in diesel-fuel-powered and gasoline-powered equipment observed in the early 1970's to the sale of solely diesel-fuel-powered equipment in the mid-1980's is well documented, the stock of gasoline-powered equipment on farms has not disappeared. Data on the annual changes in the characteristics of the U.S. farm equipment stock, unfortunately, do not exist and are not collected. That is, while data on the stock of equipment on farms and its vintage is collected by the annual Farm Costs and Returns Survey conducted by the USDA's National Agricultural Statistics Service, the data do not identify the type of fuel used by each piece of equipment and the energy efficiency of that equipment. Consequently, it is not possible to measure when, and the extent to which, the more energy efficient diesel-fuel-powered tractors, combines, hay balers, etc. have replaced gasoline-powered equipment.

What is discernable, however, based on data from the Farm and Industrial Equipment Institute, is that as equipment is replaced (whether diesel-fuel powered or gasoline powered), it has increasingly been with diesel-fuel-powered equipment. This trend continued throughout the 1970's and, by 1984, all replacements were with diesel-fuel-powered equipment. Therefore, the pattern in diesel fuel consumption is to replace relatively less energy efficient equipment with more energy efficient equipment.

Accordingly, the timing of equipment replacement decisions will affect the pattern of diesel fuel consumption by farmers. This means that, even though there is a change in the relative energy efficiency of new diesel-fuel-powered equipment, until this new equipment significantly replaces (or perhaps displaces) existing equipment (assuming the equipment is for replacement purposes only), there will be no discernable change in aggregate diesel fuel consumption. Moreover, this replacement can be spread out over several years.

What factors are important in determining the (optimal) replacement and timing of the replacement of farm equipment? A piece of farm equipment, depending on its type (e.g., a tractor, a combine, or a windrower), generally lasts from 10 to 15 years.[12] Consequently, given its durable nature, such factors as the equipment's remaining (terminal) value, income tax incentives, and the rate of inflation have all been identified as important in determining its useful life ((**2**), (13), (**20**)). Based on the analysis in this study, price of die sel fuel and the relative energy efficiency of the old and new equipment should be added to this list.

[12] This is nominally referred to as asset fixity. Chambers (6), for example, discusses this concept in detail.

Implications

What do the foregoing considerations portend for the future consumption of diesel fuel by the U.S. agriculture sector and what are the policy lessons to be learned from them? First, with regard to future diesel fuel consumption, four factors were identified as affecting this consumption. The first factor, the relative efficiency of diesel-powered equipment versus gasoline-powered equipment, is no longer a very significant consideration, because gasoline-powered equipment has been substantially replaced by diesel-fuel-using machinery.

For the second factor, the absolute change in diesel fuel equipment efficiency, it is difficult to discern whether there will be future improvements. Without some significant breakthroughs in combustion technology, however, it seems unlikely that there will be much of an improvement in efficiency.

The final two factors seem to hold more promise for reducing diesel fuel consumption (assuming, of course, that reducing energy consumption is a desirable objective). The number of small to mid-sized farms is expected to continue to decline thereby increasing average farm size (**4**). Coincident with the increase in farm size would be an expected increase in the size of tractors to work these farms. Finally, reduced tillage practices are expected to continue to make significant inroads (**1, 5**). These considerations, in concert, suggest that the consumption of diesel fuel should continue to decline, assuming no major changes in the Federal government's farm programs that affect planted acreage.

Concerning policy lessons from farmers' consumption of dievided fuel during 1971-1989, the Federal Government has provided incentives in the form of tax credits and obligation guarantee programs for energy conservation related to fixed assets.[13] While such initiatives could be entertained for agriculture, they would be difficult to justify because the various forces are continuing to work to bring about energy conservation in farming. Whether such programs would accelerate the trend towards energy conservation, however, is properly the subject of additional investigation.

13 For example, both the Energy Conservation and Production Act of 1976 and the Energy Tax Act of 1978 have such provisions. See Goodwin (12) for a discussion of the
specifics.

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Managing Price Risk With Diammonium Phosphate and Anhydrous Ammonia Futures Contracts

by

Gerald Plato*

Abstract: The new diammonium phosphate (DAP) and anhydrous ammonia (AA) futures contracts were designed in response to the need for managing price risk in the corresponding cash markets. If futures trading in these two contracts is successful, then participants in the fertilizer trade will have opportunities to use them in hedges to protect against adverse price decreases and increases before making cash market transactions. Basis risk, however, may significantly reduce the effectiveness of these hedges in some nondelivery locations. Futures trading in these two new contracts may result in expanded cash forward contracting of DAP and AA at fixed prices. The quantity of DAP and AA in cash forward contracts, unlike in futures contracts, is negotiable, making them more suitable for farmers.

Keywords: Futures contracts, forward contracts, hedging, price risk, basis risk.

Trading of diammonium phosphate (DAP) futures contracts began on October 18, 1991, on the Chicago Board of Trade (CBOT). In addition, trading of anhydrous ammonia (AA) futures contracts is scheduled to begin in September.[1] DAP and AA futures trading, if successful, will offer hedging opportunities for reducing price risk in the corresponding cash markets. Both futures contracts require quantities that are too large for most farmers. However, fertilizer futures trading, if successful, may result in considerable cash forward contracting at fixed prices between farmers and farm retailers.[2] These forward contracts would help many farmers to reduce input price risk by fixing a portion of their production costs well in advance of planting.

Fulfilling hedging needs is a prerequisite for the success of the new fertilizer futures contracts. There must be both a hedging need and successful fulfillment of it. Approval of DAP and AA futures trading by the Commodity Futures Trading Commission (CFTC), the Federal agency that regulates futures trading, required the demonstration of a hedging need.

The hedging need stems from the production and demand characteristics of the DAP and AA markets. DAP and AA are produced continuously throughout the year but are mostly used during the spring planting season. Inventories must, therefore, be held for much of the year and inventory owners face risks of price declines over long periods. Price risks are made greater by the large annual variability in fertilizer export demand. The need for inventory owners to manage or control this price risk was a major impetus for initiating trading in the new fertilizer futures contracts. In addition, the need to protect profit margins in fertilizer production from adverse DAP and AA price changes was another major impetus for initiating trading in fertilizer contracts.

DAP and AA futures contracts call for delivery at the manufacturer and first-buyer market level. The cash market at this level in the fertilizer trade for DAP and AA has the most transactions and the largest concentrated hedging need. In addition, this market level has the largest continuous availability of supplies for delivery on DAP and AA futures contracts. Sufficient availability of supplies for delivery on futures contracts is necessary to prevent price manipulation and to prevent disruption of the cash market during futures-contract delivery periods.

The DAP and AA futures contracts were made compatible with cash marketing practices to facilitate fulfilling the hedging need. In particular, the 100-ton unit and the price levels specified in DAP and AA futures contracts are typical in cash market transactions between manufacturers and first buyers. DAP futures prices are f.o.b. rail car for three counties in central Florida. AA futures prices are f.o.b. railcar, barge, or pipeline in Louisiana.

This article provides an introduction to using futures contracts for individuals who are interested in the two new fertilizer futures contracts but are unfamiliar with futures markets. The article emphasizes how these contracts may be used to reduce price risk and provides estimates of the reduction in

* Agricultural Economist, Commodity Economics Division, Economic Research Service, USDA.

[1] A glossary of futures-market terms is provided to facilitate understanding the text.

[2] Buying grain and soybeans from farmers before it is harvested with forward contracts at fixed prices, while simultaneously selling forward with futures contracts, is a common business practice for country elevators. It provides a major stimulus to futures trading in grains and soybeans.

price risk they may provide. It also examines how futures trading encourages forward contracting.

First, an outline of the procedures for trading and holding futures contracts is provided. The outline is provided because understanding futures-hedging transactions requires understanding how futures contracts are traded and maintained. Next, alternative hedges for reducing price risk that involve these two new contracts and factors that influence their hedging performance are discussed. Price risks in the DAP and AA cash markets and the tradeoff between price risk and basis risk are next examined. Use of futures contracts to hedge price risk in nondelivery locations involves trading price risk for basis risk. Basis risk is the risk that the difference between the futures price and the cash price when unwinding or terminating a hedge will differ from expectations held when entering a hedge.

Outline of Futures Trading Procedures

Procedures for entering into, maintaining, and liquidating futures contracts are discussed in this section, with an emphasis on the roles of the various futures market participants. The objective is to provide sufficient detail for understanding the basic procedures involved in trading futures contracts without becoming bogged down in institutional detail. Considerable further study would be required before using futures contracts to reduce price risk.

The outline of futures trading procedures draws upon the books listed in the references. These books, and many others, provide detailed information about trading futures contracts and about using them to reduce risk. Further information about futures trading and hedging with futures contracts is available from the CFTC, futures exchanges, USDA, and many of the State extension services and colleges of agriculture.

Trading procedures for nonexchange members are emphasized. However, some of the large firms involved in the fertilizer trade are already CBOT members and others may become members if DAP and AA futures contract trading is successful. CBOT member firms enjoy lower futures trading commissions and participate in the management of the exchange.

The actual trading of futures contracts is limited to exchange members and occurs on the floor of the exchange. Only the price of futures contracts are negotiated in this trading. All other contract specifications, for example, size and delivery procedures, are standardized and hence not negotiated. Nonmembers must place orders (instructions to buy or sell futures contracts) with exchange members through a Futures Commission Merchant (FCM). FCM's are regulated by the CFTC. Some FCM's are member firms of the CBOT.

Services provided, as well as commission fees, differ among FCM's. Therefore, selecting an FCM requires careful consideration. A thorough study of futures market trading and discussions with several FCM firms are prerequisites to selecting an FCM.

Some of the exchange members are also members of the clearinghouse. Exchange membership is a prerequisite for becoming a clearinghouse member. Clearinghouse members pledge their own capital to guarantee futures-contract performance. Exchange members that are not clearinghouse members must pay a fee to have their client, as well as their own, trades cleared by a clearinghouse member.

The clearing procedure first involves confirming or validating the futures trades that have occurred on the floor of the exchange. After a futures-contract trade is validated, it is then guaranteed by the clearinghouse assuming liability for losses on either side of the contract. This part of the clearing procedure involves the clearing house becoming both the buyer to the seller and the seller to the buyer of the validated futures-contract trade.

The taking of the opposite side to every trade by the clearinghouse frees each trader from having to deal with the original trading party in making liquidating or offsetting trades and in delivering and accepting delivery on a futures contract.[3] Traders are indifferent toward the identity of the party with whom they make offsetting trades or with whom they make or accept delivery, because futures contracts are standardized and guaranteed by the clearinghouse.

Nonmember traders must deposit funds in a margin account with their FCM's prior to beginning futures trading. A margin account is used to cover losses and to receive gains that are due to the decreases and increases, respectively, in the value of a trader's futures contracts. Losses and gains are assessed at the end of each trading day.[4] An FCM requires additional deposits in a trader's margin account when trading losses cause it to fall below a critical level. If this requirement is not met, then a trader's futures contracts are liquidated. A trader can withdraw gains from the margin account. The daily settlement of gains and losses (called marking to market), along with immediate liquidation of futures contracts when margin accounts are not replenished, helps insure the integrity of futures contracts.

[3] A trader that has brought (sold) a futures contract can liquidate it by an offsetting sale (purchase) of an identical futures contract. Speculators almost always liquidate their trades by offsetting trades. Hedgers liquidate by offsetting trades if it is not to their advantage to delivery or accept delivery on futures contracts.

[4] A decrease (An increase) in the futures price produces losses (gains) for a trader who has purchased futures contracts. Conversely, an increase (a decrease) in the futures price produces losses (gains) for a trader who has sold futures contracts.

Meeting calls for replenishing the margin account is particularly important for a hedger. Failure to do so results in a premature termination of the hedge and loss of price protection. Hedgers must either have sufficient liquidity or secure a line of credit for meeting margin calls. The liquidity problem for hedgers that can be created by losses on futures is a problem of timing. Losses on futures are assessed daily, whereas the gains on the cash-market side of the hedge are not realized until the hedge is terminated.

FCM's are required to provide the clearinghouse with payments from a trader's margin account to cover trading losses. The clearinghouse provides payments to the FCM when a trader has gains. These are deposited in the trader's margin account.

Hedging Alternatives and Performance

This section discusses alternative hedges for reducing price risk in the DAP and AA cash markets. It also discusses factors that influence hedging performance.

Alternative hedges may be classified as buying hedges, selling hedges, or as both buying and selling hedges. A *buying hedge* approximately sets the price for a later purchase in the cash market. It protects against a price rise before a commodity is purchased. A *selling hedge* approximately sets the price for a later sale in the cash market. It protects against a price decline before and during the production of a commodity or while a commodity is being held in inventory. A *buying and selling hedge* sets prices for both a later purchase and sale in the cash market. It protects against both a price rise and decline before purchasing and selling in the cash market. These type of hedges are used to assure storage and production margins before committing resources for storing and producing a commodity. Buying and selling hedges frequently involve using futures contracts on one side of the hedge and forward contracts on the other side.

A futures contract, in effect, sets the price for a later cash-market transaction at the delivery location. For example, the buyer of a futures contract obtains what amounts to the right to buy the commodity during the delivery period at the price negotiated on the floor of the futures exchange. However, if the buyer chooses delivery then, the actual market price at the time of delivery is paid. This seeming paradox is resolved by the buyer's margin-account payments and receipts. If the price increased, then the margin-account receipts cover the additional cost from the price increase. If the price decreased, payments from the margin account will have already paid part of the cost at the negotiated price. A similar example could be given for the seller of a futures contract.

Hedging involves taking opposite positions in two markets by buying in one market and selling in the other. The objective is to reduce one's exposure to price risk. For example, selling DAP futures when purchasing DAP inventory protects against a price decline in the cash market while the DAP inventory is being held. Unwinding or terminating the hedge involves buying back the futures contracts when selling the DAP inventory in the cash market or delivering DAP under the terms of the futures contract. Hedging losses from price declines in the DAP cash market are offset by hedging gains from price declines in the futures market. This hedge also eliminates gains from price increases in the cash market while the DAP inventory is being held. Eliminating opportunities to gain from favorable price changes in the cash market is the downside of hedging with fixed prices.

DAP and AA manufacturers that are licensed to issue shipping certificates are particularly well positioned to deliver on futures. A trader initiates delivery on a DAP or AA futures contract by passing a shipping certificate via his or her FCM to the clearinghouse. The clearinghouse passes it to a trader with a long (buy) futures contract via that trader's FCM. A shipping certificate gives the long the right to buy product from the certificate's issuer. The price of the product is the closing futures price on the day that the certificate was passed to the clearinghouse.

Basis risk for licensed shippers due to discounts from par grade should be negligible. In addition, licensed shippers should not be subject to basis risk from having product out of location for delivering on futures. Therefore, licensed shippers should be able to use futures to effectively set price. Basis risk for licensed shippers and other market participants is important because it can significantly reduce the effectiveness of futures in setting price.

Buyers of futures contracts (longs) who are well positioned to accept delivery on their futures contracts are also well positioned to offer cash forward contracts at fixed prices to farm retailers, especially if they can lock in transportation costs.[5] These buyers should encounter little basis risk on their long (buy) futures contracts. Buying futures contracts and selling cash forward contracts at fixed prices, before taking delivery of fertilizer, would allow these buyers to protect their storage and transportation return or margin. The desire of farm retailers to buy forward at fixed prices without basis risk may result in considerable cash forward contracting at fixed prices with buyers who can accept delivery on futures. Quantity sold forward in a cash forward contract can be smaller or larger than the quantity specified in a futures contract. The critical requirement for a hedger is that the total amount sold forward in the forward contracts be approximately offset by an equal amount of buy (long) futures contracts.

[5] Prices of forward contracts are frequently expressed as discounts and premiums relative to futures.

Instead of selling cash forward contracts, these buyers may sell later-maturing futures contracts to protect their storage and transportation margins while negotiating with farm retailers. The negotiations may result in cash sales with immediate delivery or cash forward sales at fixed prices with later delivery. The later-maturing futures contracts would be liquidated as fertilizer is delivered on the cash sales agreements and as fixed-price cash forward contracts are signed. However, there may be considerable basis risk involved with liquidating these sell (short) futures contracts.

A buyer who accepts delivery on a DAP or AA futures contract does, however, have some disadvantages relative to the licensed shipper-manufacturer that delivers. The buyer does not know the manufacturer's identity before receiving the shipping certificate and, hence, does not know the exact delivery location. The buyer also does not know the day of the delivery month the certificate will be received. However, after the buyer receives the shipping certificate, the licensed manufacturer has the disadvantage of not knowing when it will be presented by the buyer for fulfillment.

Farm retailers that buy DAP and AA with fixed-price forward contracts can, in turn, offer farmers forward contracts at fixed prices. Buying and selling cash forward contracts at fixed prices would enable farm retailers to protect their storage margin before taking delivery. In addition, forward contracts at fixed prices offer farmers the option of pricing fertilizer before taking delivery. A chain of cash forward contracting at fixed prices from first buyer to farmers, before the first buyer takes delivery on futures, could significantly reduce price risk to all participants involved.

Successful trading in fertilizer futures would provide licensed manufacturers with an open competitive market to start fixed-price contracting along the marketing chain with futures and forward contracts. Fixing prices for later cash-market transactions along the marketing chain provides greater flexibility in obtaining product as well as a means for reducing risk.

Farm retailers may also hedge by buying DAP and AA futures and selling forward to farmers with forward contracts at fixed prices. Alteratively, they may buy fertilizer and sell futures while negotiating sales to farmers. While lining up fertilizer supplies, they may also buy futures as well as sell futures. All three strategies help protect the merchandising and storage margin.

Most farm retailers, however, are not in a position to accept delivery on futures. Consequently, most would be subject to basis risk when liquidating their buy (long) futures contracts. All farm retailers are subject to basis risk when unwinding their sell (short) futures positions. Farm retailers who hedge by buying futures may increase the prices of the fixed-price forward contracts offered to farmers to offset bearing basis risk.

Some farmers use sufficient quantities of DAP and AA to hedge by buying fertilizer futures contracts. Farmers would be subject to basis risk when unwinding their hedges.[6]

DAP and AA manufacturers are primarily interested in using the two new futures contracts in selling hedges. However, DAP manufacturers may also buy AA futures while selling DAP futures to protect their manufacturing margin. This later hedge is both a buying and selling hedge. Similarly, AA manufacturers may want to buy natural gas futures while selling AA futures to protect their manufacturing margins.[7] Hedging performance in protecting margins is influenced by the proportion of costs and revenues that can be set with futures prior to production.

Hedging performance is also influenced by the ability of DAP and AA futures prices to provide reliable estimates of prices at contract maturity. Consistent under (over) estimation of price at contract maturity by the futures price prior to contract maturity results in revenue losses to hedgers that sell (buy) futures contracts. Analysis of the ability of DAP and AA futures prices to provide reliable price estimates cannot be done until there is a sufficient historical record of these futures prices.

Basis risk relative to price-level risk, the portion of cost and revenues that can be fixed by hedging, and the reliability of DAP and AA futures-price estimates are important factors in determining if DAP and AA futures will fulfill the hedging need in the corresponding cash markets.

Price and Basis Risks

Hedging with futures contracts involves trading price risk for basis risk. This section provides several estimates of price and corresponding basis risk in the DAP and AA markets. First, basis and price risks are further discussed. Then the data and procedures used to estimate basis and price risks are discussed before presenting the estimates.

The effective selling price with a futures selling hedge is the futures price when entering the hedge plus the basis when un

6 Hedgers with buy (long) futures contracts who intend to terminate their hedges by an offsetting futures transaction should do so before the beginning of the maturity or delivery month. This avoids the possibility of receiving delivery on buy (long) futures contracts. In addition, hedgers with sell (short) futures contracts who intend to terminate their hedges by an offsetting futures transaction should do so before the end of the delivery period. Only licensed manufacturers can issue delivery certificates and deliver their fertilizer.

7 Soybean processors frequently buy soybean futures while selling soybean meal and soybean oil futures to protect processing margins.

winding the hedge.[8] A smaller than expected basis decreases the effective selling price. Basis risk for a futures selling hedge is, therefore, the risk of a smaller-than-expected basis when unwinding the hedge.

The effective buying price with a futures buying hedge is the futures price when entering the hedge minus the basis when unwinding the hedge. A larger-than-expected basis increases the cost of purchasing with a buying hedge. Basis risk for a futures buying hedge is, therefore, the risk of a larger-than-expected basis when unwinding the hedge.

Price risk is the risk that price will decrease while holding inventory or while waiting for future production. It is also the risk that price will increase while waiting to purchase a commodity.

September to March price risk and March basis risk were estimated for DAP and AA using cash price data from the Green Markets Newsletter. DAP price and basis risk were estimated for North Carolina and the Western United States. DAP price risk was also estimated for central Florida; the DAP delivery location. AA price and basis risk were estimated for the Corn Belt and Northern Plains. AA price risk was also estimated for the Gulf; the AA delivery location. Prices in these locations for the first week in September from 1980 to 1990 and for the first week in March from 1981 to 1991 were used in making the price and basis risk estimates.

The March cash prices for Central Florida and the Gulf are proxies for March futures prices. This substitution is based on the assumption of cash and futures prices converging during the delivery month at the delivery location.

Price risk at each location is measured by the standard deviation of the price changes from September to the following March. Basis risk is measured by the standard deviation of the difference between the March basis and the expected March basis. Differences in the cash prices for each September between delivery and nondelivery locations were used to estimate the expected basis for the following March.

Standard deviation about the expected basis and about the average price change are not ideal measures of risk. The frequency and magnitude of unfavorable basis and price outcomes are, however, directly related to the size of the standard deviation measures used.

Table C-1 shows several estimates of price and basis standard deviation in the DAP and AA markets. The percentage that the basis standard deviation estimates are of the corresponding price standard deviations estimates are the main results in table C-1. A zero percent would indicate no basis risk and that the effective price of the hedge could have been predicted when entering the hedge. Price risk would be eliminated in this situation. This is the outcome that is expected at the delivery location for the par grade. A 100 percent would indicate that the effective price of the hedge would have as much risk as price without hedging. The percentages shown in table C-1 range from 39 to 79, indicating a reduction in price risk from hedging with futures but with considerable price risk remaining. As expected, the results show less effectiveness for locations farther from the delivery locations. Hedging with forward contracts at fixed prices may be more effective in reducing price risk than hedging with futures contracts in locations with large basis risk.

The estimates of basis risk should be treated as suggestive. Each price used is an average of individual firms over a large area. Individual firms in the fertilizer trade could make better estimates of their basis risk using prices from their own records.

In addition, individual firms may be able to make better estimates of expected basis than those used in this article. Better estimates of expected basis reduce basis risk. They may also lead to selective hedging; not hedging with futures when the basis at contract maturity is expected to be unfavorable.

The average price changes in table C-1 are the average storage returns from September to March for the 1980 to 1991 period. They also represent the average cost of waiting from September to March to buy DAP and AA. Price risk, as measured by the standard deviation of the average price changes, indicates that storing DAP and AA without hedging is an extremely risky activity. They also indicate that wait-

Table C-1. Variability Estimates of September to March Price Changes and the March Basis for Diammonium Phosphate (DAP) and Anhydrous Ammonia (AA) at Selected Locations, 1980-1991. 1/

	Location	Average price change	Standard deviation of Price change	Standard deviation about basis expectations2/	Relative price Risk with hedging3/
		$/ton (Percent)4/	$/ton	$/ton	Percent
DAP					
	Central Florida	8.80 (5.8)	15.22	-----	-----
	North Carolina	9.00 (6.2)	19.93	7.75	39
	Western U.S.	8.70 (4.5)	14.11	11.09	79
AA					
	Gulf	22.30 (23.2)	24.49	-----	-----
	Corn Belt	22.00 (17.2)	23.89	10.70	45
	Northern Plains	24.60 (19.3)	30.43	22.64	74

1/ The prices for making the estimates were taken from the Green Markets Newsletter. Prices are for the first week in September and the first week in March from 1980 to 1991. 2/ Basis is the price difference from Central Florida for DAP and from the Gulf for AA. 3/ 100 x (standard deviation from expected basis ÷ standard deviation of price changes). 4/ Average percent September to March price change.

[8] Basis is calculated as the cash price minus the futures price. This calculation makes the sign of the basis consistent with the practice of quoting a cash price as *over* or *under* the futures price. DAP and AA cash prices in nondelivery locations will usually be *over* the price of the nearest maturing futures contract.

ing to purchase DAP and AA without hedging is also extremely risky. In each location, the standard deviation of price change was larger than the average price change. These results indicate a need for managing price risk because DAP and AA must be stored for long periods.

Summary

DAP and AA futures contracts have the flexibility for use in many different types of hedging transactions for protecting against the risk of adverse price changes before buying and/or selling in the cash market. Consequently, if trading in DAP and AA futures contracts are successful, then many participants in the fertilizer trade will be provided opportunities to use them to reduce price risk. In addition, DAP and AA futures trading may stimulate considerable use of forward contracts at fixed prices. Forward contracting at fixed prices may be particularly useful in reducing price risk for participants that do not buy or sell sufficient quantities of DAP and AA to hedge with futures contracts, for example, farmers.

Estimates in this paper suggest that basis risk from using DAP and AA futures may be large for some locations. However, forward contracting between buyers who can accept delivery on DAP and AA futures contracts and their customers may reduce basis risk for their customers.

This article only provided an introduction to trading and hedging with DAP and AA futures contracts. Considerably more information is needed before making hedging transactions with DAP and AA futures contracts. The publications referenced as well many others can be used to learn more of the details. As with all new futures contracts, more detailed trading and hedging information will be forthcoming from the exchange involved and from public sources.

Glossary

Basis. The difference between a cash price of a commodity and the price of a futures contract; usually the price of the nearest maturing futures contract. The basis is influenced by the location and grade of the cash commodity.

Forward contract. An agreement between two parties to deliver and pay for a commodity or financial instrument on a later date. Price can be specified or fixed in the contract or determined later by a procedure specified in the contract.

Futures contract. A standardized and transferable agreement, traded under the bylaws of a futures exchange, to deliver and pay for a commodity or financial instrument on a later date. Price for the later date is determined by open trading among market participants.

Hedging. Buying or selling a futures contract as a temporary substitute for a later cash market transaction. Hedging reduces the risk of an adverse price change prior to making the cash market transaction.

Par grade. Quality standard of a commodity that is deliverable on a futures contract with neither a discount nor premium from the negotiated price.

Settlement price. End-of-trading-day futures price for a commodity or financial instrument. It is used in calculating daily gains and losses on futures contracts.

Shipping certificate. A document issued by a regular (exchange-licensed) shipper calling for delivery at shipper's location of a specific number of contract units to the bearer. The certificate represents a call on the shipper's current inventory or future production.

Speculating. Buying or selling an asset in anticipation of profiting from future price changes.

Trader. A person who buys or sells futures contracts.

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Reregistration of Minor Use Pesticides: Some Observations and Implications

by

Leonard P. Gianessi*

Cynthia A. Puffer**

Abstract: As reregistration of pesticides proceeds, many minor use registrations are being voluntarily withdrawn by the registrants. Lack of market incentive and fear of liability hinders the registration of new chemicals for minor uses. Consequences to growers of fruits and vegetables from limited choices in pest control chemicals will include higher costs for pesticides, greater risk of crop losses, increased problems with resistant pests, and disruption of successful Integrated Pest Management programs. Strategies to cope with these changes are varied and require effort and cooperation between public agencies and universities, chemical companies, and grower organizations, with grower organizations and commodity groups potentially playing an activist role in future minor use registrations. As yet, public policy on pesticides has not focused on the pest control needs associated with minor uses.

Key words: Pesticide, fruits and vegetables, Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Integrated Pest Management (IPM).

Introduction

In the past 25 years a significant change has occurred in the use of pesticides in U.S. agriculture. In the 1950's and early 1960's, growers of fruit and vegetable crops represented a significant share of the nation's use of synthetic pesticides. USDA survey data for 1964 indicates that of $423 million spent by the nation's farmers on pesticides, $123 million (29 percent) was spent by fruit and vegetable growers.(1)

In the past 3 decades, herbicide use by the nation's growers of field crops—particularly soybeans and field corn—has grown rapidly and currently dominates national pesticide-use totals. Data for 1990 from the National Agricultural Chemicals Association (NACA) indicates that NACA member companies shipped $4.5 billion of pesticides for use on U.S. crops.(2) Of this total, $660 million (or 15 percent) represented shipments of pesticides for fruit and vegetable growers. By contrast, field corn and soybean pesticide use shipments were valued at $2.3 billion. While $660 million of agricultural chemical shipments to fruit and vegetable growers is not an insignificant amount, the difficulty is that this usage is spread out over several thousand individual pesticide registrations covering a few hundred fruit, vegetable, and specialty crops. Consequently, there are several thousand individual pesticide registrations for fruit and vegetable crops for which the annual revenue to the pesticide manufacturer is measured in terms of thousands, not millions, of dollars.

Most fruit and vegetable crops are grown on relatively few acres in comparison to field crops. For example, according to the 1987 Census of Agriculture, U.S. acreage of lettuce (250,000), carrots (89,000), celery (30,000), strawberries (53,000), and apples (600,000) are miniscule in comparison to the nation's acreage of field corn (59,000,000), soybeans (55,000,000), and wheat (53,000,000).(3)

The nation's combined acreage of all fruit, nut, and vegetable crops amounts to 8 million acres. With costs totalling $40 to $50 million to develop, test, register, produce, and market a new active ingredient, agricultural chemical companies are directing most of their research and development efforts toward new products for large-acreage field crops and not small-acreage fruit and vegetable crops.(**13**)

Growers of many fruit and vegetable crops increasingly rely on fewer pesticides to protect their crops from pests. An over-reliance on one or a few pesticides to control an agricultural pest is an unwise pest management policy because of the potential development of pest resistance and because a single regulatory decision can have a major impact on pest damage. The lack of market incentive to increase the number of pesticide options available to growers potentially has

* Fellow and ** Research Assistant, Quality of the Environment Division, Resources for the Future, Washington, D.C. Work performed under Cooperative Agreement 58-3 AEM-9-80082 with USDA, Economic Research Service.

negative implications for the future production of U.S. fruit and vegetable crops.

This article reviews the institutional history of minor use pesticides; assesses the current state of the minor use reregistration program; discusses the implications of cancelling a select number of pesticides; and indicates several possible market and institutional responses and nonchemical alternatives.

Historical Perspective

Concern for the need to register pesticides for minor uses began in the early 1960's with the formation of the USDA-funded Interregional Research Project No. 4, known as IR-4, to obtain pesticide registrations for small acreage crops. While losses from weeds, insects, diseases, and other pests can be quite high for these crops, the revenue from sales of pesticide products would not offset the cost of developing and testing incurred by agricultural chemical companies. IR-4 continues to obtain new registrations for minor uses. The focus of the work at IR-4 is in supplying additional efficacy information and residue analyses to EPA for pesticides that have already undergone extensive toxicological and environmental impact testing for major crop uses.

The authority for registering pesticides was transferred from USDA to the newly created EPA in 1970, a time when concerns regarding adverse effects of pesticide use on the environment were raised. During the next decade, testing requirements for registration of new pesticides expanded in order to demonstrate that they would not pose an unreasonable risk to human health or the environment. To meet this standard, EPA can require up to 70 different types of tests investigating the chemistry, toxicology, environmental fate, and ecological effects of a pesticide in order for a manufacturer to register it as a new major food-use pesticide.

Carcinogenic, oncogenic, reproductive, and teratogenic studies take several years to complete and cost several million dollars.(5) Other test requirements include determining a pesticide's effects on aquatic systems and wildlife, exposure of harvest workers, and ultimate fate in the environment. EPA can choose to waive some of the testing requirements for minor uses of pesticides, but the toxicology tests are required before pesticide residues on food can be considered.

Congress became concerned that previously registered pesticides did not meet higher standards of safety to human health and the environment, so in 1972 Congress mandated the reregistration of all pesticide products. The task proved to be enormous. In 1988, concerned by the slow pace of reregistration and under pressure from public concerns about food safety, Congress amended The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to accelerate the reregistration process by scheduling a five phase process to be concluded in 1997. All pesticides registered before November 1, 1984, are to be reregistered by 1997. This decision affected 1,153 active ingredients, grouped by EPA into 611 cases of similar chemicals.

The Reregistration Process

In the first phase of the reregistration, EPA divided the pesticide active ingredients to be reregistered into four lists consolidated into cases of similar active ingredients. List A contained 194 cases of pesticide active ingredients which were already in the process of reregistration before the 1988 amendments to FIFRA were passed. These list A chemicals account for 85 to 90 percent of the pesticide volume used in the United States. The remainder of the chemicals were grouped in lists B, C and D, according to their potential for exposure to people and the environment.

The onus was put on pesticide registrants to declare which products they intended to support for reregistration with the required fees and studies. Those pesticides not supported are subject to cancellation. The increased costs of registering pesticide uses has resulted in agricultural chemical companies voluntarily withdrawing registrations of many low volume products used by the nation's fruit, vegetable, ornamental, and specialty crop producers. Typically, a manufacturer declines to renew the registration for the use of a pesticide on a particular crop when the expected future profits are too low to justify the expense of additional required testing. Other registrations are lost if evidence of either unreasonable human health or environmental risk is discovered.

Since the accelerated reregistration program started, the number of registered products has dropped from about 45,000 to less than 20,000. Most of those dropped were pesticides no longer being produced or used, many from lists B, C, and D. However, EPA has determined that about 5,000 to 6,000 of the canceled pesticide products were still in use at the time of cancellation. About 28 pesticide active ingredient cases from list A were not supported for any crop uses, and many others have had several food crop uses withdrawn from reregistration.

As of March 1991, EPA listed 417 pesticide active ingredient cases out of the original 611 as supported for reregistration. IR-4 has estimated that up to 1,000 pesticide minor uses valuable for U.S. crop production will not be supported by the registrants. Federal and State crop protection scientists were asked to assess the importance of these 1,000 registrations. The conclusion was that 60 percent of these registrations were important to U.S. crop production.(11)

In response to this situation, IR-4 has devised a strategy to develop the data required to retain registration for high priority uses. EPA has responded to the minor use problem by waiving fees and data requirements where possible, and by staying in close contact with IR-4. EPA has agreed to accept data for crop groups for some minor use registrations. Tolerances are established for the entire crop group based on data from two or more representative crops.

In a joint effort, USDA, EPA, IR-4, and NACA have established an early notification program so that grower organizations and other interested parties are informed about pesticide uses that industry will not support during reregistration. These and other initiatives have been promoted to ease the burden on growers relying on minor uses. However, even under the most optimistic scenario there will be a number of dropped registrations that will disrupt the production of some crops.

Implications of Minor Use Cancellations

A recent survey of U.S. herbicide use indicates that 96 herbicide active ingredients were used in varying amounts in 1989 crop production.(4) All registered uses of 15 of these herbicides (representing 3 percent of the total volume of herbicide use) subsequently have been dropped by their manufacturers. These include: barban, bifenox, CDAA, chloramben, chloroxuron, chlorpropham, dalapon, diallate, diphenamid, dipropetryn, fluchloralin, profluralin, propazine, terbutryn, and tridiphane. In addition, recently dropped insecticides include phosalone, phosphamidon, demeton, and monocrotophos. Dropped fungicides include dichlone, nabam, and zineb.

Although collectively small in total volume, most of the dropped herbicides had significant uses in particular states:(6)

- CDAA: 30 percent of New York's onion crop,
- Chloroxuron: 70 percent of Ohio's strawberry crop,
- Chloramben: 70 percent of Michigan's pumpkin crop,
- Chlorpropham: 90 percent of Maryland's spinach crop,
- Dalapon: 30 percent of Pennsylvania's green pea crop, and
- Diphenamid: 70 percent of Georgia's pepper crop.

Phosalone represents a typical example of an active ingredient dropped as part of the registration process. In California in 1988, 80,000 pounds of phosalone was used on nine crops: almonds, apples, artichokes, grapes, oranges, peaches, pears, plums and walnuts.(7) In announcing the decision to abandon the product, the manufacturer reported that sales did not justify providing the reregistration data which would have cost about $4 million.(8)

Many agricultural scientists and policymakers paint a picture of growers of fruit, vegetable, and specialty crops in increasingly desperate situations as cancellations increase. There is considerable consternation as to what growers are going to do when the single pesticide that is registered to control a particularly noxious pest in their crop is dropped by its manufacturer. For example:

- CDAA was the only herbicide that controlled sedge weeds in onion fields in Western and Northern New York. When it was taken off the market, some onion fields were abandoned because they were full of yellow nutsedge. Some growers made futile attempts to control weeds with an herbicide that also killed the onions.(9)

- Chlorpropham was the only herbicide which controlled broadleaf weeds in overwintering spinach in States such as New Jersey and Maryland. By growing overwintering spinach, harvest could be made early and late in the growing season making diversified vegetable farms more profitable and enabling a processing plant to remain open for much of the year. Without chlorpropham, weedy spinach fields were not harvested and were plowed under.(10)

Institutional and Market Responses to Lost Registrations

In recent years, when growers were faced with a pest for which there was no effective control method, they would petition EPA for an emergency exemption to use an effective compound not registered for that crop. If EPA decides that an emergency exists such that growers will incur significant economic losses without the pesticide, it grants an emergency exemption under Section 18 of FIFRA. One requirement of the Section 18 process is that growers and manufacturers work toward registration of these pesticides to control problems likely to reoccur frequently.

EPA has been criticized recently for granting emergency exemptions for growers to use the same compound for the same emergency year after year.(12) In response, EPA now requires evidence that a serious effort is being made to obtain a full registration for the compound within three years of the declaration of an emergency. Thus, the problem for growers not only is to find a compound that is an effective replacement but also a manufacturer willing to incur the costs of registering the compound for the particular crop or by soliciting assistance from the IR-4 project.

It is likely that growers will first seek out another chemical to fill the void of an important dropped registration. Cooperative Extension Service specialists regularly test promising chemicals for control of pests. When effective pesticides are canceled, testing of potential alternatives becomes a research priority.

For example, when the EBDC fungicides could no longer be used on spinach, a Rutgers plant pathologist began to test some newly registered copper fungicides. Two of the fungicides were effective in controlling a common disease, white rust, but damaged the crop. New Jersey spinach growers are struggling to use these compounds successfully. Spinach growers in Virginia have had a harder time with a disease not controlled by any of the copper fungicides, and losses have been severe.(14)

Another source of replacement compounds will come as manufacturers continue to develop new pesticides for major markets such as corn and soybeans. Once regulatory requirements have been met for a new registration for a major crop, additional registrations can be acquired at a relatively low incremental cost for fruit and vegetable growers. For example, when chlorambem was lost for weed control in green beans, Extension Service scientists began testing fomesafen and lactofen, herbicides recently introduced for use on soybeans.(15) In Florida lettuce, extensive weed control experiments have been conducted using imazethapyr, another new herbicide for use on soybeans.(16) Clomazone, also a new soybean herbicide, has been or will be registered for green beans, cucumbers, green peas, and pumpkins through the cooperation of the IR-4 project.

In the long run, advances in biotechnology will increase the availability of plant cultivars with resistance to particular pests of fruit and vegetable crops. Another promising technology is the development through gene transformation of herbicide tolerant crops. For example, at the University of Florida researchers have been working to make lettuce tolerant to glyphosate. (32) If the research is successful, the use of glyphosate could replace handweeding and significantly lower costs to lettuce growers.

There are new insecticide and fungicide compounds that have been developed for fruit and vegetable pests. Generally, these pesticides are much more expensive than previously-used materials. One such insecticide is abamectin, which is produced by a fermentation process. Through a process of Section 18 exemptions followed by full registrations, abamectin has been registered to control several important pests, including the celery leafminer, which had growers increasingly desperate due to its resistance to other insecticides. The current cost of insecticides for Florida celery growers is $447/acre which represents a substantial increase from previously-used chemicals costing $202/acre.(17),(18) The newly-available fungicides are not broad-spectrum in nature. They are effective in controlling single diseases only.

If growers can use only one particular product, the price can be set higher than if there were many competing products. Higher prices for new compounds can be offset by price decreases for some chemicals such as glyphosate, which is about to go off-patent.

There are indications that trust in the market to supply new pesticidal active ingredients may be misplaced, particularly with regard to fungicides. For example, the International Apple Institute (IAI) recently polled plant pathologists on the likelihood of new fungicides being developed to replace the EBDC fungicides used by apple growers. Nearly two-thirds of the pathologists responding indicated that there was no likelihood that adequate alternatives would be developed for the EBDCs in the next five years. The other respondents indicated that there was a likelihood of 25 percent or less that adequate substitutes would be developed.(19)

Concerns regarding pest resistance are heightened whenever growers rely on only a single compound for control of a pest species. With fewer choices available, growers may find minor use pesticides short-lived as pest populations develop resistance after repeated exposure. Leafminers in celery developed resistance to several insecticides due to repeated use of a single insecticide year after year until it was no longer effective. Populations of leafminers, with 25 generations per year, have developed resistance to individual insecticides in 1-7 years.(37) Now that most celery growers are relying primarily on abamectin for controlling leafminers, it may be that its currently high level of effectiveness will diminish as well.

Nonchemical Alternatives

Growers will likely consider nonchemical control options to replace lost chemical registrations. Some fruit and vegetable growers have already adopted them to fill the void created by the loss of effective pesticides. In Florida lettuce fields, growers use a substantial amount of hand labor for weeding due to the loss in the early 1980's of effective herbicides (CDEC and nitrofen) for weed control in organic soils.(20)

Most non-pesticidal means of pest control will be more expensive than the pesticides they replaced. Non-pesticidal controls usually require more management time and expertise. For example, a recently developed artificial pheromone, which disrupts the mating of the grape berry moth, is an effective potential alternative to the recently withdrawn registration of parathion for grape insect control.(21) However, the cost of the pheromone technology is about $50/acre in comparison to insecticide sprays of about $17/acre.(22) In addition, biological controls using pheromones are species specific in comparison to the broad spectrum control afforded by conventional insecticides. Other insect pests of grape vineyards could necessitate the use of insecticides in addition to pheromone technology.

In most cases, currently available nonchemical alternatives (for example, rotational crop growing or the use of biopesticides, such as Bacillus thuringiensis, [Bt]) are not as cost-effective in controlling pests as chemicals are.(23) For example, Bt will generally control 50-60 percent of the caterpillars in tomato fields in comparison to synthetic insecticides that produce greater than 90 percent control.(24) As a result of this difference, growers would incur significant yield losses if they relied exclusively on the nonchemical alternatives. Resistance of certain insect species to Bt has also been recently documented.(38)

With the current priority being given to funding research into nonchemical alternatives for pest control, there will undoubtedly be some development of more effective nonchemical alternatives. Considerable research is being conducted to breed plant cultivars with natural resistance to particularly noxious pests. Lettuce breeders predict that they are 5-6 years away from commercially acceptable lettuce varieties with season-long resistance to downy mildew.(25)

One of the problems with reliance on nonchemical means for pest control is that pests can overcome nonchemical controls. The history of downy mildew problems illustrates this potential. Resistant lettuce varieties effectively prevented downy mildew outbreaks for many years, but several new races of the fungus appeared in 1976 and overcame the resistance.(26) Fortunately, registrations of effective fungicides (the EBDC's) had been maintained and were used, in various combinations, to control the disease. However, when the EBDC registrations for lettuce were voluntarily dropped, resistance to the remaining fungicides accelerated. Lettuce growers have had to rely on a series of Section 18 registrations to combat the problem. The cost of controlling downy mildew has also risen dramatically; from approximately $50/acre in 1980 to nearly $450/acre in 1990.(27)

Ironically, much of the research into alternatives to chemicals is being directed at the same crops—corn and soybeans—for which there are numerous pesticides. The research agenda into nonchemical alternatives is not designed to develop replacements for dropped chemicals for small acreage crops. These crops have not received priority for the same reason that they do not receive priority from chemical manufacturers; they account for only a small fraction of the nation's pesticide use. To substantially reduce pesticide use, the research must be targeted at replacing pesticide use on major field crops.

Effects on Organic Growers and IPM Programs

Growers could opt to go without synthetic chemicals and use methods that organic growers currently use to control pests. However, one of the ironies of the reregistration process is that it may pose significant problems for organic growers who use pesticides to control particular pests.

Organic growers do not use synthetic organic compounds, but they do use certain inorganic active ingredients, derived from natural substances, that kill fungi and insects. Natural insect killers include ryania, rotenone, pyrethrin, and sabadilla. These natural pesticides must carry pesticide registration labels just as synthetic chemicals do, and are subject to reregistration as well. There are unresolved human health and environmental issues associated with several of these compounds. Rotenone, for example, is a potent fish killer. Pyrethrin is associated with respiratory problems.(28) Certain products acceptable to organic growers may not make it through the reregistration process. Because of insufficient toxicity tests, the California Environmental Protection Agency has prohibited rotenone use starting in early 1992.(28)

Unfortunately, the reregistration process has disrupted several ongoing successful Integrated Pest Management (IPM) programs. For more than a decade, growers have been encouraged to adopt IPM methods that combine biological and cultural pest controls with synthetic chemicals to create a pest management program that is effective with fewer pesticide applications. IPM methods have been credited with significant reductions in pesticide spraying in tree fruit and nut crops.

The chemicals that fit best into IPM programs narrowly control a key pest, limiting the disruption of biological systems which continue to suppress outbreaks of other pests. However, many effective IPM programs are being dismantled because some of the selective chemicals are being dropped by their manufacturers.

The insecticide phosalone was the key pesticide in the walnut IPM program developed by the University of California and described favorably by the National Academy of Sciences (NAS) in its report Alternative Agriculture.(29) Phosalone provided adequate control of codling moth—the key pest of walnuts—and was gentle on populations of aphid predators and parasites which controlled other pests. However, the manufacturer of phosalone decided to drop its registration for economic reasons. The walnut IPM program as described in the NAS report no longer exists. The alternative chemicals either harm the walnut trees or are broad spectrum in nature, killing aphid parasites, which requires additional chemicals to kill aphid outbreaks.

In apple production, a key IPM material recently lost during reregistration was phosphamidon, an insecticide, which at low rates controlled aphids without destroying predators of mites.(30). Now that phosphamidon is gone, apple growers will return to using miticides because alternative chemicals to control aphids will also kill many beneficial predators, causing outbreaks of mites.(31) Phosphamidon was considered important because it allowed apple growers to nearly eliminate the use of miticides in apple orchards.

Responses of Growers and Concerns of the Pesticide Industry

IR-4 has estimated that, in order to handle requests to collect data for minor uses of pesticides for both reregistration and new registrations, a budget of about $14 million annually would be required for the next several years. This figure is several times its annual budget in the past. The combined IR-4 and Agricultural Research Service (ARS) minor use program had a budget of about $6 million for 1992, a significant increase over the previous year, but far below the requested amount.

As of August 31, 1991, IR-4 has received requests to gather data on 5,082 minor uses. IR-4 has identified 1,324 of these requests as those for which the chemical company is willing to register the use if IR-4 fills the data needs. Since it is not possible to fill all the requests given the current budget, IR-4 has focused on prioritizing requests through regional liaison meetings and national workshops.(39) Given the current situation, growers will need to develop new strategies to maintain crop registrations. Some growers have already developed new avenues through which they can obtain registration of minor uses.

One example of increased pursuit of registrations by grower organizations is the formation of the U.S. Hops Industry Plant Protection Committee.(34) While hops are essential inputs for breweries, they fall into the category of "minor use crops" for which the expenses of registering a pesticide usually are not justified given the potential revenue. As a result of reregistration, seven minor uses for hops are being canceled; these include cyhexatin, an important miticide, and demeton, a systemic insecticide that controls aphids.

Disturbed by the loss of so many pesticides within a brief interval of time, the state-based hops grower organizations formed a committee to ensure that growers will have access to registered pesticides for their crops. They met with EPA to obtain information on what was required for registration, and to gain the approval of the chemical manufacturers to label their compounds for use on hops. Using funds assessed from growers and grants from breweries, they were able to conduct all the tests needed for registration of new pesticides with the cooperation of IR-4. IR-4 then assembled the results of the tests into the form required by EPA. Growers belonging to established commodity organizations may find this the best way to obtain new pesticides.

For some growers, the barrier to obtaining a registration of a minor use will not be costs. The cost to register a new food crop use of a pesticide can be as low as $20,000 to $30,000 given that all the required testing for toxicological, ecological, and environmental effects is complete. It is the fear of liability for crop damage that prevents many manufacturers from registering new uses of their pesticides on high value crops such as fruits and vegetables.

As an example of how costly liability from damage to high value crops can get, DuPont recently paid out $120 million in claims to nursery growers from damages connected with a well known fungicide, benomyl.(35) Although this is an unusual case involving a large number of nursery operations in several States, some individual claims for damages have amounted to over $1 million. Many agricultural chemical producers fear that one or two large claims could exceed several years of profits from sales of a minor use pesticide. This is especially true in the case of herbicides.

Herbicides are designed to kill plants. When a chemical company develops a new herbicide, it is tested repeatedly and under a wide range of conditions to determine how and when it can be safely applied to one or several particular crops. Many herbicides developed for major crops are phytotoxic to fruit and vegetable crops if not applied under the right conditions. A solution to registering these newer herbicides on minor use crops has been to arrange for a third party registration, which assumes the liability for the use of the herbicide.

The New York State Vegetable Growers Association has developed a system by which it obtained a third party registration for the use of the herbicide metolachlor on transplanted cabbage.(36) Metolachlor can cause stunting of cabbage and lower yields, but it is effective in controlling certain weed species that can be a major problem in the crop. The officers of the Growers Association sign a release which transfers the liability to the organization. In order to use metolachlor on cabbage, a grower must sign a waiver with the New York State Vegetable Growers Association. The grower may then use the herbicide legally.

The actual product container will not have any language instructing its use on cabbage, nor will any Extension Service bulletins recommend the use of metolachlor on cabbage. The grower decides whether the weed problem warrants the risk of potential crop damage to control it. Residue tests establish a tolerance for metolachlor on cabbage; but the grower who uses metolachlor without obtaining the waiver can be held responsible for an illegal use of a pesticide if residues are found on the grower's cabbage.

Many chemical companies are reluctant to agree to third party registrations of their products for fear that the waiver of liability will be challenged in court. Those few companies who have cooperated with grower-based organizations have had no problems with liability thus far.

The Florida Fruit and Vegetable Association (FFVA) has developed a different system. A separate non-profit corporation (Third Party Registration, Inc. [TPR]) has been set up to hold the registration. TPR assumes full liability for failure of the pesticide to perform adequately and for any phytotoxic effects. To use the pesticide, a grower must be a member of FFVA and must sign a waiver of liability.

Regulatory and Legislative Options

Many regulatory and legislative changes have been suggested recently to address the issue of lost pesticide registrations for low acre crops. A single issue coalition, the Minor Crops Farmers Alliance, has been formed to advocate changes. The Council on Agricultural Science and Technology (CAST) is due to issue a report on the subject this spring. Undoubtedly, there will be hearings on the subject as Congress considers changes in FIFRA in 1992. Typically, the recommended solutions include:

- More public funding for the IR-4 program,
- Extension of the time period for submission of data,
- Waivers of fees and registration requirements,
- Extension of patent protections, and
- Incentives for manufacturers to register products for minor uses.

International Implications

Concerns have been raised that lost pesticide registrations may hurt the economic viability of U.S. production of fruits, vegetables, and specialty crops. About $5 billion in fruits and vegetables was exported in 1990. Some of the pesticides which are being voluntarily dropped in the U.S. (such as phosalone) will continue to be used in other countries. Those growers may gain a competitive edge over the U.S. in international markets as a result of being able to use low cost effective chemicals that are no longer available to U.S. growers.

Further technological advances may accrue to foreign growers as well. For example, increased use of mechanized harvesting of vegetables would offer significant cost savings. The development of effective abscission chemicals to loosen vegetables from stems and vines would greatly facilitate mechanical harvesting.(33) Given the difficulty of registering new limited-use crop chemicals in the U.S., it may be that these advances will occur elsewhere in the world.

The U.S. represents a major market for imported produce. Imported produce accounts for about 25 percent of the fruits and vegetables consumed in the U.S. Exporters to the U.S. will not be able to use pesticides that are no longer registered in the U.S. and that leave detectable residues in foods although not all pesticides leave detectable residues. U.S. growers may also face difficulties in exporting produce if residues of pesticides labeled for minor uses here are not accepted abroad. The GATT and NAFTA talks are attempting to resolve these differences by adopting international standards.

Summary and Conclusions

In the short run, the loss of numerous effective low-cost pesticide products will disrupt the growing of many crops in many regions. Successful growing of fruit and vegetable crops is highly profitable. Growers can be expected to search for ways to maintain lucrative operations. They may incur higher-than-normal yield losses and production costs during a transition period of experimentation with pest control methods. In some cases, it might not be possible to overcome the production difficulties and, as a result, a crop no longer will be grown in a particular region.

The growers who are most likely to overcome reregistration difficulties are those organized into strong regional commodity organizations. However, in many States, fruit and vegetable growers have not organized into effective commodity organizations. Typically these are States with relatively small acreage of diverse crops and highly competitive growers. U.S. growers in many States can be overwhelmed by preserving needed pesticide registrations. This may lead to increased concentration of fruit and vegetable production in certain States and regions.

During the past four years, more pesticide registrations have been voluntarily dropped by manufacturers than have been canceled by EPA in its entire history. Most are being dropped because it does not make economic sense for manufacturers to reregister them. However, there is no clear understanding of the role these pesticides play in the management of resistance, development of Integrated Pest Management programs, or economic viability of crop production.

There is no consideration of the alternative human health or environmental risks that may be posed by substitutes. In some cases, the remaining chemicals may lose their effectiveness more rapidly because of the development of resistance by pests.

Based on some case examples, minor crop growers will no longer take the availability of low cost effective pesticides for granted. Costs are anticipated to be higher. The economic risks of producing fruits and vegetables acceptable in the marketplace are likely to be greater. Among some of the questions that can be asked are: How big will this adjustment be? Will production in some areas be affected to the extent that food processors may re-locate operations? Will the introduction of new specialty crops or the expansion of domestic and international markets be constrained by the availability of pesticides? What is the future of Integrated Pest Management programs in fruits and vegetables?

Thus far, public policymaking on pesticides has not thoroughly focused on consideration of the pest control needs of the nation's fruit and vegetable growers.

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List of Tables

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Appendix table 1--U.S. fertilizer imports: Declared value of selected materials

Material	Fertilizer year 1989/90	Fertilizer year 1990/91	July-November 1990	July-November 1991
	$ million			
Nitrogen:				
Anhydrous ammonia	252	297	120	124
Aqua ammonia	4	1	#	#
Urea	203	210	90	71
Ammonium nitrate	43	44	17	21
Ammonium sulfate	29	24	7	9
Sodium nitrate	14	15	8	6
Calcium nitrate	10	6	3	5
Nitrogen solutions	28	19	8	7
Other	7	8	3	6
Total 1/	590	624	255	247
Phosphate:				
Ammonium phosphates	3	1	1	1
Crude phosphates	17	22	8	10
Phosphoric acid	#	#	#	#
Normal and triple superphosphate	#	#	#	#
Other	1	1	#	#
Total 1/	21	24	9	11
Potash:				
Potassium chloride	500	519	185	202
Potassium sulfate	9	10	4	4
Potassium nitrate 2/	15	13	3	1
Other	28	28	13	9
Total 1/	552	570	205	215
Mixed fertilizers	34	28	10	8
Total 1/	1,198	1,247	480	482

na = Not available. # = Less than $500,000.

1/ Totals may not add due to rounding. 2/ Includes potassium sodium nitrate.

Appendix table 2--Plant nutrient use by State for years ending June 30 1/

State/ region	1990 Nitrogen	1990 Phosphate	1990 Potash	1991 Nitrogen	1991 Phosphate	1991 Potash
	1,000 nutrient tons					
Maine	12	10	10	11	10	10
New Hampshire	4	2	3	2	1	1
Vermont	6	4	7	5	4	5
Massachusetts	13	5	7	12	5	7
Rhode Island	2	1	2	2	1	1
Connecticut	7	2	3	4	2	2
New York	92	68	94	80	57	78
New Jersey	29	16	20	31	17	21
Pennsylvania	74	53	58	73	52	62
Delaware	21	7	21	21	7	24
Maryland	44	27	36	59	36	53
NORTHEAST	306	197	261	299	191	266
Michigan	251	122	228	265	115	224
Wisconsin	236	125	307	243	112	266
Minnesota	647	261	406	621	252	342
LAKE STATES	1,134	508	941	1,128	479	832
Ohio	388	193	319	346	138	268
Indiana	584	252	430	563	242	410
Illinois	897	383	636	1,006	392	638
Iowa	947	328	500	957	322	485
Missouri	398	177	247	408	169	244
CORN BELT	3,215	1,334	2,132	3,280	1,262	2,044
North Dakota	278	148	27	302	136	27
South Dakota	169	84	22	197	86	24
Nebraska	725	156	39	752	151	35
Kansas	579	163	44	640	168	41
NORTHERN PLAINS	1,751	550	133	1,890	541	127
Virginia	91	63	90	92	63	91
West Virginia	9	9	9	7	8	7
North Carolina	219	105	192	196	101	179
Kentucky	192	109	132	202	109	137
Tennessee	156	96	116	149	92	113
APPALACHIA	667	381	538	646	374	527
South Carolina	82	36	68	75	32	64
Georgia 2/	210	115	164	193	106	151
Florida	248	104	256	237	95	239
Alabama	128	53	71	123	49	64
SOUTHEAST	670	308	559	628	282	518
Mississippi	208	66	94	198	46	74
Arkansas	258	62	85	251	65	93
Louisiana	176	48	61	159	43	61
DELTA STATES	643	177	240	609	154	229
Oklahoma	326	89	32	345	80	33
Texas	791	227	111	878	254	116
SOUTHERN PLAINS	1,117	315	143	1,223	334	150
Montana	97	71	14	97	61	14
Idaho	166	84	20	152	74	32
Wyoming	40	11	1	81	18	2
Colorado	171	55	21	165	48	20
New Mexico	44	12	5	36	13	8
Arizona	87	29	1	75	28	2
Utah	32	15	2	20	11	2
Nevada	4	2	0	4	2	1
MOUNTAIN	642	279	65	628	255	80
Washington	198	50	32	169	51	35
Oregon	147	44	33	130	43	28
California	554	184	95	514	169	117
PACIFIC	899	279	160	813	263	180
48 States and D.C.	11,043	4,329	5,172	11,144	4,135	4,953
Alaska	3	1	0	3	1	0
Hawaii	18	9	19	18	9	19
Puerto Rico	11	5	11	14	5	13
U.S. TOTAL	11,076	4,344	5,203	11,179	4,151	4,984

1/ Totals may not add due to rounding. 2/ data is estimated.

Source: (3).

Appendix table 3--Fertilizer use on corn for grain, 1991

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer				Application rates N			Proportion fertilized At or before seeding		
			Any ferti-lizer	N	P205	K20	N	P205	K20	At or before seeding	After seeding	Both
	Thousand	No.	----------Percent--------				---Pounds/acre-----			------Percent-------		
Illinois	11,300	633	99	99	87	85	159	79	104	81	1	18
Indiana	5,800	516	99	98	94	86	135	78	112	57	1	42
Iowa	12,200	573	98	98	79	77	120	58	68	79	4	17
Michigan	2,600	302	97	97	89	90	124	63	95	45	1	54
Minnesota	6,600	651	97	97	85	83	110	50	63	84	1	15
Missouri	2,200	310	98	97	76	79	136	54	72	77	7	15
Nebraska	8,300	572	99	99	64	29	135	36	20	63	4	33
Non-irrigated	2,747	190	97	97	51	21	89	39	18 *	74	9	17
Irrigated	5,553	382	99	99	71	33	158	35	21	57	2	41
Ohio	3,800	507	98	98	94	91	151	75	103	39	1	60
South Dakota	3,750	295	83	83	67	26	71	36	22	85	6	9
Wisconsin	3,800	374	96	95	93	93	86	44	69	74	1	25
Area	60,350	4,733	97	97	82	73	128	60	81	71	3	26

* = CV greater than 10 percent.

1/ Preliminary.

Appendix table 4--Fertilizer use on cotton, 1991

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer				Application rates N			Proportion fertilized At or before seeding		
			Any ferti-lizer	N	P205	K20	N	P205	K20	At or before seeding	After seeding	Both
	Thousand	No.	----------Percent--------				----Pounds/acre----			------Percent-------		
Arizona	370	78	99	99	62	18	170	66	10 **	12	38	51
Arkansas	990	109	96	96	70	73	86	40	61	32	9	59
California	950	212	96	95	35	10	138	87	38 **	41	21	38
Louisiana	800	61	92	90	46	43	100 *	55	79 *	41	30	29
Mississippi	1,250	151	100	100	52	68	109	50	76	25	10	65
Texas	6,500	522	70	70	53	25	69	41	23	68	14	18
Area	10,860	1,133	81	81	52	34	91	47	48	51	16	34

* = CV greater than 10 percent. ** = CV greater than 20 percent.

1/ Preliminary.

Appendix table 5--Fertilizer use on rice, 1991

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer				Application rates N			Proportion fertilized At or before seeding		
			Any ferti-lizer	N	P205	K20	N	P205	K20	At or before seeding	After seeding	Both
	Thousand	No.	----------Percent---------				----Pounds/acre----			------Percent-------		
Arkansas	1,350	325	99	98	10	12	134	45 *	52	6	70	24
Louisiana	530	221	99	99	82	84	108	47	45	5	69	26
Area	1,880	546	99	99	30	32	127	46	47	6	70	24

* = CV greater than 10 percent.

1/ Preliminary.

Appendix table 6--Fertilizer use on soybeans, 1991

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer				Application rates N			Proportion fertilized At or before seeding		
			Any ferti-lizer	N	P205	K20	N	P205	K20	At or before seeding	After seeding	Both
	Thousand	No.	Percent				Pounds/acre			Percent		
Northern:												
Illinois	9,200	442	31	13	22	27	21 *	60	91	92	7	1
Indiana	4,450	370	36	19	28	35	15 *	41	79	99	1	0
Iowa	8,800	432	14	9	9	10	45 *	51	73	88	12	0
Minnesota	5,500	465	14	12	10	10	39 *	41 *	53	92	6	2
Missouri	4,500	339	25	16	19	21	19 *	43	68	94	6	0
Nebraska	2,500	256	20	19	17	8	15 *	32	20 **	90	8	2
Ohio	3,900	380	49	21	34	48	17 *	49	91	97	1	2
Sub-area	38,850	2,684	26	14	19	22	24	49	70	94	6	1
Southern:												
Arkansas	3,200	290	31	11	26	29	22 **	40	56	88	12	0
Georgia	650	128	70	56	62	67	26 *	45	90	92	3	4
Kentucky	1,150	179	56	36	53	49	52 *	63	76	97	0	3
Louisiana	1,450	152	8	3	8	8	33 **	39	57 *	92	8	0
Mississippi	1,900	258	21	10	18	18	29 **	50	59	96	4	0
North Carolina	1,350	182	60	47	51	59	18 *	34	87	94	3	3
Tennessee	1,100	175	55	27	51	53	25 *	44	58	100	0	0
Sub-area	10,800	1,364	37	21	33	35	28	45	70	94	5	2
Area	49,650	4,048	28	16	22	25	25	48	77	94	5	1

* = CV greater than 10 percent. ** = CV greater than 20 percent.
1/ Preliminary.

Appendix table 7--Fertilizer use on wheat, 1991

State	Acres 1/ 2/	Fields in survey	Acres receiving:				Application rates			Proportion fertilized		
			Any ferti-lizer	N	P205	K20	N	P205	K20	At or before seeding	After seeding	Both
	Thousand	No.	Percent				Pounds/acre			Percent		
Winter wheat:												
Arkansas	930	64	100	100	36	36	96	44	53	1	66	32
Colorado	2,300	86	54	54	22	2	48 *	31 **	#	83	9	9
Idaho	700	85	78	78	51	3	100	35	21 *	41	32	28
Illinois	1,400	76	96	96	94	83	87	65	83	15	4	81
Indiana	750	69	99	97	87	86	80	58	69	18	12	71
Kansas	10,800	358	89	89	53	10	58	33	34 *	66	8	26
Missouri	1,550	73	99	99	79	83	89	51	59	35	10	55
Montana	1,900	90	73	73	71	8	36	27	8 **	91	0	9
Nebraska	2,100	96	80	80	30	4	42	29	11 **	80	10	11
Ohio	1,100	68	99	99	91	93	77	61	67	5	15	81
Oklahoma	5,000	149	92	92	45	7	67	35	26 *	52	15	33
Oregon	800	83	98	98	11	6	58	38 *	32 **	81	9	11
South Dakota	1,300	69	41	41	38	3	28 **	39 **	4 **	78	7	14
Texas	2,800	174	72	72	37	12	86	39	26 **	62	9	29
Washington	750	115	99	98	28	9	72	26 *	21 **	78	6	17
Area	34,180	1,655	84	84	50	20	65	40	54	57	11	32
Spring wheat:												
Minnesota	2,100	137	96	96	92	66	86	36	31 *	98	1	1
Montana	2,600	70	51	51	50	10	29 *	26	10 **	100	0	0
North Dakota	7,000	118	75	75	62	19	51	29	12 *	100	0	0
South Dakota	1,800	62	63	63	52	8	47	24	12 *	100	0	0
Area	13,500	387	72	72	63	23	55	29	20 *	100	0	0
Durum wheat:												
North Dakota	3,000	130	72	72	63	7	47	28 *	8 **	100	0	0
All wheat 3/												
Arkansas	930	64	100	100	36	36	96	44 *	53	1	66	32
Colorado	2,300	86	54	54	22	2	48 *	31 **	nr	83	9	9
Idaho	700	85	78	78	51	3	100	35	21 *	41	32	28
Illinois	1,400	76	96	96	94	83	87	65	83	15	4	81
Indiana	750	69	99	97	87	86	80	58	69	18	12	71
Kansas	10,800	358	89	89	53	10	58	33	34 *	66	8	26
Minnesota	2,100	137	96	96	92	66	86	36	31 *	98	1	1
Missouri	1,550	73	99	99	79	83	89	51	59	35	10	55
Montana	4,500	160	60	60	59	9	33	27	9 *	96	0	4
Nebraska	2,100	96	80	80	30	4	42	29	11 **	80	10	11
North Dakota	10,000	248	74	74	62	15	50	28	11 *	100	0	0
Ohio	1,100	68	99	99	91	93	77	61	67	5	15	81
Oklahoma	5,000	149	92	92	45	7	67	35	26 *	52	15	33
Oregon	800	83	98	98	11	6	58	38 *	32 **	81	9	11
South Dakota	3,100	131	54	54	46	6	41	30 *	11 *	93	2	5
Texas	2,800	174	72	72	37	12	86	39	26 **	62	9	29
Washington	750	115	99	98	28	9	72	26 *	21 **	78	6	17
Area	50,680	2,172	80	80	54	20	62	36	43	69	8	22

* = CV greater than 10 percent. ** = CV greater than 20 percent. # = Insufficient data.
1/ Acres are harvested for winter wheat and planted for all other crops. 2/ Preliminary. 3/ Does not include winter wheat in MN, and ND; spring wheat in CO, and WA; or durum wheat in MN, MT, and SD.

Appendix table 8--Projected world supply-demand balances of plant nutrients for years ending June 30

World regions	Nitrogen		Phosphate		Potash	
	1991	1996	1991	1996	1991	1996
	Million metric tons					
Africa:						
Supply	1.92	2.45	5.11	5.99	0.00	0.00
Demand	2.27	2.61	1.21	1.37	0.52	0.61
Balance	-0.36	-0.16	3.90	4.62	-0.52	-0.60
America:						
Supply	15.72	16.58	11.76	12.15	10.35	11.54
Demand	15.20	15.97	6.90	7.37	7.32	7.73
Balance	0.52	0.61	4.87	4.79	3.03	3.81
North America--						
Supply	10.99	11.50	9.99	10.30	10.35	11.44
Demand	11.13	11.25	4.43	4.20	5.10	5.20
Balance	-0.14	0.25	5.56	6.10	5.25	6.24
Central America--						
Supply	3.30	3.39	0.71	0.72	0.00	0.00
Demand	2.15	2.46	0.60	0.70	0.35	0.35
Balance	1.15	0.93	0.11	0.02	-0.35	-0.35
South America--						
Supply	1.43	1.69	1.06	1.14	0.00	0.10
Demand	1.92	2.26	1.87	2.47	1.87	2.18
Balance	-0.49	-0.57	-0.81	-1.33	-1.87	-2.08
Asia:						
Supply	30.00	35.82	7.13	8.30	2.09	2.30
Demand	37.29	43.61	13.36	15.17	4.71	5.67
Balance	-7.29	-7.79	-6.23	-6.87	-2.62	-3.37
West Asia--						
Supply	3.30	4.66	1.27	1.72	2.07	2.21
Demand	2.68	3.05	1.56	1.88	0.16	0.18
Balance	0.62	1.61	-0.29	-0.16	1.91	2.03
South Asia--						
Supply	8.04	10.45	0.93	1.11	0.00	0.00
Demand	10.12	12.31	3.96	4.60	1.36	1.66
Balance	-2.08	-1.87	-3.03	-3.49	-1.36	-1.66
East Asia--						
Supply	18.66	20.72	4.92	5.46	0.02	0.10
Demand	24.49	28.25	7.84	8.69	3.19	3.83
Balance	-5.83	-7.53	-2.92	-3.23	-3.17	-3.73
Europe:						
Supply	14.02	14.74	6.75	6.99	7.96	6.98
Demand	13.90	13.50	6.60	6.90	7.30	7.05
Balance	0.12	1.24	0.15	0.08	0.66	-0.07
East Europe--						
Supply	5.13	5.69	2.94	3.20	0.00	0.00
Demand	3.50	4.00	1.60	2.10	2.00	2.10
Balance	1.63	1.69	1.34	1.10	-2.00	-2.10
West Europe--						
Supply	8.88	9.05	3.81	3.79	7.96	6.98
Demand	10.40	9.50	5.00	4.80	5.30	4.95
Balance	-1.52	-0.45	-1.19	-1.01	2.66	2.03
Former USSR:						
Supply	15.95	16.46	7.03	7.14	8.94	9.40
Demand	8.60	9.00	7.80	8.20	5.40	5.80
Balance	7.35	7.46	-0.77	-1.06	3.54	3.60
Oceania:						
Supply	0.40	0.40	1.04	1.15	0.00	0.00
Demand	0.50	0.68	0.70	0.90	0.26	0.29
Balance	-0.10	-0.28	0.34	0.25	-0.26	-0.28
WORLD TOTAL:						
Supply	77.99	86.45	38.81	41.71	29.34	30.22
Demand	77.76	85.37	36.57	39.91	25.51	27.14
Balance	0.23	1.08	2.24	1.80	3.83	3.08

Source: (4).

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