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Economic Effects of Nitrogen in Rainfall on Cropland

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Economic Effects of Nitrogen in Rainfall on Cropland. By Joseph R. Barse, Rebecca A. Pfeifer, Margaretha V. Rudstrom, and Otto C. Doering. Natural Resources and Environment Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES 9423.

Abstract

One goal of the U.S. Government's policy to reduce air pollution is to reduce the application (deposition) of nitrogen to the Earth's surface by placing controls on the emissions of oxides of nitrogen to the atmosphere. This report evaluates what the environmental and economic effects would be in the future if less nitrogen were applied to the Earth's surface. Agronomic estimates were made of the impacts of the assumed withdrawal of all rainfall nitrogen on the trendline yields of eight crops over an 8-year period (1993-2000). Largely because of price increases accompanying reduced yields from less nitrogen, results show that consumers of the eight crops would be worse off, but the producers would be better off. Without the rainfall nitrogen, Government farm program payments could be about $2.4 billion less over the 8-year period than if current levels of nitrogen in rain continued. Changes in nitrogen use could stem from public policies or widespread private decisionmaking by farmers, or both.

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Introduction

U.S. Government policy to reduce air pollution (Clean Air Act, most recently amended in 1990) aims, among other things, to reduce the application (deposition) of nitrogen to the Earth's surface by placing controls on the emissions of oxides of nitrogen to the atmosphere. Numerous policy-related scenarios extending into the future seem to be focusing on a common theme, namely, evaluating what the environmental and economic effects would be if less nitrogen were applied to the Earth's surface. Congress has assigned the U.S. Department of Agriculture and other departments and agencies to work in an interagency program to assess the costs and benefits of controlling emissions to the atmosphere of some of the precursors of nitrogen in rainfall (*9*).[1] [2]

A nationwide network of monitoring stations and laboratories samples rainfall across the country and analyzes chemical composition of the rain samples. Results show that liquid forms of nitrogen, capable of fertilizing plants, are a regular component of rainfall. Do farmers or consumers derive any economic benefit from the "free" nitrogen that falls on crops and cropland? And if this free nitrogen were "removed" (by assumption) in future years, what difference would it make in projections of key economic variables for those years?

This report analyzes the economic effects of rainfall nitrogen by comparing two (or more) sets of projections of the future. The first is a "baseline" projection of economic variables assuming no change in rainfall nitrogen, while the second is a "scenario" or alternative

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[1] The Clean Air Act Amendments of 1990, Title IV, mandated a new acid deposition control program including a 10-million-ton reduction in sulfur dioxide emissions from 1980 levels, and a 2-million-ton reduction in emissions of oxides of nitrogen, also from 1980 levels. In addition, Title IX of the Amendments, Sec. 901 (j) continued the National Acid Precipitation Assessment Program (NAPAP), a Federal inter-departmental research and evaluation program begun in 1980. That section also specified that a Task Force be set up to direct the Program. The Act further specified that the Secretaries of Energy, Interior, and Agriculture, as well as the Administrators of the Environmental Protection Agency, National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration, should constitute this Task Force. In addition, that Section also mandated a series of reports, including a report on the "costs and benefits of the acid deposition control program created by Title IV of this Act." The cost-benefit report is due first in 1996 and every 4 years thereafter.

[2] Italicized numbers in parentheses refer to sources listed in the References section of this report.

projection, with everything the same as in the baseline projection, except that the rainfall nitrogen is assumed to have disappeared.

This alternative assumption that less nitrogen will be applied to crops (that is, no rainfall nitrogen but the same levels of farmer-applied nitrogen) is central to the analysis. But, the analysis in this report could also be recast. One could also assume that other influences, such as nitrogen taxes, or public policies and regulations, could cause farmers to reduce their own applications of nitrogen to cropland. Presumably, environmental objectives, such as reducing fertilizer residuals in surface water runoff or percolation to groundwater, would be motivating such taxes or policies. Thus, the analytical procedures used in this report may be relevant to any policy analysis focused on nitrogen reduction, and it is possible that the results in this report could point in the same direction as results from other kinds of scenarios of projected reduction in nitrogen applied to crops.

The nitrogen cycle, depicted in literature (for example, in (*2*)), shows that nitrogen moves through soils, unmanaged terrestrial ecosystems, managed crop and livestock production systems, as well as into and out of surface water, groundwater, and the atmosphere. Here we are assuming that nitrogen in rainfall is used and useful--that it is contributing to crop growth. This might not be the case where other factors are limiting, such as drought or flooding, or where there is an overabundance of nitrogen due to over-fertilizing or other factors.

Further, we assume that rainfall N is no more nor less effective than farmer-applied N. This is assuredly a simplifying assumption, which leaves for future analyses the question of comparing the influence of variables, such as seasonal timing of application and chemical form of N with both farmer-applied and rainfall nitrogen. This report evaluates some, but by no means all, economic implications of one part of the nitrogen cycle--applications of N to crops through the natural process of rainfall.

The phenomenon of fertilization of plants by nitrogen coming from rainfall is described in numerous scientific reports. A report from the National Research Council discusses both physiological processes and empirical evidence of how plants use nutrients from the atmosphere, as well as how they are affected by air pollutants (*8*). The Council for Agricultural Science and Technology, in a report on acid precipitation and agriculture, mentions literature showing some beneficial effects on plants of nutrients added to soils from acid deposition and also taken up directly by plants during deposition events (*1*). A report from the Iowa State Agricultural Experiment Station on nutrients in precipitation in the North Central States quantifies the amounts of these nutrients, building upon the prior knowledge that they can be used beneficially by plants (*12*). In addition, a "State-of-Science" report from the National Acid Precipitation Assessment Program examines the whole array of scientific evidence on terrestrial effects of acid precipitation and concludes that nitrogen in rainfall does have a fertilization effect on vegetation (*6*). Thus, there is scientific justification to the concept that nitrogen in rainfall is capable of fertilizing crops. How much it does fertilize crops is discussed below, especially in a report from staff at Purdue University (*10*).

Method of Analysis

The economic value of rainfall nitrogen is estimated in six steps, as follows:
(1) Determining how much of this nitrogen now falls on cropland, by region; (2) assuming a

contrary-to-fact condition, namely, that none of this kind of nitrogen is deposited; (3) estimating the impact on crop yields of a reduction in nitrogen application equal to the amount of nitrogen now deposited in rainfall; (4) placing the estimated crop yield reductions into the AGSIM econometric-simulation model; (5) running the model for conditions both before and after the estimated yield reductions; and (6) evaluating the differences between the before and after simulations from the AGSIM model runs. Eight crops are analyzed: Corn, soybeans, wheat, barley, oats, grain sorghum, cotton, and hay. The following 10 production regions are employed: Corn Belt, Lake States, Northern Plains, Southern Plains, Delta States, Northeast, Appalachian States, Southeast, Mountain States, and Pacific States. These are standard crop production regions employed by USDA's Economic Research Service in other reports and analyses (figure 1).

Nitrogen in rainfall occurs in two forms: Ammonium (NH4) and Nitrate (NO3). The authors convert observed data for each form into pure N (nitrogen) equivalent, a common denominator, so that data for each form are directly additive to each other. As a simplifying assumption for this initial analysis of aggregate relationships, we consider N equivalent data as annual totals only, without regard to whether the data come from NH4 or NO3, or apply to spring, summer, fall, or winter. Quarterly data by nitrogen type are available, however, and could be used in future analyses. We thus assume initially that an annual change in N equivalent from NH4 results in a crop yield response identical to the response from the same amount of annual change in N equivalent from NO3. A micro-analytic study, limited to one geographic point, might choose immediately to employ more complex assumptions about nitrogen forms and season of deposition. However, our preference is to start with the aggregated picture first.[3]

Amount of Nitrogen in Rainfall

The amount of nitrogen in rainfall (as well as other items in rain) is monitored by the National Atmospheric Deposition Program at 200+ stations in the 48 conterminous States and reported as kilograms deposited per square meter. Data on nitrogen (NO3 and NH4) deposition for the crop years 1985-87 for those monitoring stations was obtained from the Program office on a quarterly basis. Data on the two types of nitrogen for the 200+ sample points were then converted to pure N equivalent, added together, and converted to pounds of pure N per acre. Then, the coordinates of each of the sample points were used in a geographic interpolation program to produce regional average estimates of pounds of pure N for each of 11 farm production regions (see table 1 and figure 2).

[3] No policy could directly regulate a meteorological event such as the deposition of nitrogen in rainfall. Policies can be targeted toward this end, however, by influencing the emissions to the atmosphere of precursors of this deposition, such as oxides of nitrogen emitted by vehicles, industry, and electric power plants (precursors of HNO3 [nitric acid] in rainfall) or ammonia from cattle feedlots (precursor of NH4 [ammonium] in rainfall). Presumably such policies would influence, though not control, the amount of nitrogen falling to the Earth in rain, as well as the distribution of such nitrogen over space and time. Other kinds of policies might operate by attempting to influence the amounts, kinds, timing, and spatial distribution of farmer-applied nitrogen. Thus, the authors have used one generalizable method to analyze all such policies, namely to assume that nitrogen deposition/application is reduced by so much (as an alternative to actual conditions), estimating the effect of the reduction on crop yields, and further estimating the effects of those yield changes on physical and economic variables. Using actual observations of actual nitrogen in rainfall is just one way to arbitrarily select the amount of nitrogen reduction that is to be considered. One could just as well have assumed some percentage reduction across the board, but it seemed somewhat more realistic to use the nitrogen-in-rainfall observations to establish a regional distribution of where greater and lesser reductions might occur.

Alabama is identified as a separate region because it is so defined in the AGSIM econometric simulation model maintained at Auburn University, Alabama.[4] Later, results for Alabama can be integrated with those for other States of the Southeast farm production region. The highest annual level of wet deposition of N occurred in the Corn Belt at 4.61 pounds per acre; the lowest in the Pacific States at 0.88 pounds per acre.

We assume that a region's cropland planted to any of the eight crops considered here receives wet deposition of N at the same rate as that region's average deposition. (Wet deposition of N means: Nitrogen deposited on the Earth's surface in precipitation, or "nitrogen in rainfall" as used in this manuscript. The word should be interpreted broadly here to include all forms of precipitation.) Then, in order to conduct the analysis, we assume a contrary-to-fact condition, namely, that there is no wet deposition of N anywhere. This contrary-to-fact assumption allows us to estimate the impact on crop yields of reducing the existing application of nitrogen.

Effect of Rainfall Nitrogen on Crop Yields

What would happen to the regional average trend-line yield of each of the eight crops if average total nitrogen applied by farmers were reduced by the amount of rainfall nitrogen for that region? A number of important assumptions are made in answering this question. At the start, it is assumed that the yield impact on soybeans and on legume hay (alfalfa) would be zero, since they are legumes that can fix their own nitrogen.

Yield reductions that do occur are taken as "instantaneous," that is, they occur immediately as the nutrient is withdrawn, and apply to the next harvest that could be influenced by fertilization. This is the assumption in most exercises of this kind. There would probably be a phase-in of the impact in the real world as nitrogen declines from its reservoir levels in the soil system.

To start estimating the answer to the above question, average yields for each of the remaining seven crops were calculated by region (tables 2, 3, 4, 5, 6, 7, and 8). We started by trying to base yield impacts on the consistent national regional response functions developed by Ibach and Adams in the 1960's (*5*). As part of this process, we tested the representativeness of these against more disaggregated current functions for some major crops. The Adams and Ibach functions were derived from 1960's conditions, and we feel that these functions are no longer representative of current data. This is a disappointment, because these regional functions are the most recent developed across the country on a consistent basis at one time for the major crops. In a sense, they are a unique data source for relative regional comparisons.

Ultimately, we did not use experiment station data or other production functions, but went State-by-State, crop-by-crop across the country to crop production specialists for their best

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[4] AGSIM is an econometric-simulation model of regional crop and national livestock production in the United States. The model was developed to analyze the aggregate economic impacts of a wide variety of issues facing agriculture, such as technological change, withdrawing pesticides, farm programs, and the conservation reserve. C. Robert Taylor (*13, 14*)

estimates, which provided the guidance for the regional estimates developed as follows.

In an interview process, conducted by staff at Purdue University, agronomists and crop production specialists were contacted and asked to estimate yield reductions that would likely occur if applied nitrogen were reduced by the small amounts as above (that is, equivalent to no nitrogen being present in rainfall). (This interview process is similar to the process used in pesticide benefit assessment in which plant protection specialists are asked to estimate the impact on crop yields of reducing or banning certain pesticides. The specialists draw upon their knowledge of field experiments, if there are any, plus their own experience and judgment (*10*).) In this case, the changes considered were relatively small, so no change in the basic production function, farm practices, crop rotations, etc., were assumed or considered. The resulting estimates from these interviews, shown as the yield reductions in tables 2-9, are then used to reduce the regional trendline yields employed in the AGSIM model for the seven crops.

The AGSIM Model: Baseline Projection

The AGSIM model was run to produce a baseline projection of economic effects associated with eight crops and all livestock in the United States starting in 1991 and ending in 2000. This baseline projection provides a view of the future prior to any adjustments being made for reduced applications of nitrogen or the effects of any but existing policies and existing conditions, projected to 2000. The baseline projection can also be called a "business-as-usual" scenario. Several highlights of tables on exogenous variables, trendline yield estimates, and economic results of the baseline run are shown in figures 3-7.

Projected acreage planted to wheat rises somewhat during 1991-2000, while acreage devoted to cotton falls, as does acreage diverted under Government programs. A modest cost-price squeeze is projected for 1995-97, as trendline net farm income before government payments dips somewhat in those years, to begin recovery later. Government payments to farmers for the eight crops studied are projected to drop consistently after 1995. Net farm income from eggs and broilers is projected to fluctuate cyclically over the 1991-2000 decade, with income from dairy trending down and income from hogs and cow/calf trending upward. The income projection from fed cattle during these years appears bleak. To this projected picture, a relatively small shock is introduced in the form of the contrary-to-fact assumption that nitrogen from rainfall is eliminated (or nitrogen reduced comparably because of policy initiatives), thus defining an alternative scenario projection of the future.

Alternative AGSIM Projection: Reduced N Scenario

Hereafter in this report this alternative projection is called the "Reduced N Scenario." The scenario is presumed to have begun in time for the 1993 crop year, and thus comparisons of baseline and scenario do not apply to the years 1991 and 1992. Highlights of this Reduced N Scenario projection and its results are found by focusing on the differences (or changes) between the baseline and scenario projections in figures 8-28.

Crop Yields

It is assumed that projected crop yields for each year 1993-2000 remain below the baseline yields by the yield reduction amount estimated by the Purdue Staff Paper and shown in tables 2-9. The reduced N scenario operates within the AGSIM model using regional yield differentials, but only the national aggregate yield differences are shown in figures 8-14. The baseline yield projection for each crop is of trend or central tendency, and does not attempt to capture the annual variability that would undoubtedly occur. The yield changes for each crop are relatively small; however, the economic effects of these changes mount up because they are persistent over time and widespread over space. Even small changes at the micro level can have significant aggregate impacts.

Crop Acreage

Differences in crop acreage results between the Baseline Scenario and Reduced N Scenario are extremely small relative to total crop acreage. The changes in projected crop acreages over time during the 1990's shown in figure 3 are undoubtedly of greater interest than the acreage differences between the two scenario outcomes. Nevertheless, the effect of the Reduced N Scenario is to change total crop acreage downward by approximately 80,000 acres annually during the 1993-2000 period (figure 15). For the year 2000, most of this change occurs in the Corn Belt, with offsetting changes in the other crop regions (figure 16). During the 1990's, the Reduced N Scenario leads to an increased acreage for cotton and a reduced acreage for wheat, while corn acreage declines relative to baseline acreage, then returns to approximately equal it by the year 2000 (figure 17). Differences between the two scenarios in the "diverted acreage" category account for much of the difference between the acreage totals for those scenarios.

Production and Prices

In the Baseline projection, corn production rises gradually during 1993-2000 to new record levels over 9 billion bushels, with production in the Reduced N Scenario projection being narrowly less in each year. Projected prices move downward by about 30 cents per bushel in 1993-97 and rise little thereafter for the Baseline, but are a bit higher consistently for the Reduced N Scenario (figure 18). Projections of milo/grain sorghums show similar patterns, but the projected price drop is greater than for corn. Again, the Reduced N Scenario projection shows somewhat less production and somewhat higher prices than the Baseline (figure 19). Wheat production, both Baseline and the Reduced N Scenario, is projected to rise during 1993-2000, but projected prices are much more stable than for corn and milo (figure 20). Baseline cotton production, by contrast, is projected to decline into the mid-1990's, then recover slightly by 2000, with the Reduced N Scenario quantities a shade less each year. Prices drop a few cents a pound to 1994-95, then recover by a penny (figure 21). Typically, Reduced N Scenario production is slightly less than Baseline and Reduced N Scenario prices are slightly higher.

Net Farm Income and Government Farm Program Payments

Net farm income before Government program payments under the Reduced N Scenario is more than the Baseline amount by about $250 million annually from the mid-1990's to 2000.

As noted earlier, a cost-price squeeze depresses both the Baseline and Reduced N Scenario amounts in the middle of the decade (figure 22). Government farm program payments, declining anyway, are about $250-$330 million less annually under the Reduced N Scenario than under the Baseline (figure 23). The cumulative amount of the difference between the two projections for the 8-year period is about $2.4 billion, with the "saving" in program costs to the favor of the Reduced N Scenario (table 10 and figure 24).

Measures of Producer and Consumer Welfare

Calculations of economic "surplus"--specifically, **changes** in "surplus"--are characteristically regarded as measures of economic welfare for both producers and consumers (*3, 11*). AGSIM calculates these changes. In general, consumers of the eight crops are less well off because of the Reduced N Scenario (figure 25), while producers of these crops are better off under the Reduced N Scenario than under the Baseline (figure 26). This is intuitively consistent with "common sense," since prices would be slightly higher for both producers and consumers under the Reduced N Scenario than under the Baseline. Neither consumers nor producers of livestock products become better off under the Reduced N Scenario (figures 27 and 28). Higher prices for grain inputs to livestock production apparently squeeze these producers somewhat, who are only partially successful in passing on their increased costs to consumers.

Conclusions and Implications

Although the crop yield reductions attributable to reduced nitrogen fertilization are relatively small, even these small amounts can have significant impacts when replicated consistently over time and space. If the measure of economic value of the nitrogen resource in rainfall is what happens when you take it away, then clearly there is no one measure of this value, but an array of measures. One such array can be found in the projected effects coming out of running the AGSIM econometric simulation model to compare future economic effects accompanying existing rainfall nitrogen to the effects without such nitrogen.

This analysis compares alternative futures, one with higher levels of nitrogen, one with lower levels. Thus, the AGSIM model results found here are just specific answers to the general question: What would the economic impacts be if nitrogen applied to crops were reduced by "X" amount or by "Y" amount? The results here--although specific in quantity to this particular case--could well point in the general direction of results stemming from assumptions about greater or lesser nitrogen reduction.

The specific economic results of this case of assuming that rainfall nitrogen does not exist show that consumers of the eight crops studied would be slightly worse off, but the crop producers would be slightly better off. Further, without the rainfall nitrogen, taxpayers would be slightly better off because Government farm program payments cumulated over the 1993-2000 period would be about $2.4 billion less than program costs likely if current levels of nitrogen in rain continued.

The value to producers of the loss from reduced N is much greater than the cost of additional N, so we would expect them to compensate if, individually, they noticed this small reduction.

But, they might not, because a yield reduction could be interpreted as nothing more than a yield change within an expected range of annual variability rather than a small change in trendline yield.

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Table 1--Estimated U.S. and regional average wet deposition of nitrogen from NH4 (ammonium) and NO3 (nitrate) in pure N equivalents, 1985-87 average[1]

Farm production region, number and name		GEOEAS grid points	85-87 Ann.avg NH4 N	85-87 Ann.avg NO3 N	85-87 Ann.avg TOT N	85-87 Fall NH4 N	85-87 Fall NO3 N	85-87 Fall TOT N	85-87 Winter NH4 N	85-87 Winter NO3 N	85-87 Winter TOT N	85-87 Spring NH4 N	85-87 Spring NO3 N	85-87 Spring TOT N	85-87 Summer NH4 N	85-87 Summer NO3 N	85-87 Summer TOT N
		Number	Pounds per acre														
1	Alabama	26	1.24	1.80	3.04	0.19	0.34	0.53	0.24	0.35	0.60	0.46	0.50	0.96	0.34	0.62	0.96
2	Corn Belt	143	2.06	2.55	4.61	0.43	0.59	1.03	0.23	0.35	0.58	0.77	0.75	1.51	0.63	0.87	1.49
3	Lake States	122	1.99	2.16	4.15	0.45	0.54	0.99	0.15	0.28	0.44	0.73	0.62	1.35	0.66	0.72	1.38
4	Northern Plains	166	1.45	1.30	2.76	0.26	0.25	0.51	0.12	0.12	0.24	0.60	0.43	1.03	0.47	0.50	0.97
5	Southern Plains	164	1.27	1.38	2.66	0.22	0.32	0.54	0.21	0.23	0.44	0.57	0.44	1.01	0.26	0.44	0.70
6	Delta States	73	1.50	1.93	3.43	0.27	0.43	0.70	0.28	0.34	0.62	0.61	0.55	1.16	0.34	0.64	0.98
7	Mountain States	477	0.46	0.62	1.08	0.09	0.12	0.21	0.06	0.08	0.14	0.17	0.17	0.34	0.14	0.23	0.37
8	Pacific States	200	0.37	0.51	0.88	0.11	0.15	0.25	0.09	0.14	0.24	0.13	0.15	0.28	0.04	0.07	0.11
9	Northeast	107	1.53	3.07	4.60	0.27	0.61	0.88	0.17	0.59	0.76	0.51	0.81	1.32	0.58	1.05	1.64
10	Appalachian States	102	1.51	2.39	3.90	0.21	0.42	0.63	0.21	0.45	0.66	0.49	0.65	1.14	0.60	0.87	1.47
11	Southeast	78	0.98	1.66	2.63	0.13	0.28	0.42	0.16	0.29	0.46	0.31	0.39	0.70	0.38	0.71	1.09
	United States (48 States)	1,658	1.10	1.42	2.52	0.21	0.30	0.51	0.14	0.23	0.37	0.41	0.41	0.82	0.33	0.49	0.82

[1] The estimated values for the above 15 variables (the column headings above) are derived from biweekly sample values of NO3 and NH4 (grams per square meter) in wet deposition (rainfall) at 200 monitoring stations in the National Trends Network, as reported by source (*7*) below for 1985-87 crop years. In addition to nitrogen, the amount of precipitation, acidity, and other chemical constituents are reported. The monitoring stations are identified by name, county location, and coordinates of west longitude and north latitude, and thus sample values from each station are tagged with station coordinates. The authors define a crop year to begin on September 1 and end on August 31. By definition, the fall season is September 1-November 30, and so on for the other seasons at 3-month intervals through August. Thus the actual period covered by the above table begins September 1, 1984 and ends August 31, 1987. The authors derived 3-year annual and seasonal averages from these biweekly nitrogen observations by both types of nitrogen individually and together, making 15 variables, and then converted these averages to pure N equivalents using the following conversion factors: NH4 x .7777 = N, and NO3 x .2258 = N. The authors then estimated regional averages for each of these variables as follows: The 3-year averages for each variable and each of the 200 sample points with their coordinates were entered into a geographic interpolation program (GEOEAS) (source (*4*)) to estimate variable values at uniformly-distributed gridpoints covering the entire 48 States. This geographic interpolation process is called "kriging," akin to the process by which temperature isolines are created on daily weather maps from observations at weather stations around the country. In this case, the interpolated grid yields variable values at 1,658 points, uniformly-spaced geographically and identified by coordinates within the 48-State boundaries at intervals of 1 degree longitude and 1\2 degree latitude. Because USDA crop production regions follow State boundary lines, comparing these grid point coordinates with State maps makes it possible to allocate each of the 1,658 grid points to a certain State, and thus a crop region. (In interim calculations, Alabama is defined as a separate region because the AGSIM model used in later calculations originated at Auburn University in Alabama and defines that State as a region. Final calculations combine Alabama values with those of other States in the Southeast.) Coordinates for each of the 1,658 points are the same for each of the 15 variables. The table above shows the number of grid points located in each crop region. For any variable, the average value for a region is the simple average of the values for all the grid points in that region, and the 48-State average is the simple average of the values for all 1,658 points.

Sources: (*4, 7*)

Table 2--Corn: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Corn Belt	33,660		4,209,500			32,704	0.78
Iowa	12,400	126		1.20	0.96	11,909	0.76
Missouri	1,960	105		1.00	1.15	2,259	1.10
Indiana	5,450	129		1.20	0.96	5,234	0.74
Illinois	10,400	127		1.20	0.96	9,988	0.76
Ohio	3,450	121		1.20	0.96	3,313	0.79
Lake States	11,220		1,354,650			10,219	0.75
Minnesota	6,150	124		1.20	0.86	5,317	0.70
Wisconsin	3,000	118		1.00	1.04	3,113	0.88
Michigan	2,070	115		1.20	0.86	1,790	0.75
Northern Plains	12,210		1,393,700			7,427	0.53
North Dakota	460	80		1.25	0.55	254	0.69
South Dakota	3,000	78		1.20	0.58	1,725	0.74
Nebraska	7,300	128		1.20	0.58	4,198	0.45
Kansas	1,450	130		0.80	0.86	1,251	0.66
Southern Plains	1,538		140,532			852	0.61
Texas	1,450	90		1.20	0.55	804	0.62
Oklahoma	88	114		1.22	0.55	48	0.48
Delta States	399		39,711			263	0.66
Louisiana	186	116		1.30	0.66	123	0.57
Mississippi	140	80		1.30	0.66	92	0.82
Arkansas	73	95		1.30	0.66	48	0.69
Pacific States	258		42,300			47	0.11
Washington	80	175		1.20	0.18	15	0.10
Oregon	18	150		1.20	0.18	3	0.12
California	160	160		1.20	0.18	29	0.11

Continued--

Table 2--Corn: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Mountain States	399		151,160			1,137	0.75
Idaho	30	130		1.20	0.90	27	0.69
Wyoming	50	120		1.20	0.90	45	0.75
Montana	9	95		1.20	0.90	8	0.95
Utah	19	140		1.20	0.90	17	0.64
Colorado	830	155		0.90	1.20	996	0.77
Arizona	7	160		1.20	0.90	6	0.56
New Mexico	55	145		1.60	0.68	37	0.47
Northeast	2,287		252,100			2,182	0.87
New York	620	98		1.22	0.94	584	0.96
Pennsylvania	970	113		1.20	0.96	930	0.85
Maryland	450	118		1.20	0.96	431	0.81
New Jersey	75	118		1.20	0.96	72	0.81
Delaware	172	115		1.20	0.96	165	0.83
Appalachia	3,195		289,080			2,649	0.92
North Carolina	1,070	68		1.20	0.81	869	1.19
West Virginia	50	105		1.20	0.81	41	0.77
Tennessee	510	107		1.20	0.81	414	0.76
Kentucky	1,200	100		1.20	0.81	975	0.81
Virginia	365	100		1.20	0.81	350	0.96
Southeast	945		58,085			518	0.89
Florida	75	71		1.20	0.55	41	0.77
Georgia	550	68		1.20	0.55	301	0.81
South Carolina	320	48		1.20	0.55	175	1.14
Alabama	240		13,920			152	1.09
Alabama	240	59		1.20	0.96	72	1.09
Total, All Regions	66,952		7,944,738			58,151	0.73

Source: (*10*)

Table 3--Grain sorghum: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Corn Belt	715		54,665			687	1.26
Missouri	520	77		1.20	0.96	499	1.25
Illinois	195	75		1.20	0.96	187	1.28
Northern Plains	4,460		357,300			3,127	0.88
South Dakota	260	55		1.10	0.63	163	1.14
Nebraska	1,400	77		0.80	0.86	1,208	1.12
Kansas	2,800	84		1.10	0.63	1,756	0.75
Southern Plains	2,950		151,650			1,302	0.86
Texas	2,600	52		1.50	0.44	1,153	0.85
Oklahoma	350	47		1.56	0.43	149	0.91
Delta States	488		31,995			335	1.05
Louisiana	128	65		1.25	0.69	88	1.06
Mississippi	85	65		1.25	0.69	58	1.06
Arkansas	275	66		1.25	0.69	189	1.04
Mountain States	270		13,590			35	0.26
Colorado	220	47		2.10	0.13	28	0.27
New Mexico	50	65		2.10	0.13	6	0.20
Appalachia	126		8,679			82	0.94
North Carolina	40	46		1.50	0.65	26	1.41
Tennessee	55	77		1.50	0.65	36	0.84
Kentucky	31	84		1.50	0.65	20	0.77
Southeast	48		1,464			21	1.44
Georgia	40	30		1.50	0.44	18	1.46
South Carolina	8	33		1.50	0.44	3	1.33
Alabama	22		990			10	0.97
Alabama	22	45		1.50	0.44	10	0.97
Total, All Regions	9,079		620,333			5,599	0.90

Source: (*10*)

Table 4--Barley: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Lake States	893		55,680			618	1.11
Minnesota	800	63		1.50	0.69	553	1.10
Wisconsin	50	54		1.50	0.69	35	1.28
Michigan	43	60		1.50	0.69	30	1.15
Northern Plains	2,993		156,154			1,200	0.77
North Dakota	2,450	53		1.75	0.39	966	0.74
South Dakota	500	49		1.60	0.43	216	0.88
Nebraska	22	40		1.60	0.43	9	1.08
Kansas	21	44		1.60	0.43	9	0.98
Southern Plains	33		1,305			13	0.99
Texas	16	38		1.70	0.39	6	1.03
Oklahoma	17	41		1.70	0.39	7	0.95
Pacific States	750		45,060			118	0.26
Washington	390	58		1.40	0.16	61	0.27
Oregon	130	70		1.40	0.16	20	0.22
California	230	58		1.40	0.16	36	0.27
Mountain States	2,564		144,745			501	0.35
Idaho	780	72		1.40	0.19	150	0.27
Wyoming	125	74		1.50	0.18	23	0.24
Montana	1,380	41		1.40	0.19	266	0.47
Nevada	9	75		1.40	0.19	2	0.26
Utah	105	81		1.40	0.19	20	0.24
Colorado	150	80		1.10	0.25	37	0.31
Arizona	15	105		1.40	0.19	3	0.18

Continued--

Table 4--Barley: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Northeast	156		10,271			128	1.27
Pennsylvania	60	69		1.40	0.82	49	1.19
Maryland	63	68		1.40	0.82	52	1.21
New Jersey	6	62		1.40	0.82	5	1.32
Delaware	27	70		1.40	0.82	22	1.17
Appalachia	127		8,305			99	1.19
North Carolina	30	53		1.40	0.70	21	1.31
Kentucky	17	60		1.40	0.70	12	1.16
Virginia	80	66		1.40	0.82	66	1.24
Southeast	13		676			6	0.90
South Carolina	13	52		1.40	0.47	6	0.90
Total, All Regions	7,529		422,196			2,682	0.64

Source: (*10*)

Table 5--Oats: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Corn Belt	1,112		75,516			2,136	2.83
Iowa	600	68		0.60	1.92	1,153	2.82
Missouri	42	53		0.60	1.92	81	3.62
Indiana	70	69		0.60	1.92	134	2.78
Illinois	170	68		0.60	1.92	327	2.82
Ohio	230	70		0.60	1.92	442	2.74
Lake States	1,665		108,800			2,361	2.17
Minnesota	730	66		0.90	1.15	842	1.75
Wisconsin	710	67		0.70	1.48	1,052	2.21
Michigan	225	58		0.50	2.08	467	3.58
Northern Plains	1,950		103,840			1,023	0.99
North Dakota	600	51		1.35	0.51	307	1.00
South Dakota	950	56		1.30	0.53	504	0.95
Nebraska	280	48		1.30	0.53	149	1.11
Kansas	120	55		1.30	0.53	64	0.97
Southern Plains	285		11,505			171	1.49
Texas	225	41		1.10	0.60	136	1.47
Oklahoma	60	38		1.13	0.59	35	1.55
Delta States	45		2,700			39	1.43
Arkansas	45	60		1.00	0.86	39	1.43
Pacific States	130		10,605			29	0.27
Washington	40	66		1.00	0.22	9	0.33
Oregon	45	102		1.00	0.22	10	0.22
California	45	75		1.00	0.22	10	0.29

Continued--

Table 5--Oats: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Mountain States	192		9,386			58	0.62
Idaho	30	66		1.00	0.27	8	0.41
Wyoming	35	44		1.00	0.27	9	0.61
Montana	70	40		1.00	0.27	19	0.68
Utah	12	68		1.10	0.25	3	0.36
Colorado	45	50		0.65	0.42	19	0.83
Northeast	423		31,876			811	2.54
Maine	31	65		0.60	1.92	59	2.95
New York	135	61		0.60	1.92	259	3.14
Pennsylvania	240	86		0.60	1.92	460	2.23
Maryland	17	58		0.60	1.92	33	3.30
Appalachia	46		2,782			45	1.61
North Carolina	40	61		1.00	0.98	39	1.60
West Virginia	6	57		1.00	0.98	6	1.71
Southeast	72		4,064			47	1.16
Georgia	40	56		1.00	0.66	26	1.17
South Carolina	32	57		1.00	0.66	21	1.15
Alabama	25		1,250			19	1.52
Alabama	25	50		1.00	0.76	19	1.52
Total, All Regions	5,945		362,324			6,739	1.86

Source: (*10*)

Table 6--Wheat: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Corn Belt	5,060		244,425			3,953	1.62
Iowa	75	45		1.30	0.89	66	1.97
Missouri	520	38		1.30	0.89	461	2.33
Indiana	970	52		1.30	0.89	860	1.70
Illinois	1,900	48		1.60	0.72	1,369	1.50
Ohio	1,350	59		1.30	0.89	1,197	1.50
Lake States	3,807		189,996			2,149	1.13
Minnesota	2,865	48		2.40	0.43	1,239	0.89
Wisconsin	192	53		1.50	0.69	133	1.32
Michigan	750	55		1.00	1.04	778	1.89
Northern Plains	28,749		1,070,691			14,613	1.36
North Dakota	10,910	35		2.50	0.46	5,030	1.31
South Dakota	3,789	34		2.50	0.46	1,747	1.36
Nebraska	2,250	38		2.50	0.46	1,037	1.21
Kansas	11,800	40		2.00	0.58	6,800	1.44
Southern Plains	10,500		331,800			3,661	1.10
Texas	4,200	31		2.00	0.33	1,397	1.07
Oklahoma	6,300	32		1.85	0.36	2,265	1.12
Delta States	2,310		87,038			990	1.14
Louisiana	390	33		2.00	0.43	167	1.30
Mississippi	520	48		2.00	0.43	223	0.89
Arkansas	1,400	35		2.00	0.43	600	1.23
Pacific States	4,062		255,405			560	0.22
Washington	2,480	61		1.50	0.15	364	0.24
Oregon	968	60		1.50	0.15	142	0.25
California	614	78		2.50	0.09	54	0.11

Continued--

Table 6--Wheat: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per bushel	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Bu.	Thousand bu.	Lbs.	Bu.	Thousand bu.	Percent
Mountain States	9,969		364,182			1,878	0.52
Idaho	1,370	73		1.50	0.18	247	0.25
Wyoming	211	29		1.70	0.16	34	0.55
Montana	5,185	28		1.50	0.18	933	0.64
Nevada	14	38		1.50	0.18	3	0.47
Utah	176	41		1.80	0.15	26	0.37
Colorado	2,590	34		1.25	0.22	559	0.64
Arizona	98	95		1.50	0.18	18	0.19
New Mexico	325	27		1.50	0.18	59	0.67
Northeast	634		31,792			487	1.53
New York	145	49		1.50	0.77	111	1.56
Pennsylvania	210	50		1.50	0.77	161	1.54
Maryland	190	52		1.50	0.77	146	1.48
New Jersey	29	43		1.50	0.77	22	1.79
Delaware	60	51		1.50	0.77	46	1.51
Appalachia	1,812		72,962			957	1.31
North Carolina	550	41		2.00	0.49	268	1.19
West Virginia	12	46		2.00	0.49	6	1.06
Tennessee	490	36		2.00	0.49	239	1.35
Kentucky	500	40		2.00	0.49	244	1.22
Virginia	260	47		1.50	0.77	200	1.63
Southeast	1,025		36,905			270	0.73
Florida	55	33		2.50	0.26	14	0.80
Georgia	590	35		2.50	0.26	155	0.75
South Carolina	380	38		2.50	0.26	100	0.69
Alabama	190		6,650			72	1.09
Alabama	190	35		2.00	0.38	72	1.09
Total, All Regions	70,340		2,691,846			29,590	1.10

Source: (*10*)

Table 7--Cotton: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per pound	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Lb.	Thousand lb.	Lbs.	Lb.	Thousand lb.	Percent
Corn Belt	235		150,635			2,708	1.80
Missouri	235	641		0.10	11.53	2,708	1.80
Northern Plains	1		336			8	2.46
Kansas	1	280		0.10	6.90	8	2.46
Southern Plains	5,427		2,605,823			35,679	1.37
Texas	5,057	479		0.10	6.65	33,629	1.39
Oklahoma	370	496		0.12	5.54	2,050	1.12
Delta States	2,761		1,972,738			23,676	1.20
Louisiana	790	715		0.10	8.58	6,774	1.20
Mississippi	1,221	728		0.10	8.58	10,470	1.18
Arkansas	750	692		0.10	8.58	6,431	1.24
Pacific States	1,116		1,339,716			2,454	0.18
California	1,116	1201		0.10	2.20	2,454	0.18
Mountain States	553		539,782			1,518	0.28
Arizona	472	1022		0.10	2.70	1,274	0.26
New Mexico	81	706		0.09	3.00	244	0.42
Appalachia	720		366,594			7,032	1.92
North Carolina	200	631		0.10	9.75	1,950	1.55
Tennessee	515	461		0.10	9.75	5,021	2.11
Virginia	5	562		0.10	11.50	61	2.05

Continued--

Table 7--Cotton: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per pound	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Lb.	Thousand lb.	Lbs.	Lb.	Thousand lb.	Percent
Southeast	540		286,898			3,550	1.24
Florida	36	640		0.10	6.58	237	1.03
Georgia	350	555		0.10	6.58	2,301	1.18
South Carolina	154	452		0.10	6.58	1,013	1.45
Alabama	378		179,928			2,873	1.60
Alabama	378	476		0.10	7.60	2,873	1.60
Total, All Regions	11,731		7,442,449			79,499	1.07

Source: (*10*)

Table 8--Hay, non-legume: Decrease in yield per acre and production if there were no nitrogen in rainfall

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per ton	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Tons	Thousand tons	Lbs.	Tons	Thousand tons	Percent
Corn Belt	4,640		8,891			534.76	6.01
Iowa	300	2.4		10	0.12	34.58	4.80
Missouri	3,100	1.7		10	0.12	357.28	6.98
Indiana	300	2.2		10	0.12	34.58	5.24
Illinois	240	2.4		10	0.12	27.66	4.80
Ohio	700	2.6		10	0.12	80.68	4.43
Lake States	1,400		2,620			121.04	4.62
Minnesota	800	1.8		12	0.09	69.17	4.80
Wisconsin	400	1.8		12	0.09	34.58	4.80
Michigan	200	2.3		12	0.09	17.29	3.76
Northern Plains	8,100		10,205			223.56	2.19
North Dakota	2,100	1.1		25	0.03	57.96	2.63
South Dakota	2,100	1.2		25	0.03	57.96	2.30
Nebraska	2,200	1.1		25	0.03	60.72	2.51
Kansas	1,700	1.8		25	0.03	46.92	1.53
Southern Plains	5,500		10,150			60.96	0.60
Texas	3,800	2.0		60	0.01	42.12	0.55
Oklahoma	1,700	1.5		60	0.01	18.84	0.74
Delta States	1,825		3,358			26.08	0.78
Louisiana	300	2.2		60	0.01	4.29	0.65
Mississippi	575	1.8		60	0.01	8.22	0.79
Arkansas	950	1.8		60	0.01	13.58	0.82
Pacific States	1,497		3,131			8.20	0.26
Washington	320	2.5		40	0.01	1.76	0.22
Oregon	600	1.7		40	0.01	3.30	0.32
California	570	2.3		40	0.01	3.14	0.24

Continued--

Table 8--Hay, non-legume: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per ton	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Tons	Thousand tons	Lbs.	Tons	Thousand tons	Percent
Mountain States	2,860		4,281			19.31	0.45
Idaho	170	2.0		40	0.01	1.15	0.34
Wyoming	590	1.2		40	0.01	3.98	0.56
Montana	800	1.4		40	0.01	5.40	0.48
Nevada	250	1.5		40	0.01	1.69	0.45
Utah	140	2.0		40	0.01	0.95	0.34
Colorado	810	1.5		40	0.01	5.47	0.45
Arizona	30	3.9		40	0.01	0.20	0.17
New Mexico	70	1.8		40	0.01	0.47	0.38
Northeast	3,121		6,368			91.64	1.44
Maine	200	1.9		30	0.04	7.67	2.07
New Hampshire	61	2.0		40	0.03	1.75	1.44
Vermont	260	2.0		40	0.03	7.48	1.44
New York	1,120	2.0		40	0.03	32.20	1.47
Connecticut	67	2.2		40	0.03	1.93	1.31
Pennsylvania	1,090	2.1		40	0.03	31.34	1.37
Maryland	145	2.6		40	0.03	4.17	1.13
New Jersey	84	2.0		40	0.03	2.42	1.44
Delaware	15	2.3		40	0.03	0.43	1.25
Rhode Island	5	2.3		40	0.03	0.14	1.25
Massachusetts	74	2.1		40	0.03	2.13	1.40
Appalachia	5,270		10,677			167.46	1.57
North Carolina	440	2.1			0.03	14.30	1.55
West Virginia	500	1.9		30	0.03	16.25	1.71
Tennessee	1,430	2.1		30	0.03	46.48	1.55
Kentucky	1,880	2.0		30	0.03	61.10	1.63
Virginia	1,020	2.0		40	0.03	29.33	1.44

Continued--

Table 8--Hay, non-legume: Decrease in yield per acre and production if there were no nitrogen in rainfall--Continued

Region and State	Harvested acres	Average yield per acre	Production 1990	Nitrogen need per ton	Yield decrease per acre	Total decrease in production	Decrease
	Thousand	Tons	Thousand tons	Lbs.	Tons	Thousand tons	Percent
Southeast	1,050		2,148			17.26	0.80
Florida	240	2.3		40	0.02	3.95	0.71
Georgia	570	2.0		40	0.02	9.37	0.82
South Carolina	240	1.9		40	0.02	3.95	0.87
Alabama	750		1,125			9.50	0.84
Alabama	750	1.5		60	0.01	9.50	0.84
Total, All Regions	36,009		54,062			1,013	1.87

Source: (*10*)

Table 9--Regional average decrease in crop yield if there were no nitrogen in rainfall[1]

Region and crop	Harvested area	Decrease in production	Decrease in yield per acre
	Thousand acres	Thousand bu./lb./ton	Bu./lb./ton
Corn			
Corn Belt	33660	32704	1.0
Lake States	11220	10219	0.9
Northern Plains	12210	7427	0.6
Southern Plains	1538	852	0.6
Delta	399	263	0.7
Mountain	1000	1137	1.1
Pacific	258	47	0.2
Northeast	2287	2182	1.0
Appalachian	3195	2649	0.8
Southeast	945	518	0.5
Alabama	240	152	0.6
Grain sorghum			
Corn Belt	715	687	1.0
Northern Plains	4460	3123	0.7
Southern Plains	2950	1302	0.4
Delta	488	335	0.7
Mountain	270	35	0.1
Appalachian	126	82	0.7
Southeast	48	21	0.4
Alabama	22	10	0.5
Barley			
Lake States	893	618	0.7
Northern Plains	2993	1200	0.4
Southern Plains	33	13	0.4
Mountain	2564	501	0.2
Pacific	750	118	0.2
Northeast	156	128	0.8
Appalachian	127	99	0.8
Southeast	13	6	0.5

Continued--

Table 9--Regional average decrease in crop yield if there were no nitrogen in rainfall[1]--Continued

Region and crop	Harvested area	Decrease in production	Decrease in yield per acre
	Thousand acres	Thousand bu./lb./ton	Bu./lb./ton
Oats			
Corn Belt	1112	2136	1.9
Lake States	1665	2361	1.4
Northern Plains	1950	1023	0.5
Southern Plains	285	171	0.6
Delta	45	39	0.9
Mountain	192	58	0.3
Pacific	130	29	0.2
Northeast	423	811	1.9
Appalachian	46	45	1.0
Southeast	72	47	0.7
Alabama	25	19	0.8
Wheat			
Corn Belt	5060	3953	0.8
Lake States	3807	2149	0.6
Northern Plains	28749	14613	0.5
Southern Plains	10500	3661	0.3
Delta	7000	990	0.1
Mountain	9969	1878	0.2
Pacific	4062	560	0.1
Northeast	634	487	0.8
Appalachian	1812	957	0.5
Southeast	1025	270	0.3
Alabama	190	72	0.4
Cotton			
Corn Belt	235	2708	11.5
Northern Plains	1	8	8.0
Southern Plains	5427	35697	6.6
Delta	2761	23676	8.6
Mountain	553	1518	2.7
Pacific	1116	2454	2.2
Appalachian	720	7032	9.8
Southeast	540	3550	6.6
Alabama	378	2873	7.6

Continued--

Table 9--Regional average decrease in crop yield if there were no nitrogen in rainfall[1]--Continued

Region and crop	Harvested area	Decrease in production	Decrease in yield per acre
	Thousand acres	Thousand bu./lb./ton	Bu./lb./ton
Hay			
Corn Belt	4640	534.76	0.12
Lake States	1400	121.04	0.09
Northern Plains	8100	223.56	0.03
Southern Plains	5500	60.96	0.01
Delta	1825	26.08	0.01
Mountain	2860	19.31	0.01
Pacific	1497	8.2	0.01
Northeast	3121	91.64	0.03
Appalachian	5270	167.46	0.03
Southeast	1050	17.26	0.02
Alabama	750	10	0.01

[1] Regional average crop yield decreases per acre are calculated from tables 2-8. The regional average decreases per acre are then entered to the AGSIM model.

Table 10--Calculation of cumulative government program payments for selected crops AGSIM baseline and reduced N scenario projections

Year	Baseline	Reduced N scenario
	Dollars (000)	
1991	4,188,008	4,188,008
1992	6,452,686	6,452,686
Scenario begins:		
1993	3,009,022	2,699,820
1994	3,608,726	3,288,226
1995	3,593,610	3,267,741
1996	3,063,123	2,741,448
1997	2,539,280	2,233,340
1998	1,876,760	1,583,532
1999	1,254,508	983,462
2000	707,031	486,163
Total, 1993-2000	19,652,060	17,283,732
Difference, baseline total-reduced N scenario total, 1993-2000		2,368,328

Source: AGSIM United States runs: Baseline, and reduced N scenario, 1993.

Note: Contact the first author, now retired, Joseph R. Barse, ERS/USDA, Room 424, 1301 New York Ave., N.W., Washington, DC 20005-4788, for a copy of the 71-page data tables of the AGSIM econometric model by C. Robert Taylor on which this report is based.

Figure 1

Farm Production Regions

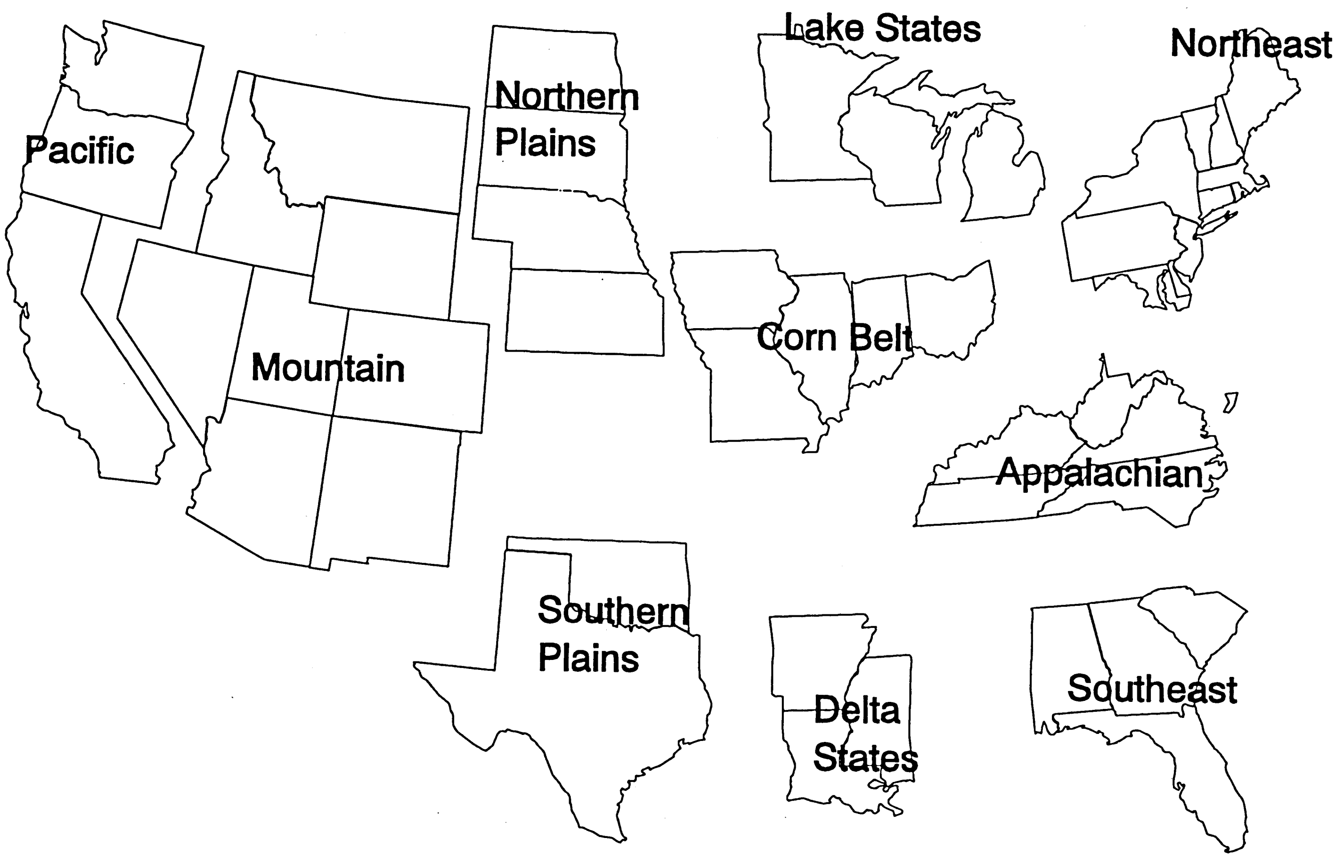
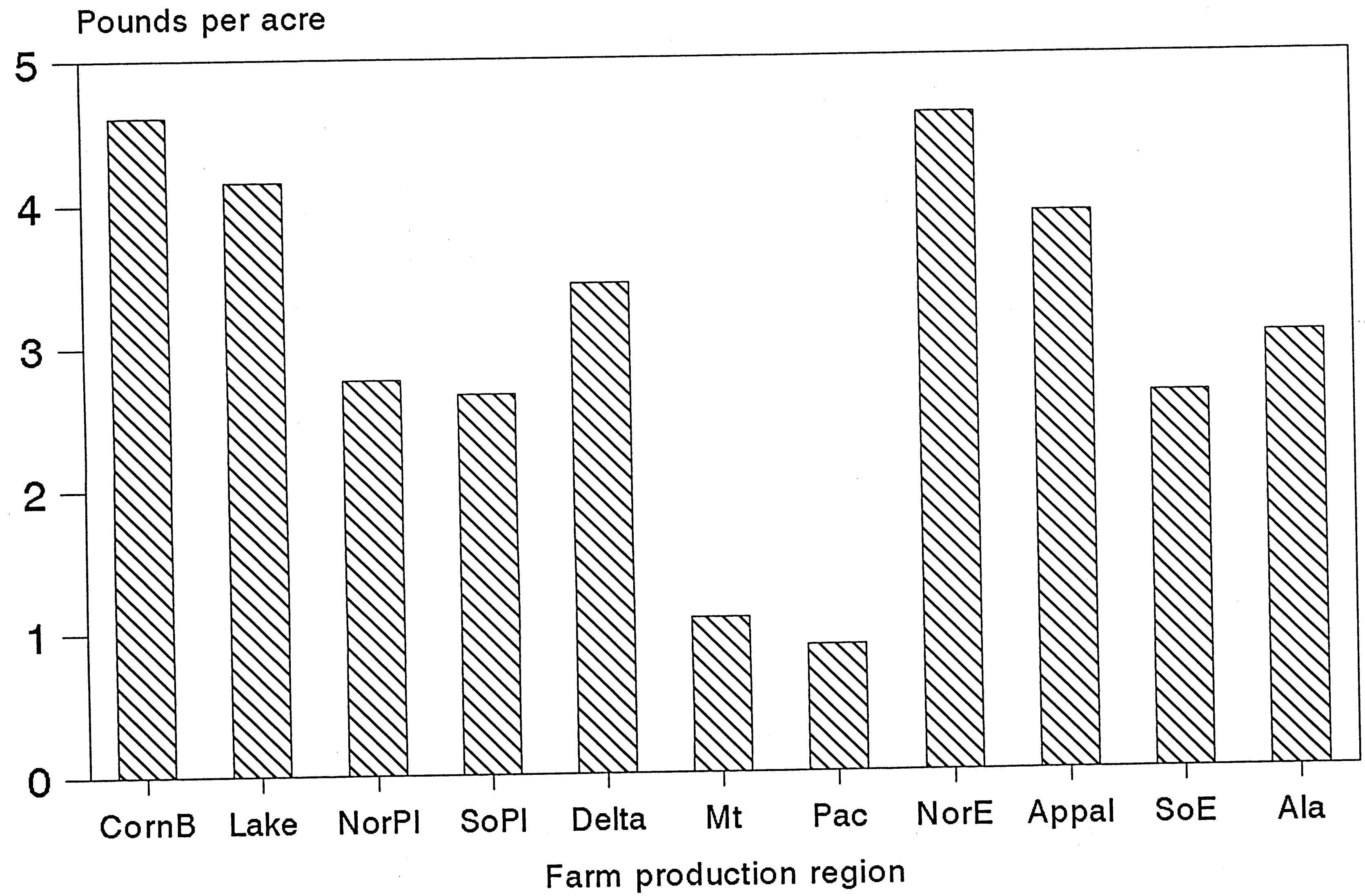


Figure 2
Nitrogen in rainfall, annual average, 1985-87



Pure N equivalents from NH4 and NO3.

Pure N equivalents from NH4 and NO3.

Figure 3
Projected crop acreages, 1991-2000, AGSIM baseline

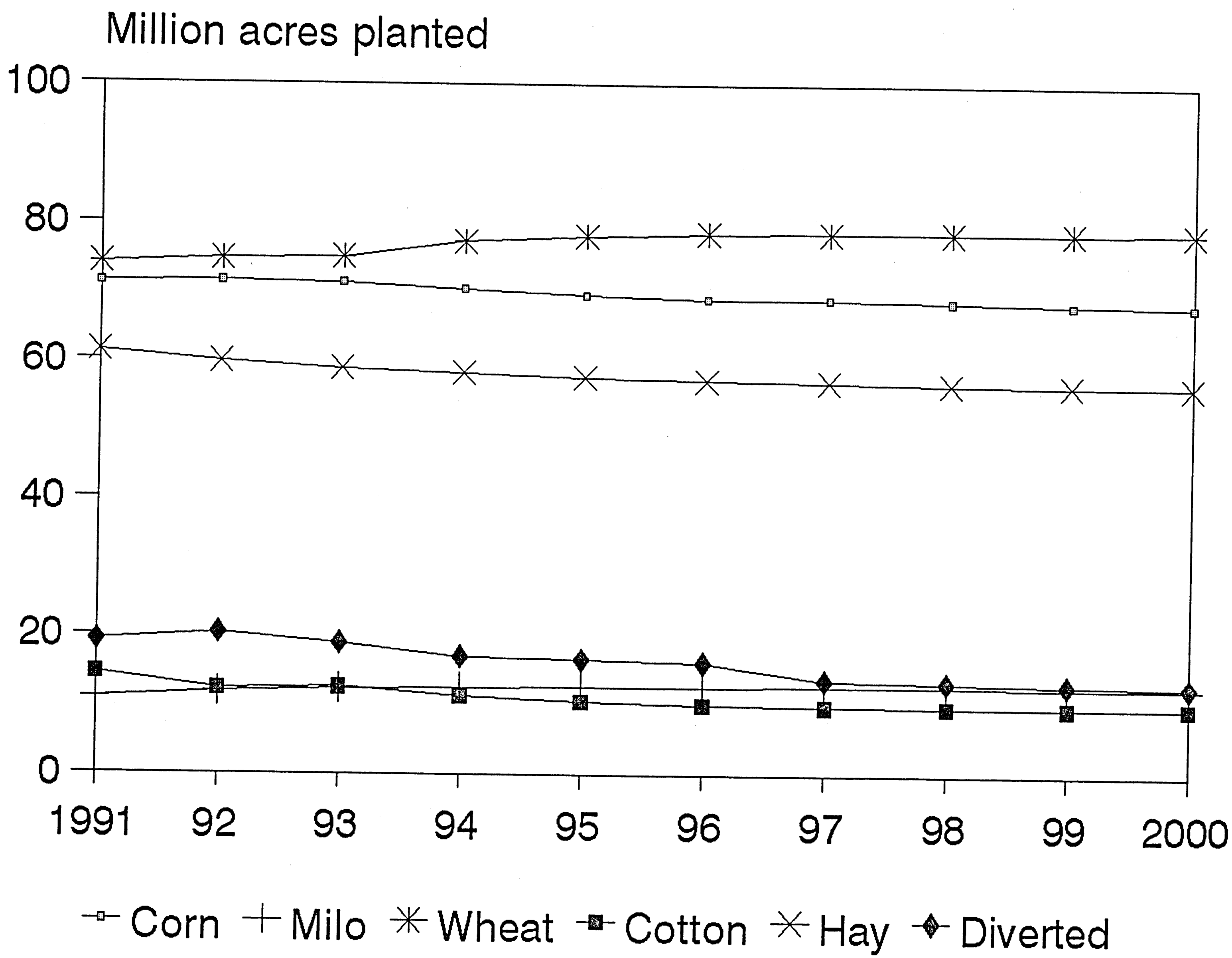
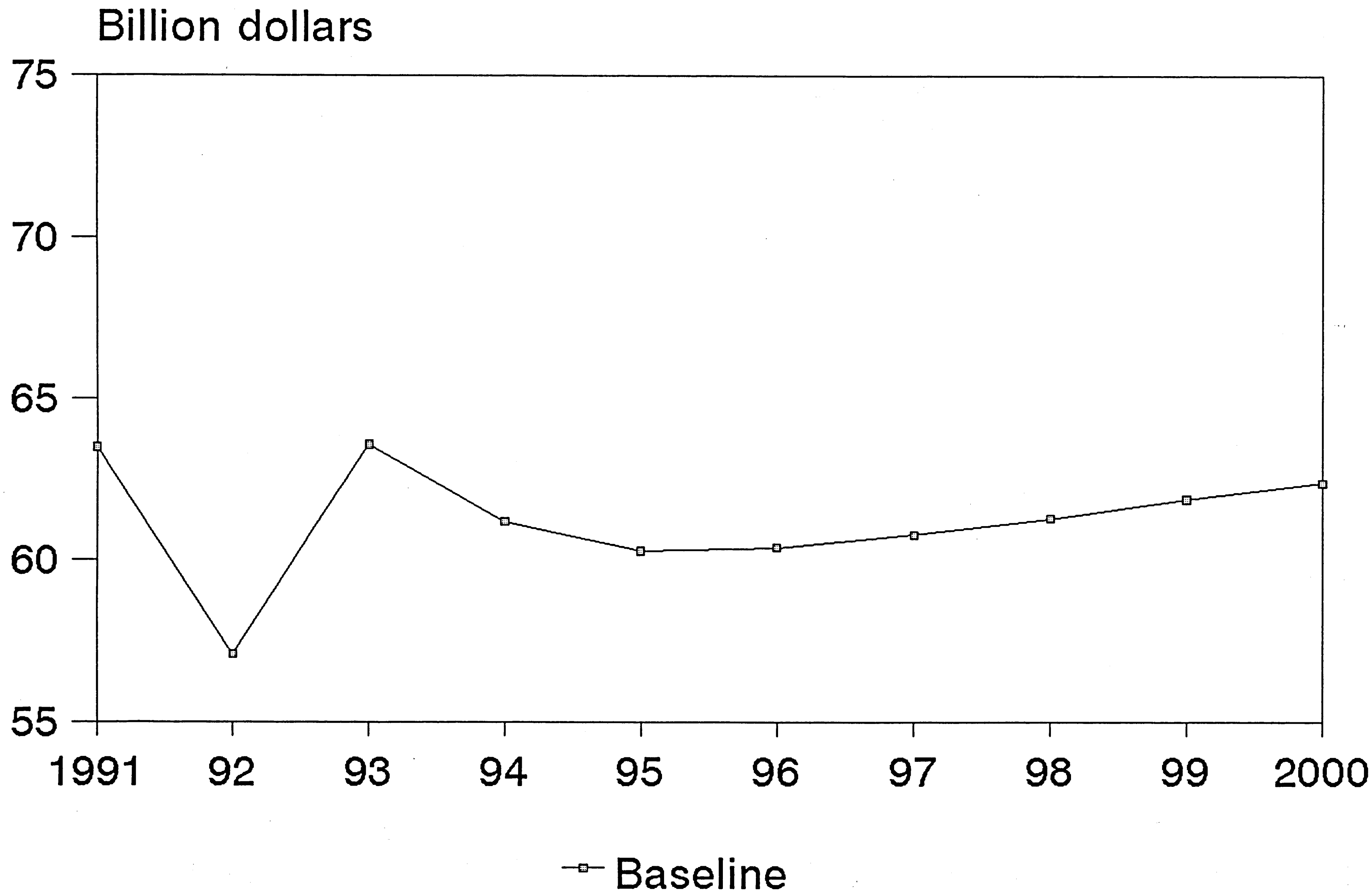


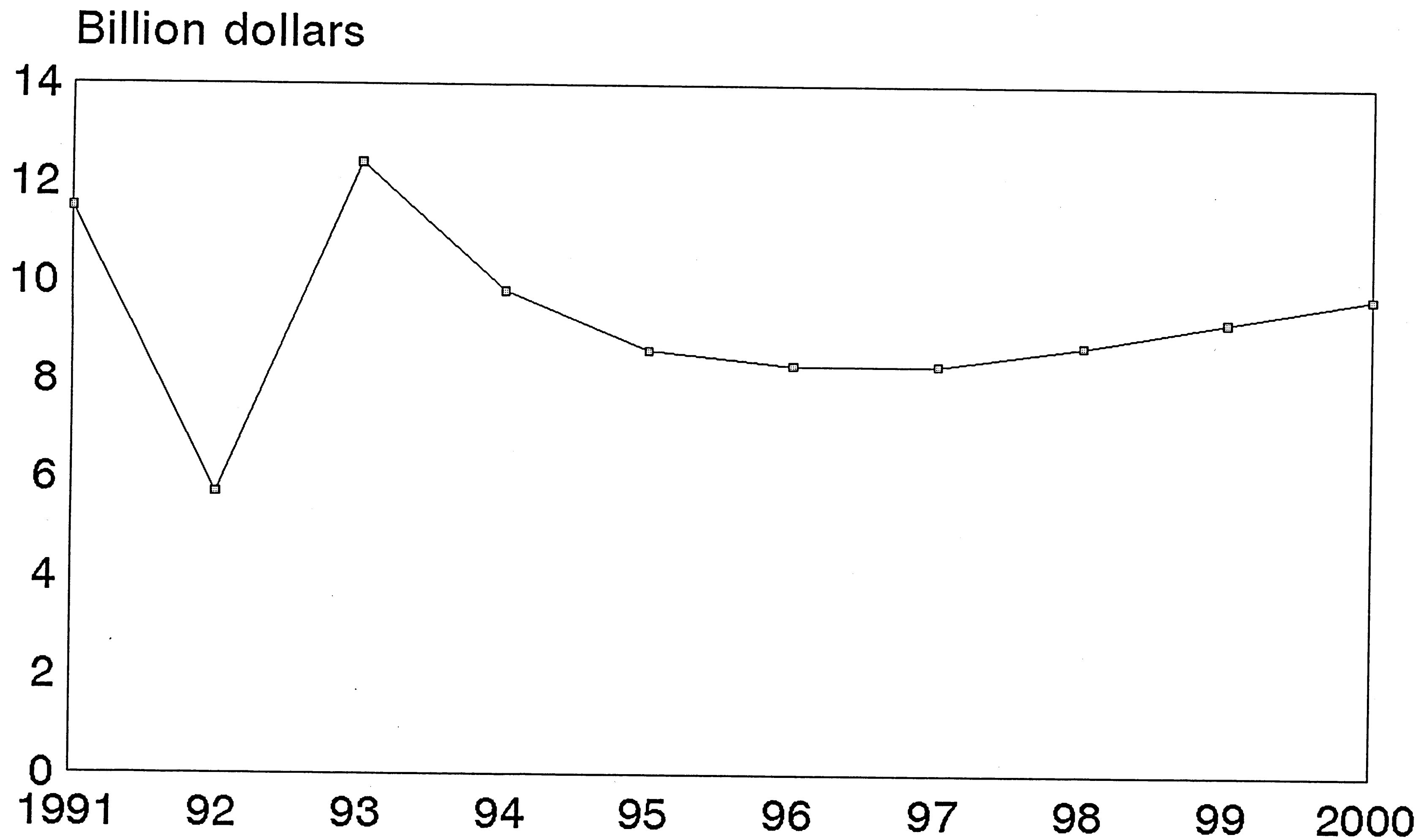
Figure 4
Eight-crop gross receipts, baseline 1991-2000



Valued at constant prices.

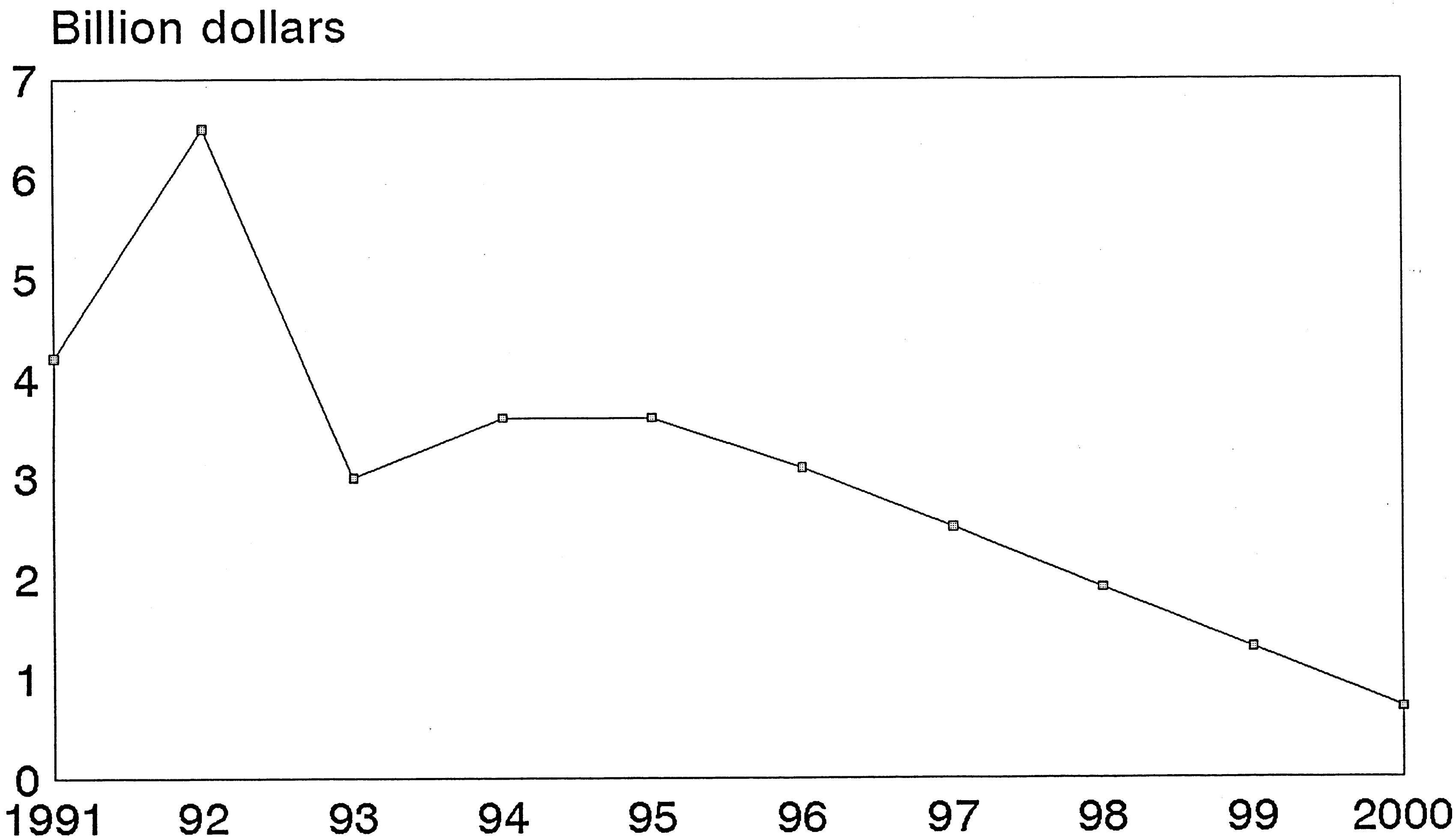
Valued at constant prices.

Figure 5
Projected net farm income from eight crops before government payments, 1991-2000, AGSIM baseline



Valued at constant prices.

Figure 6
Projected Government payments to farmers, eight crops, 1991-2000, AGSIM baseline



Valued at constant prices.

Valued at constant prices.

Figure 7
Net farm income from livestock, AGSIM baseline projections, 1991-2000

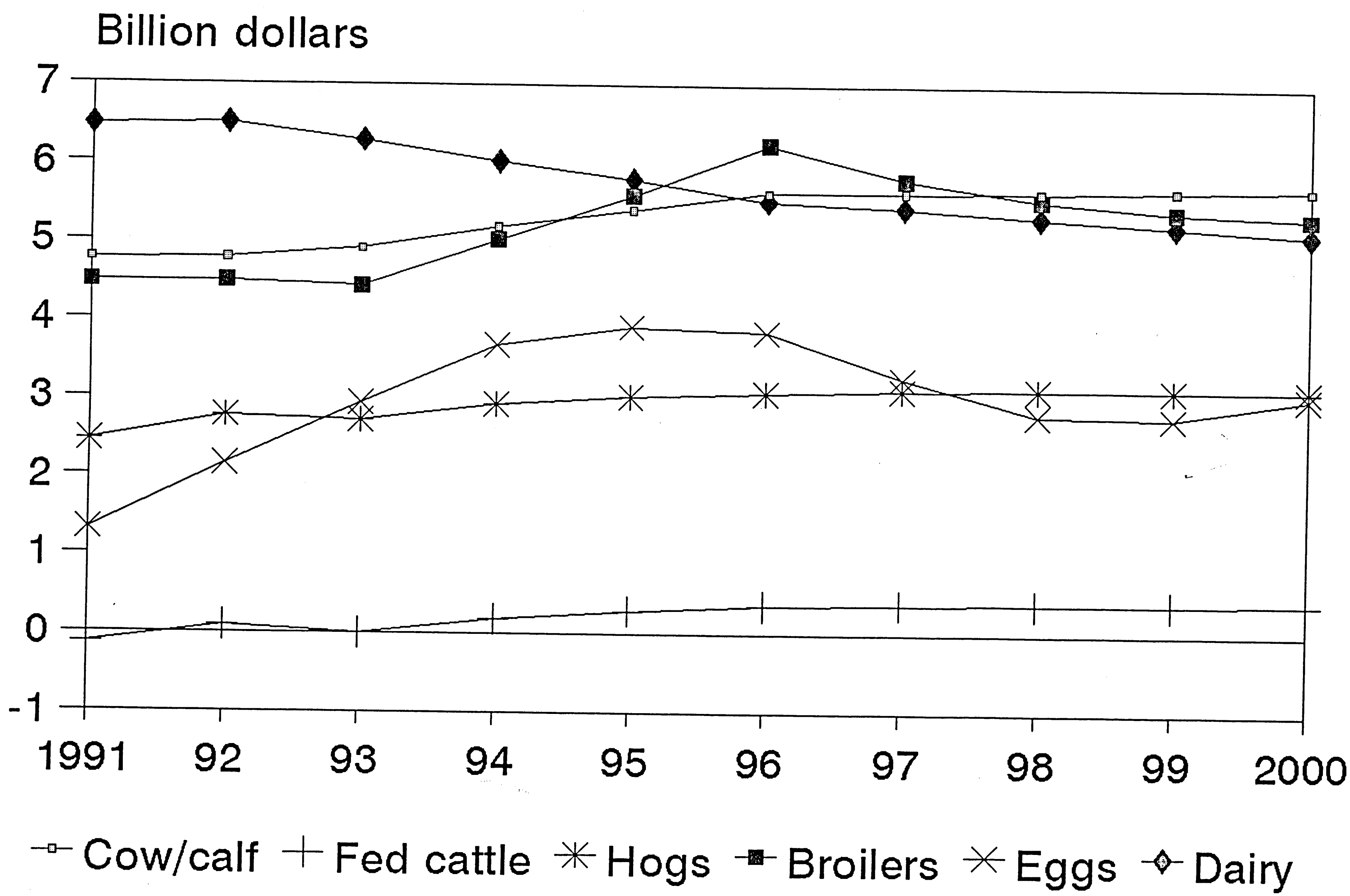


Figure 8
Trendline corn yields, 1993-2000,
AGSIM baseline scenario versus reduced N scenario

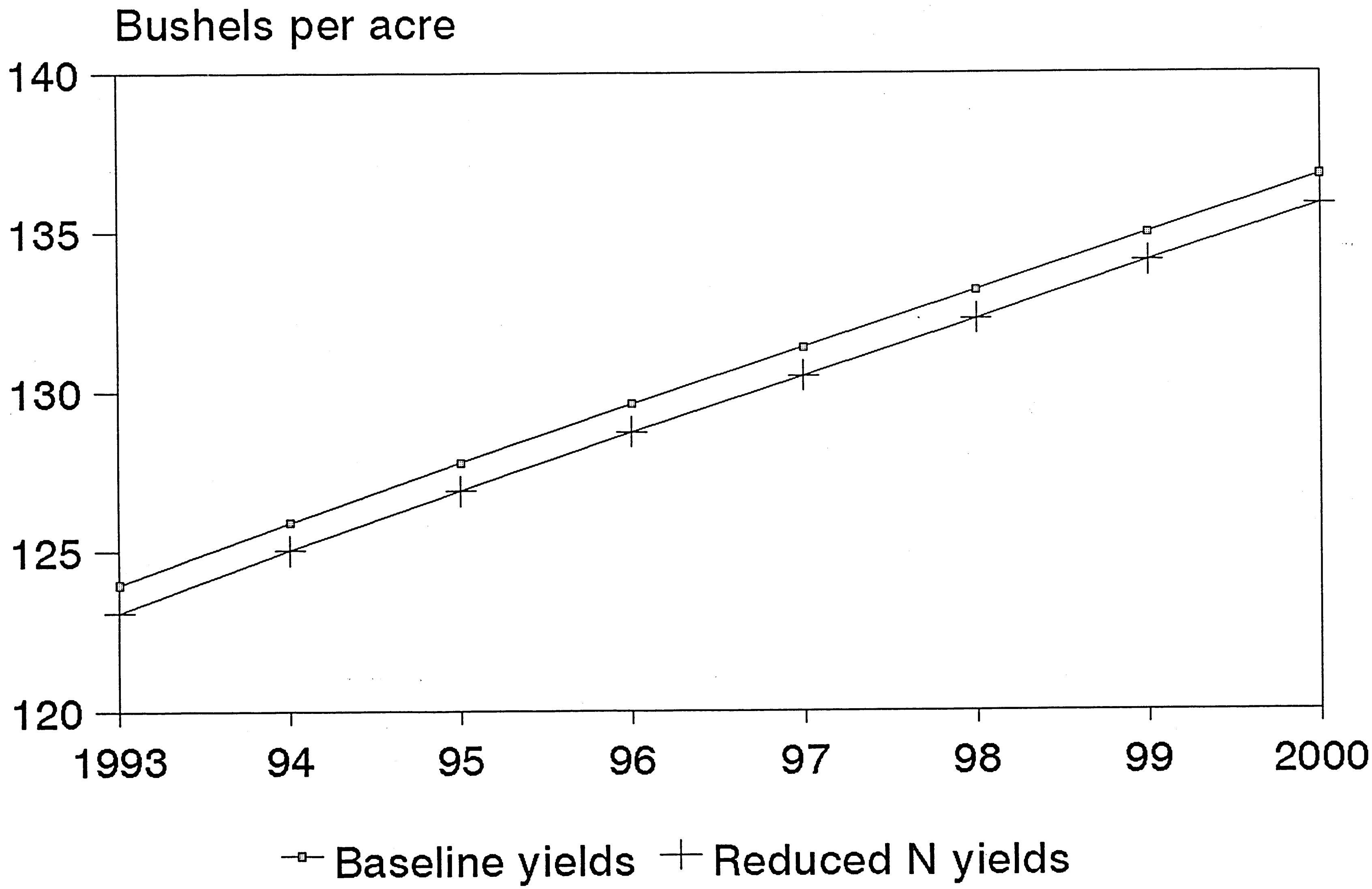
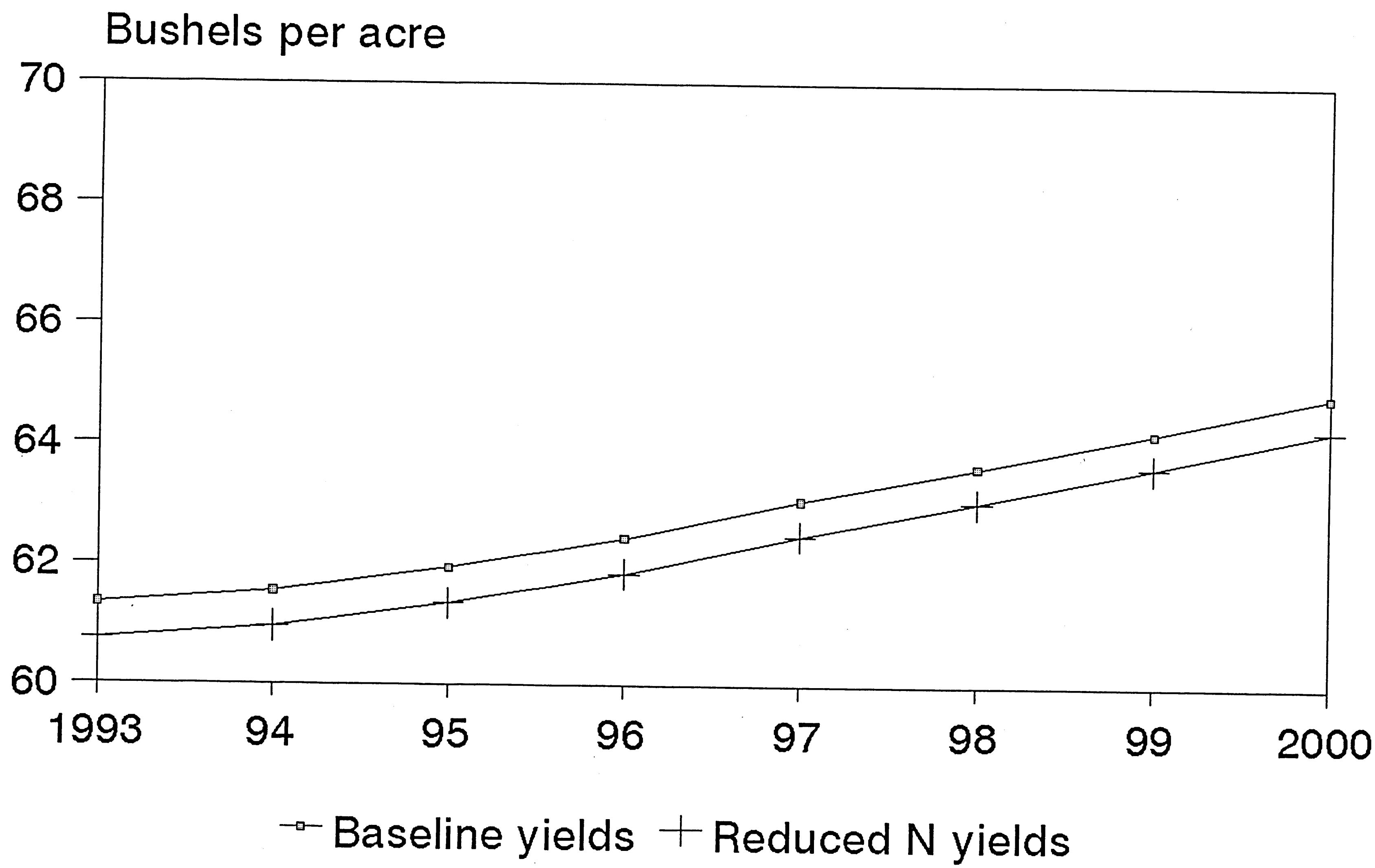


Figure 9
Trendline milo yields, 1993-2000, AGSIM baseline scenario versus reduced N scenario



Also includes other grain sorghums.

Figure 10
Trendline barley yields, 1993-2000, AGSIM baseline scenario versus reduced N scenario

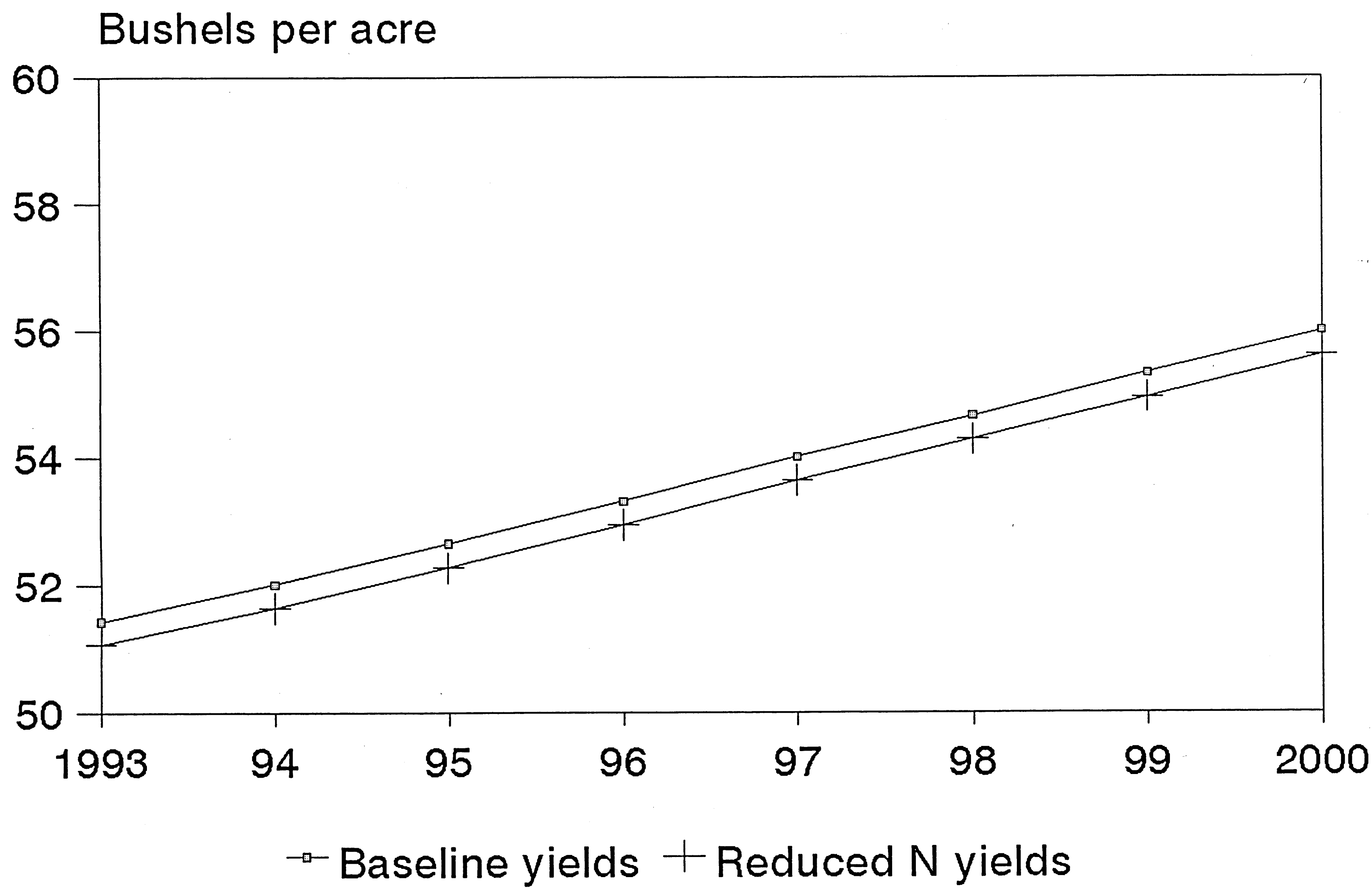


Figure 11

Figure 11
Trendline oats yields, 1993-2000,
AGSIM baseline scenario versus reduced N scenario

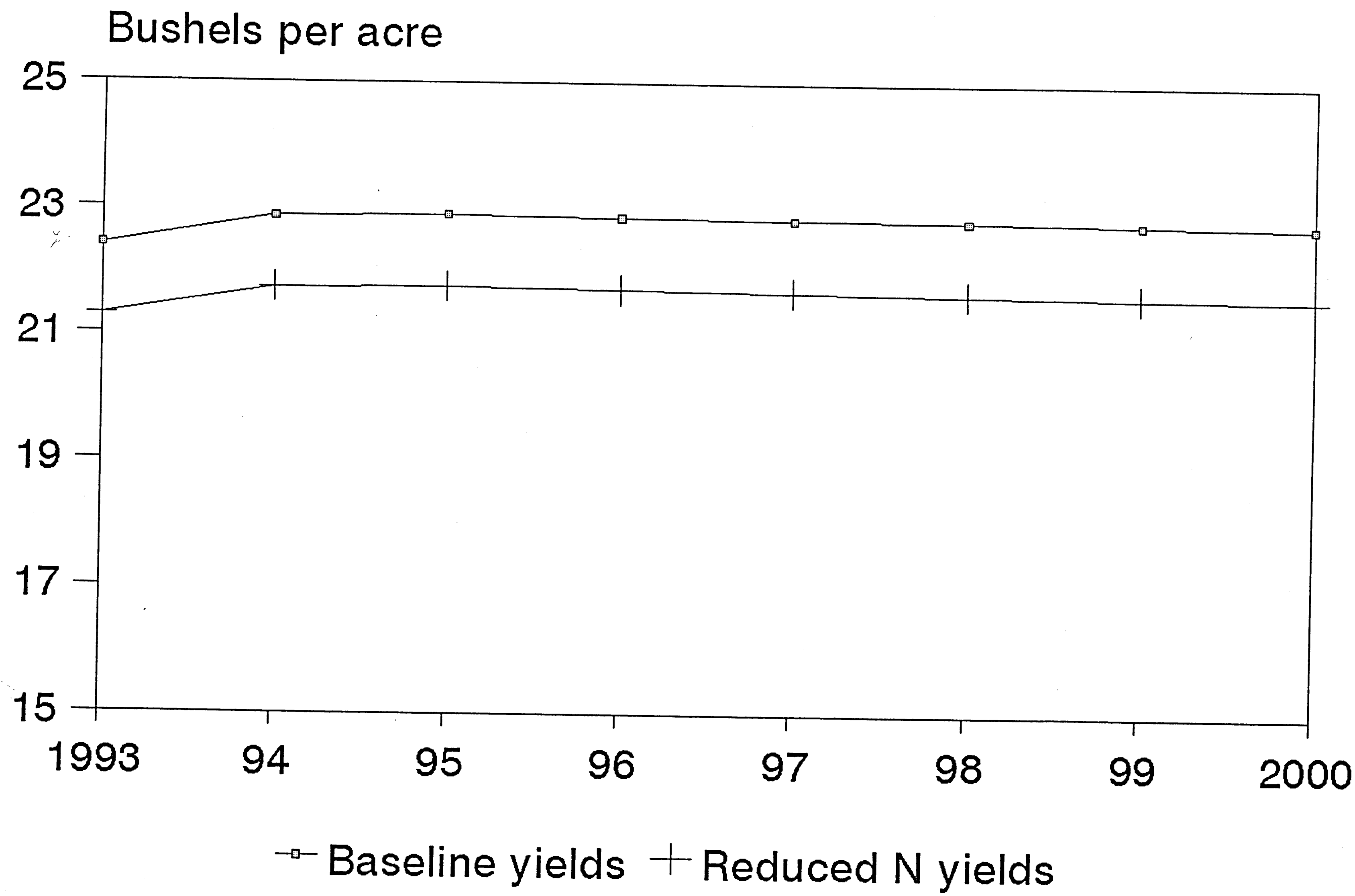


Figure 12
Trendline wheat yields, 1993-2000, AGSIM baseline scenario versus reduced N scenario

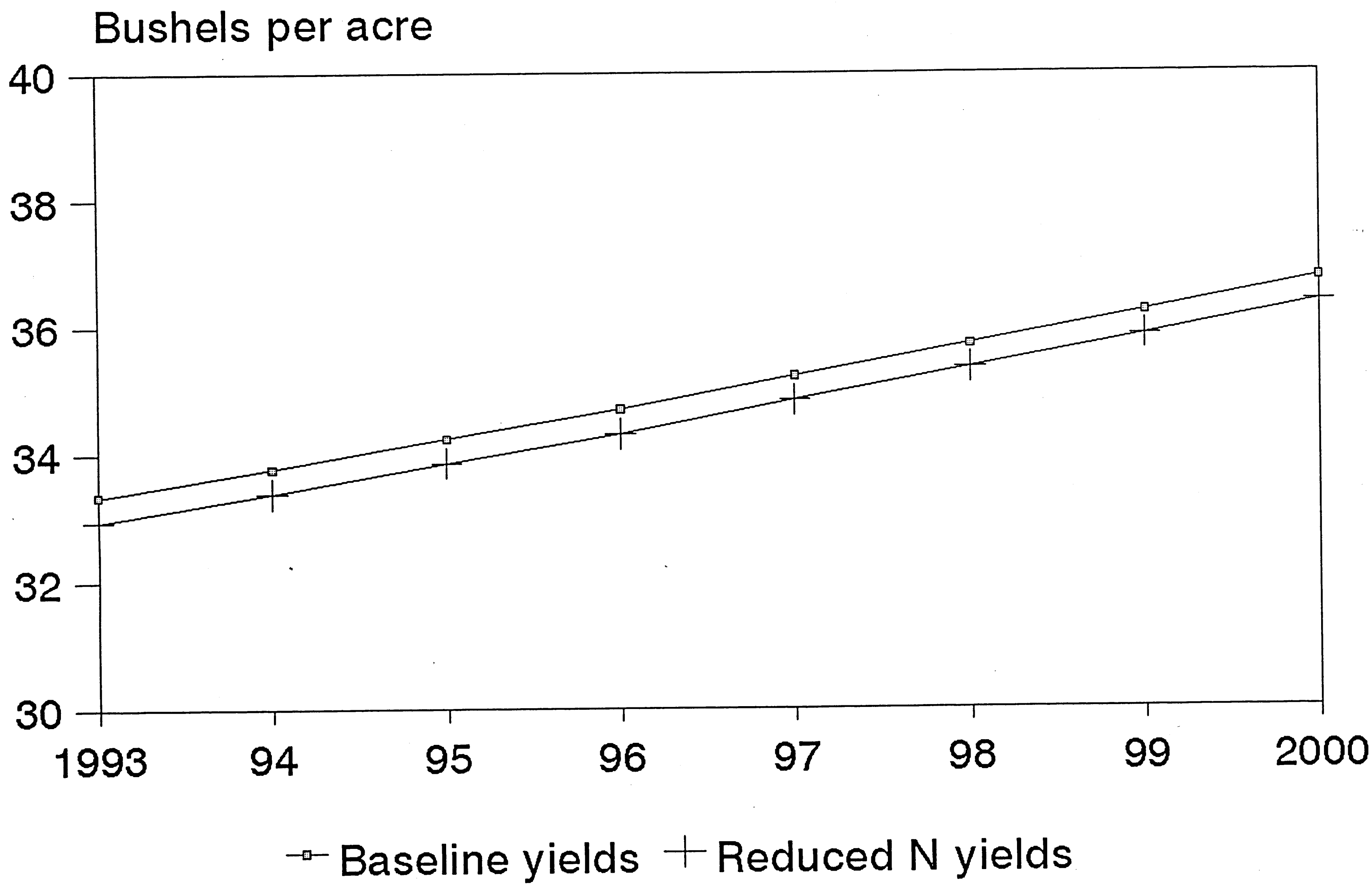


Figure 13

Figure 13
Trendline cotton yields, 1993-2000, AGSIM baseline scenario versus reduced N scenario

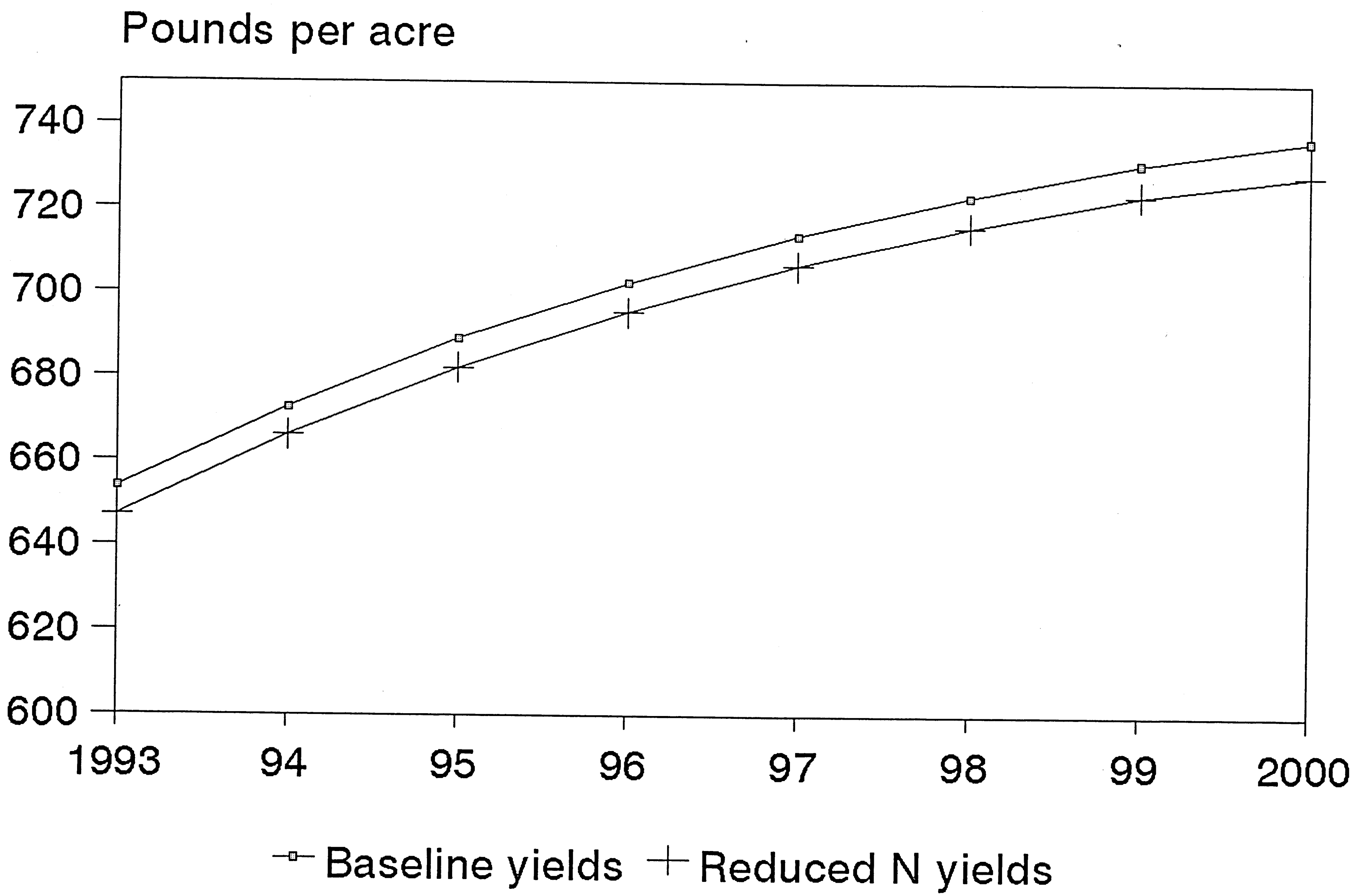


Figure 14
Trendline hay yields, 1993-2000,
AGSIM baseline scenario versus reduced N scenario

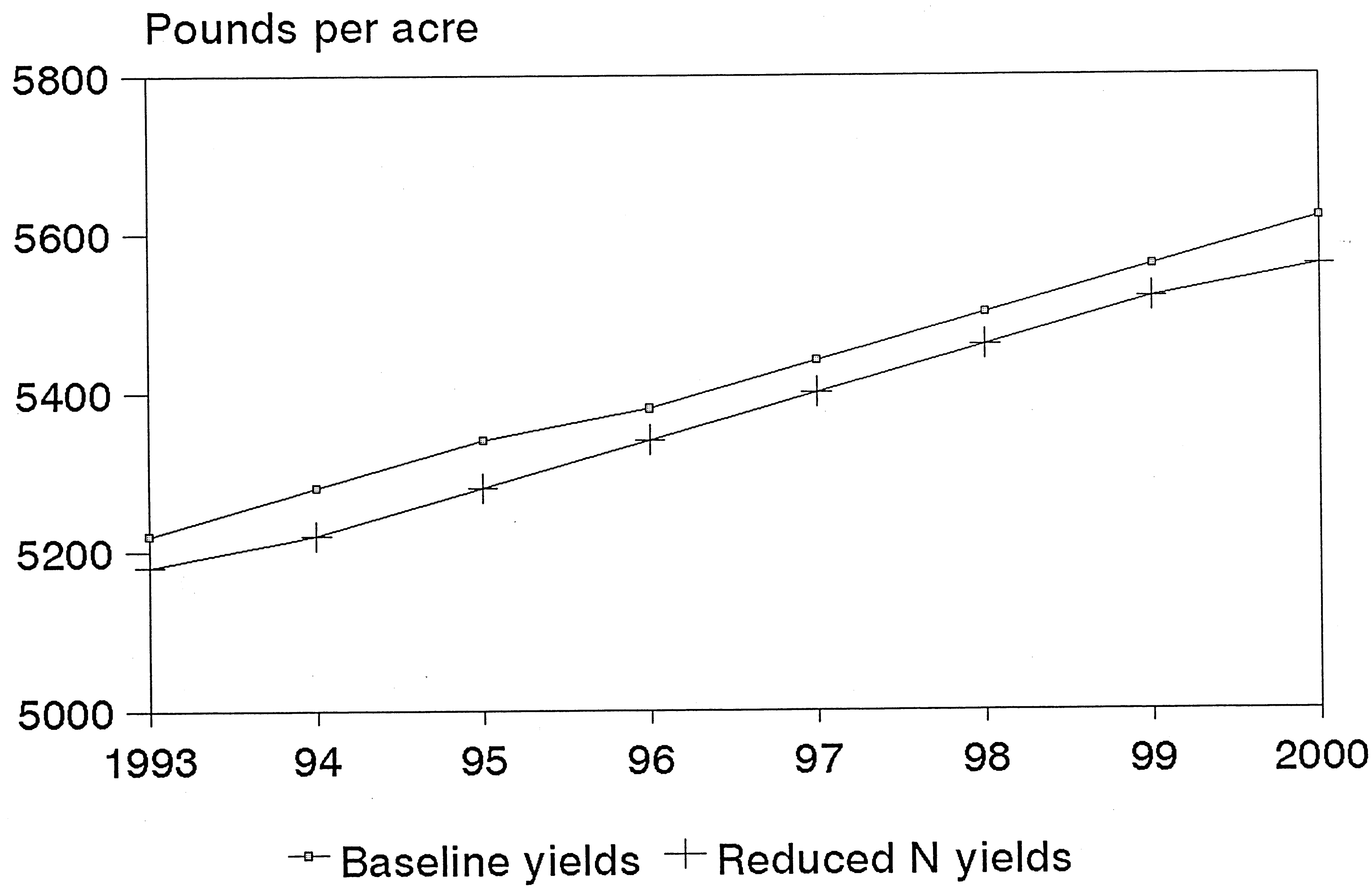


Figure 15

Figure 15
Change in projection for total crop acreage, 1993-2000, resulting from reduced N scenario

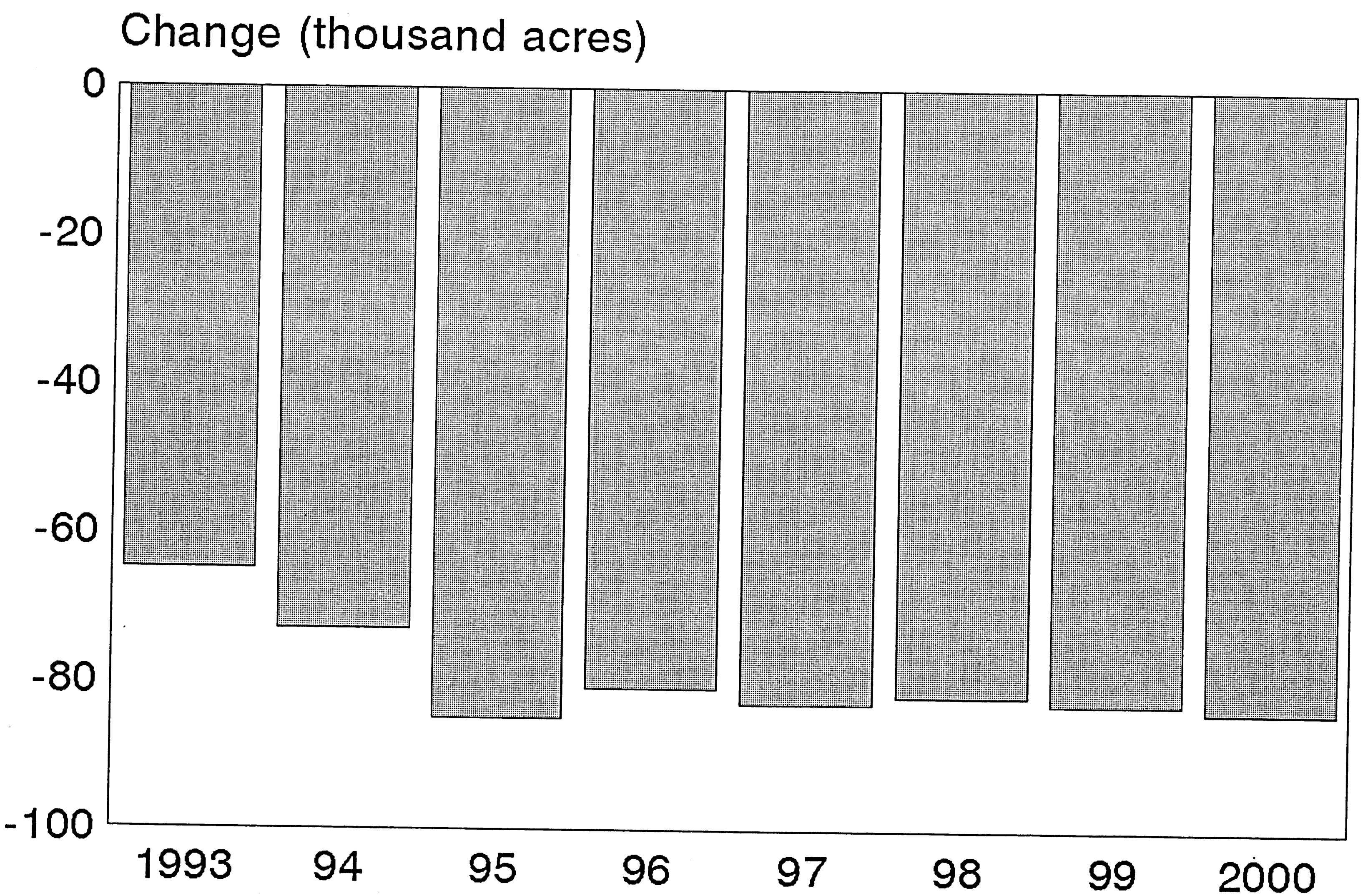
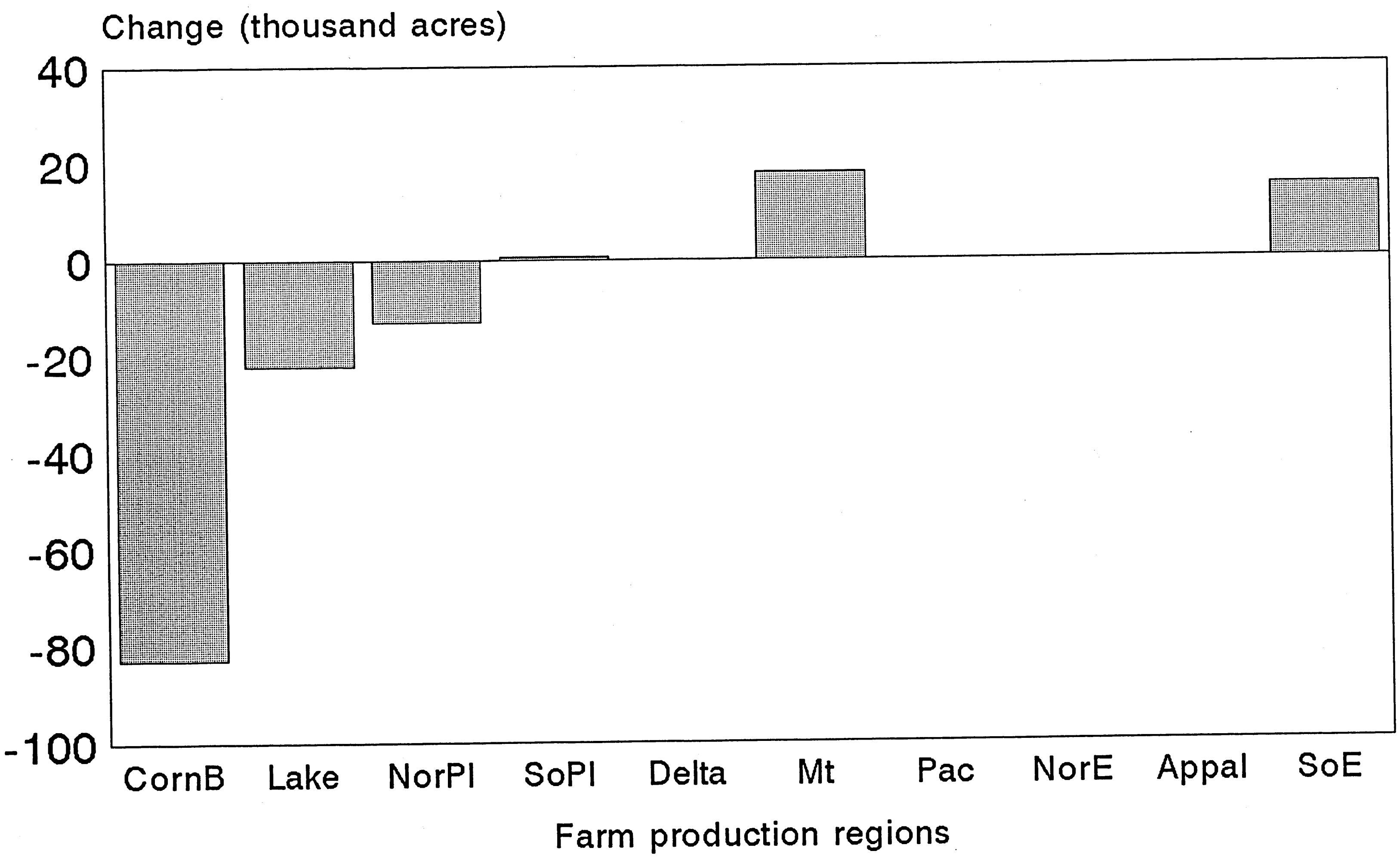


Figure 16
Change in projection for regional crop acreage, year 2000, resulting from reduced N scenario



Total, eight crops plus fallow and diverted.
SoE includes Alabama.

Figure 17

SoE includes Alabama.

Figure 17
Change in projection for corn, wheat, and cotton acreage, 1993-2000, resulting from reduced N scenario

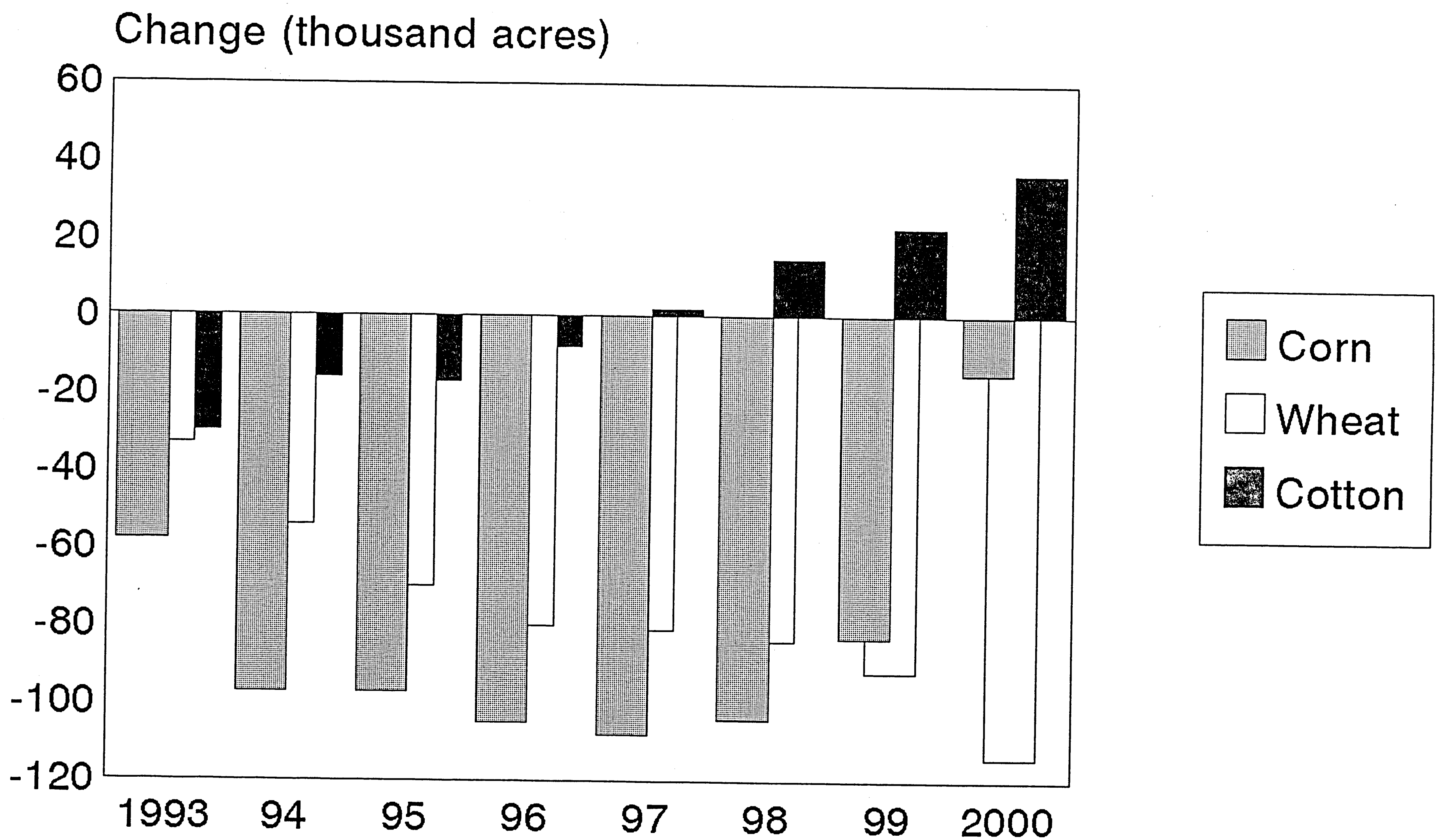


Figure 18
Corn: Projected production and prices, 1993-2000, baseline scenario versus reduced N scenario

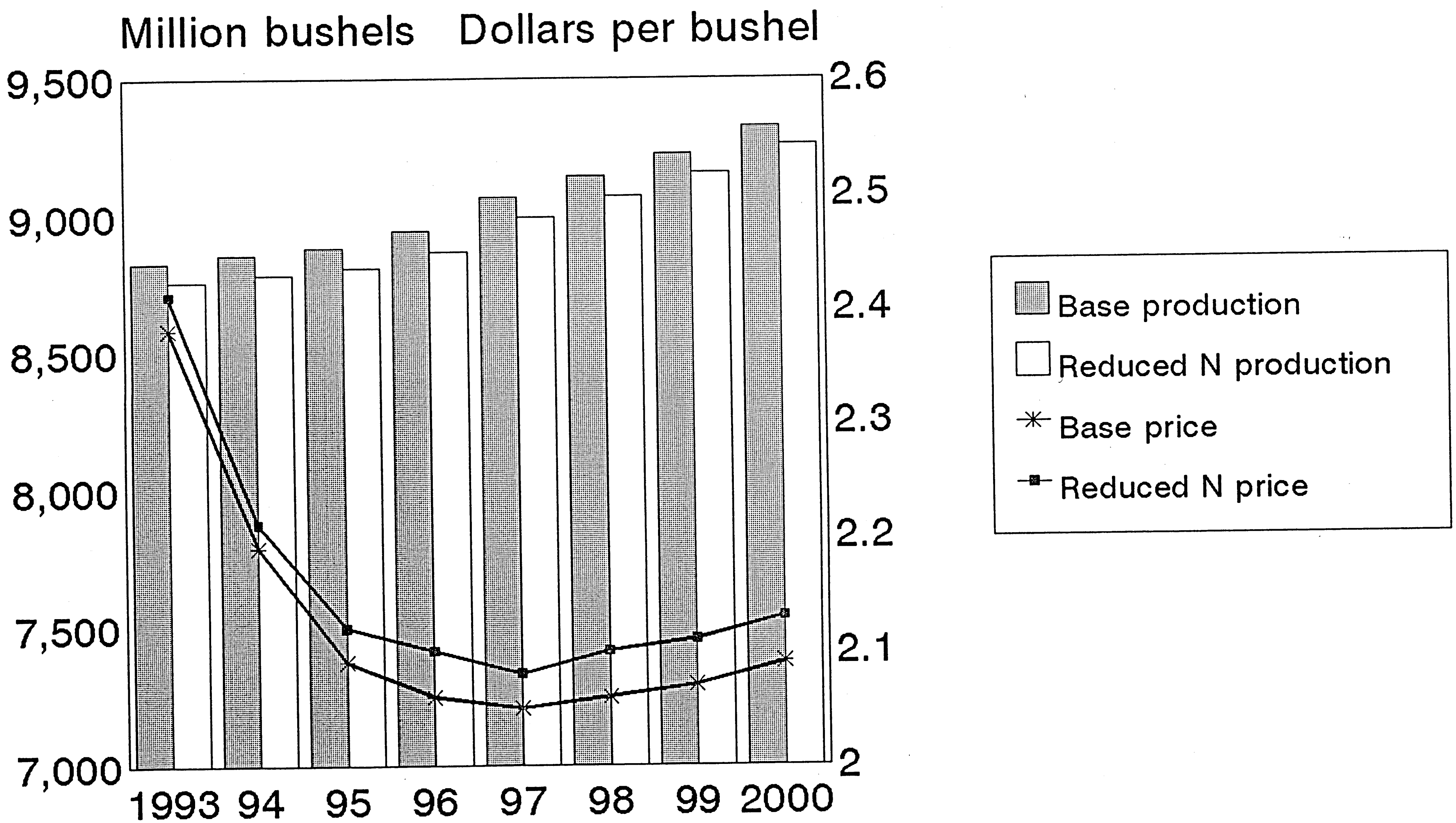


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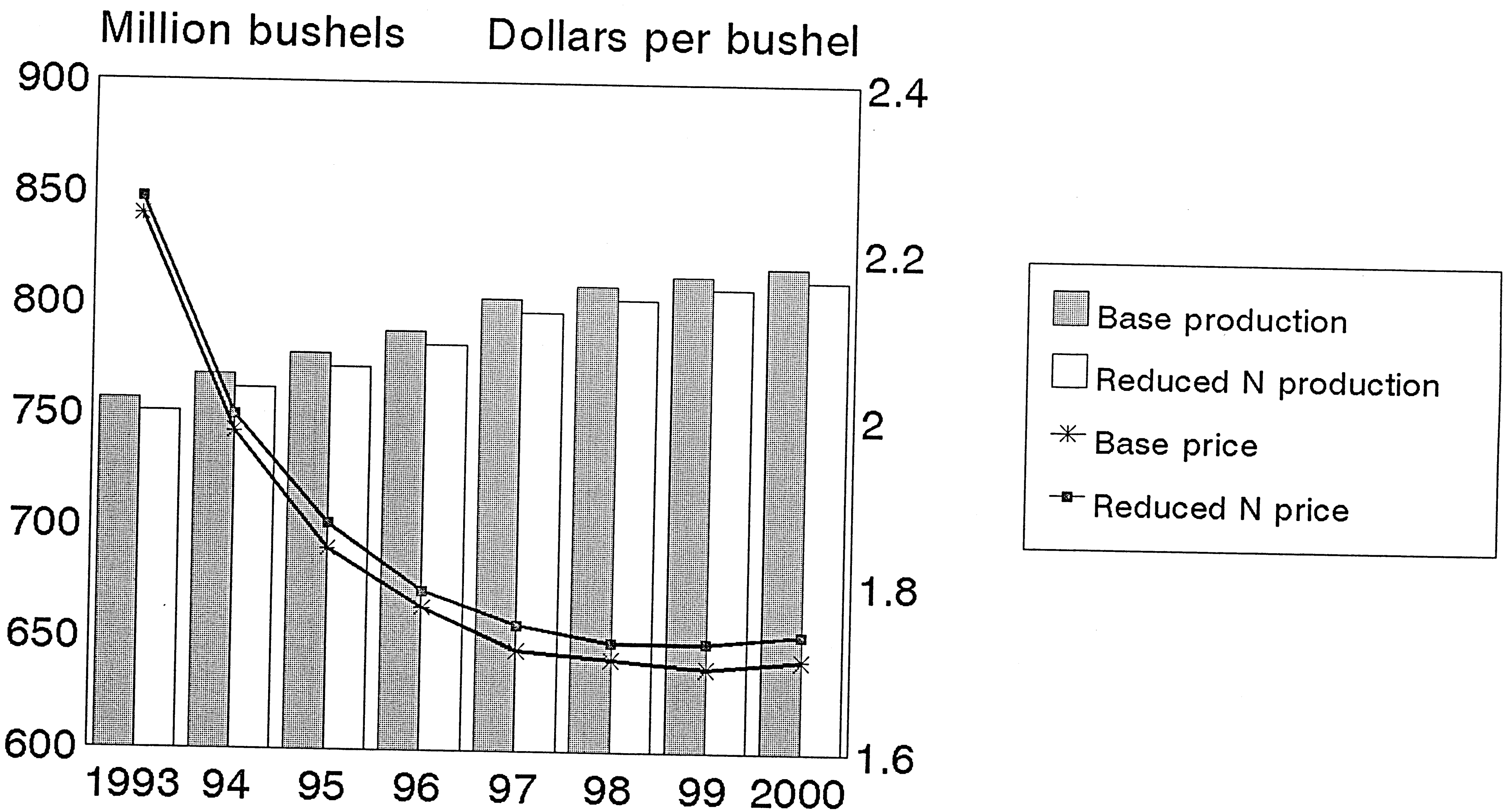
Figure 19

Figure 19
Milo: Projected production and prices, 1993-2000, baseline scenario versus reduced N scenario



Includes all grain sorghums.

Figure 20
Wheat: Projected production and prices, 1993-2000, baseline scenario versus reduced N scenario

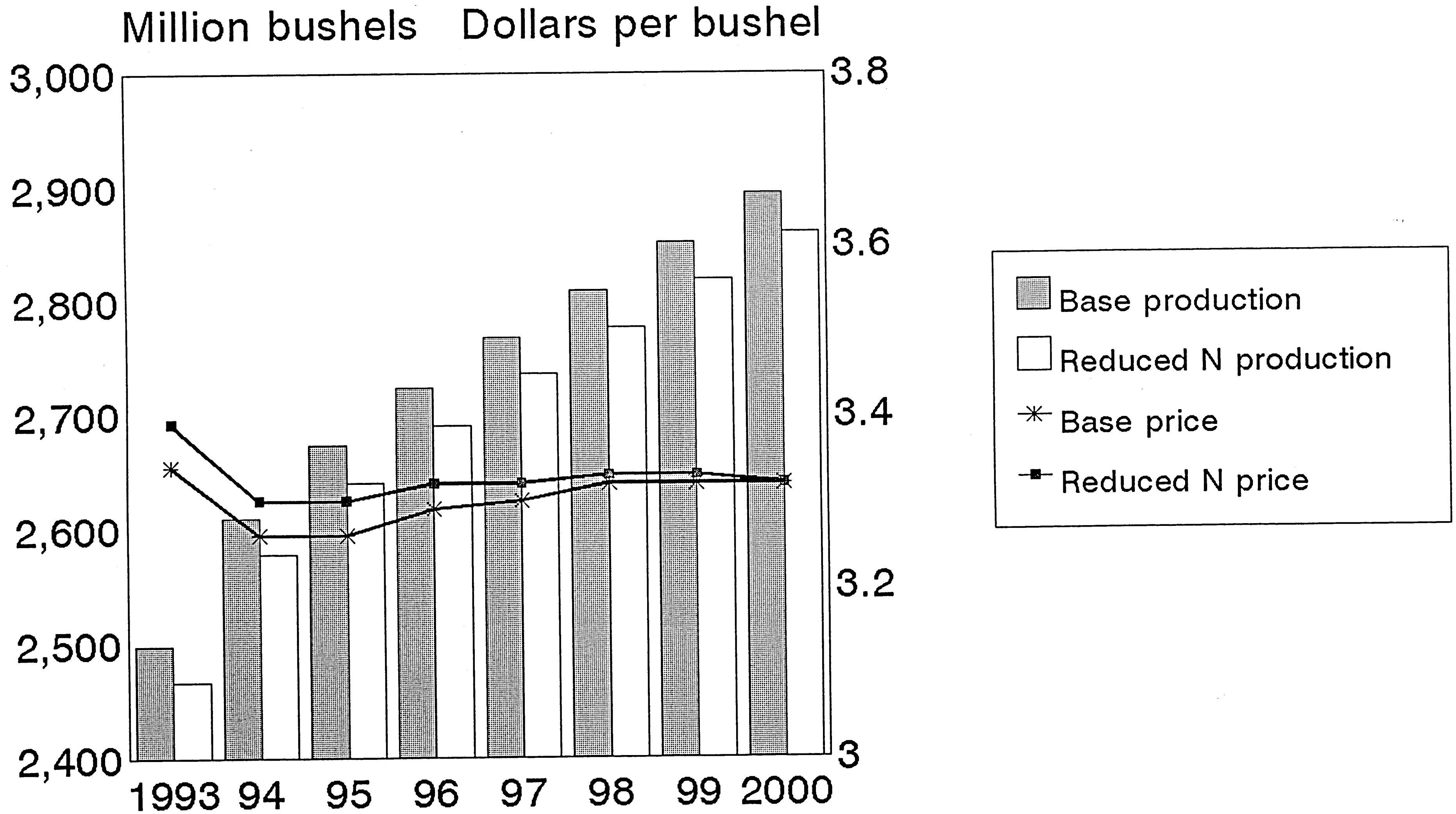


Figure 21

Figure 21
Cotton: Projected production and prices, 1993-2000, baseline scenario versus reduced N scenario

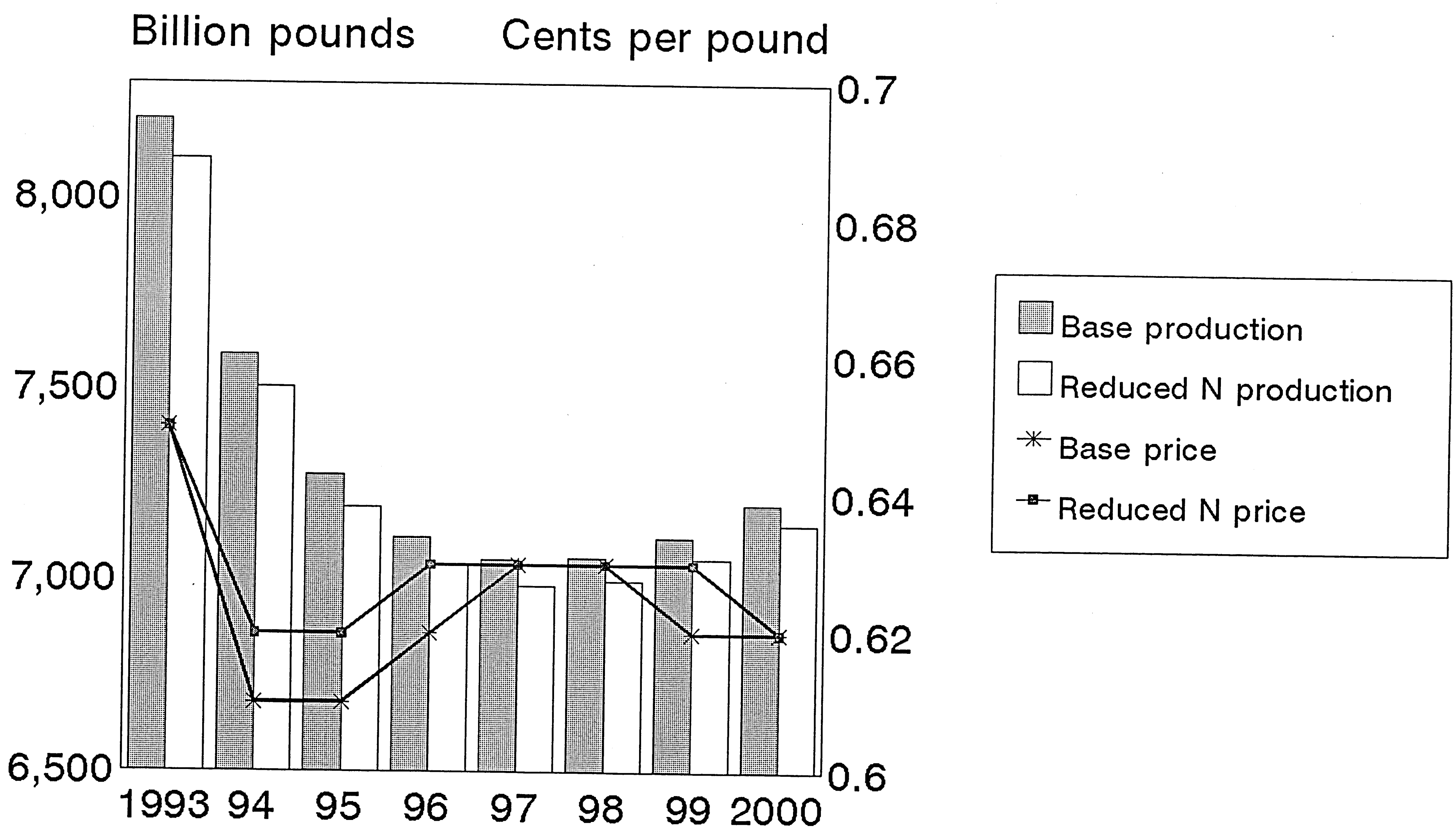
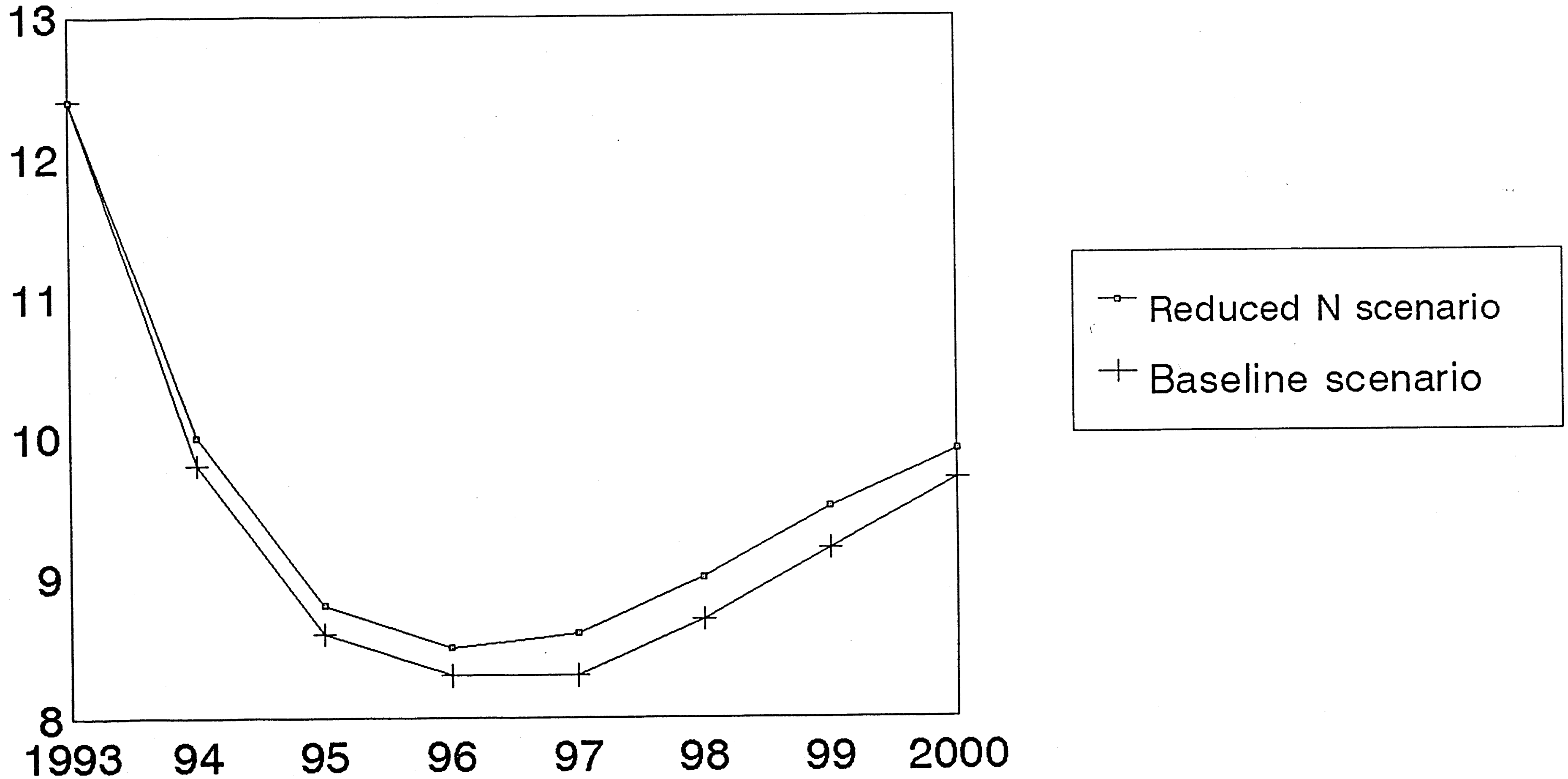


Figure 22 -- Projected net farm income from eight crops before Government payments, 1993-2000, baseline scenario versus reduced N scenario

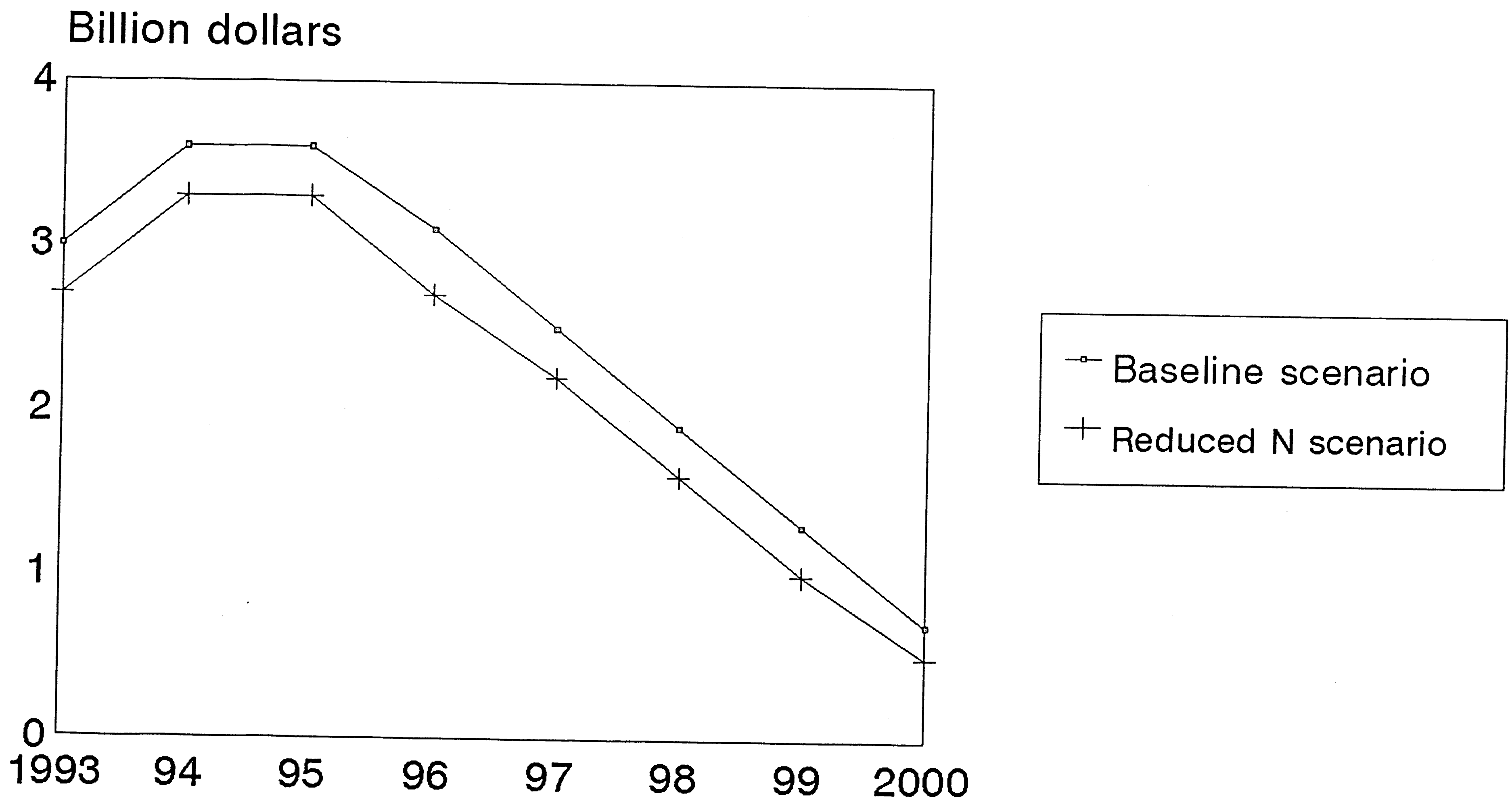


Valued at constant prices.

Figure 23 -- Projected Government payment

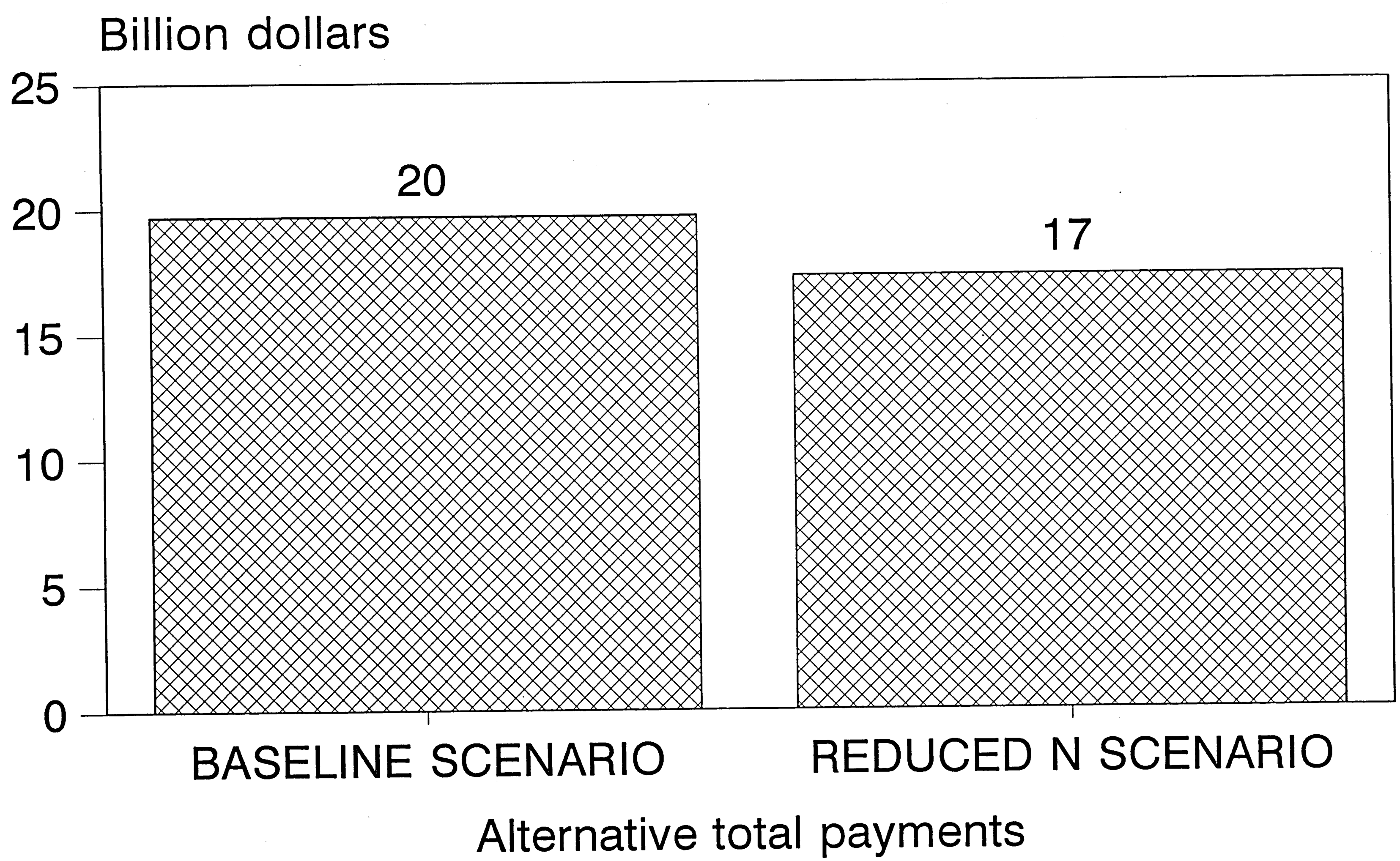
Valued at constant prices.

Figure 23 -- Projected Government payments for farmers' eight crops, 1993-2000, baseline scenario vs. reduced N scenario



Valued at constant prices.

Figure 24 -- Projected Government payments to farmers, cumulative, eight crops, 1993-2000, baseline scenario vs. reduced N scenario

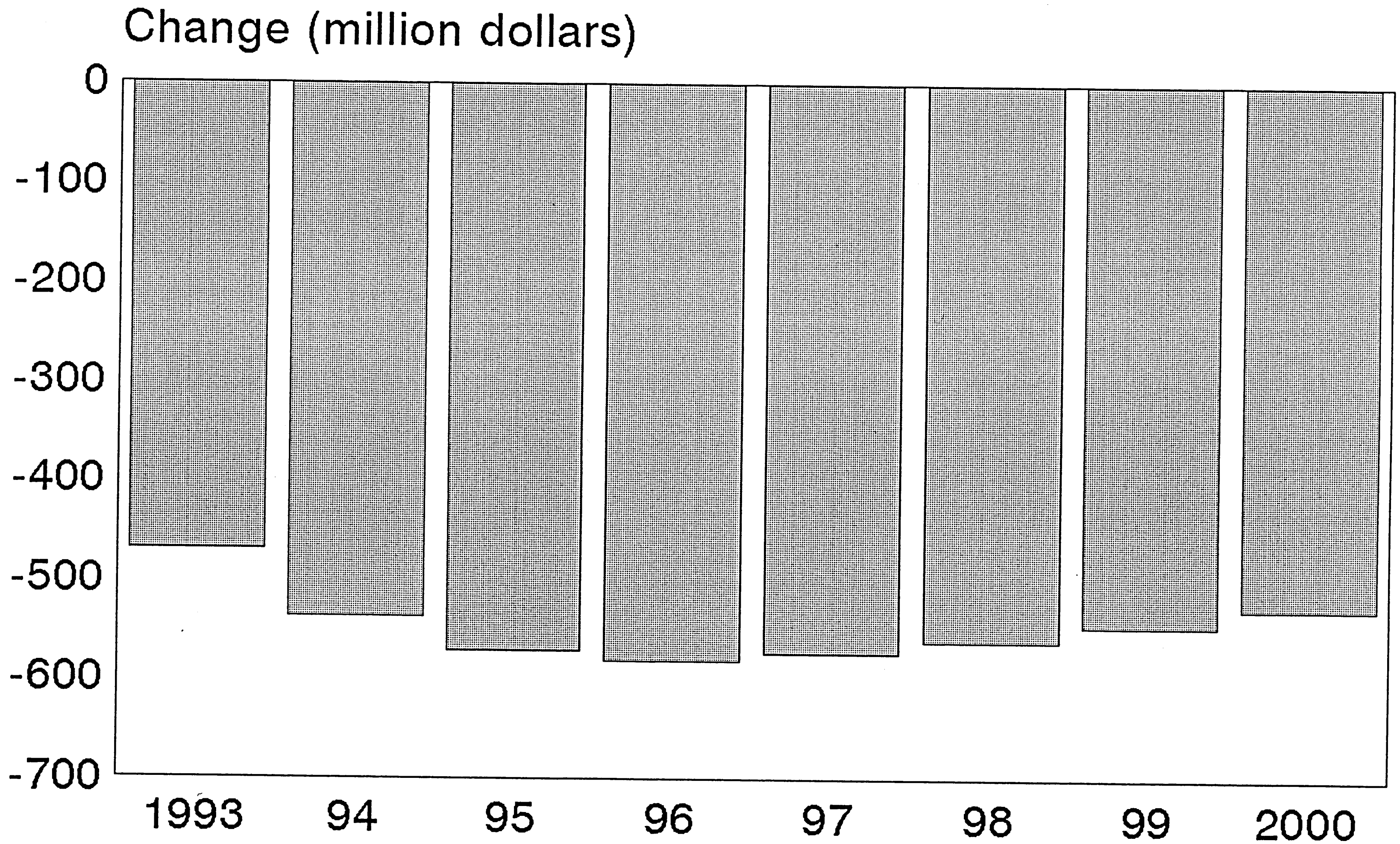


Valued at constant prices.

Figure 25 -- Change in AGSIM projection for

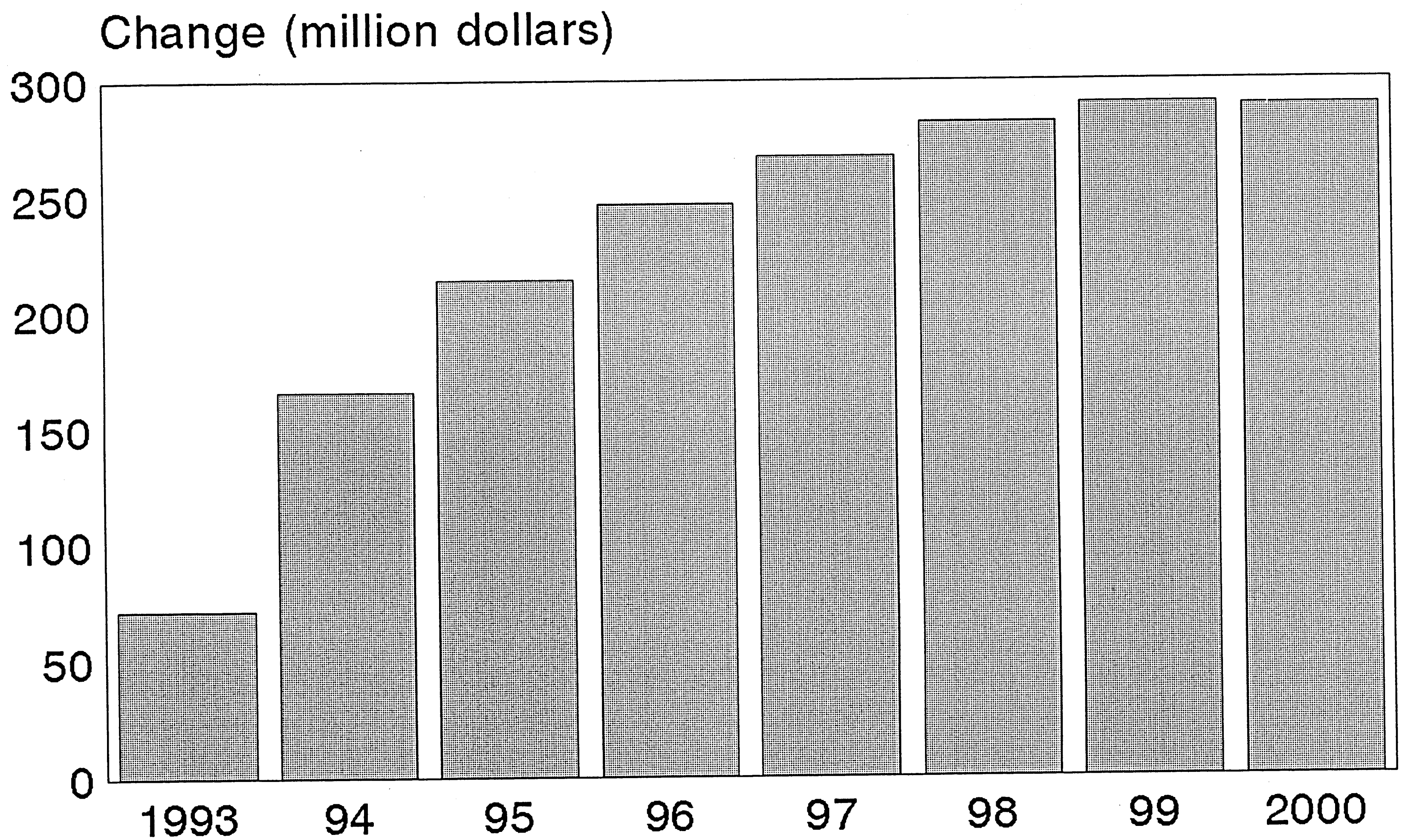
Valued at constant prices.

Figure 25 -- Change in AGSIM projection for eight-crop consumer surplus, 1993-2000, resulting from reduced N scenario



Crop surplus for both domestic and foreign consumers.

Figure 26 -- Change in AGSIM projection for eight-crop producer surplus, 1993-2000, resulting from reduced N scenario

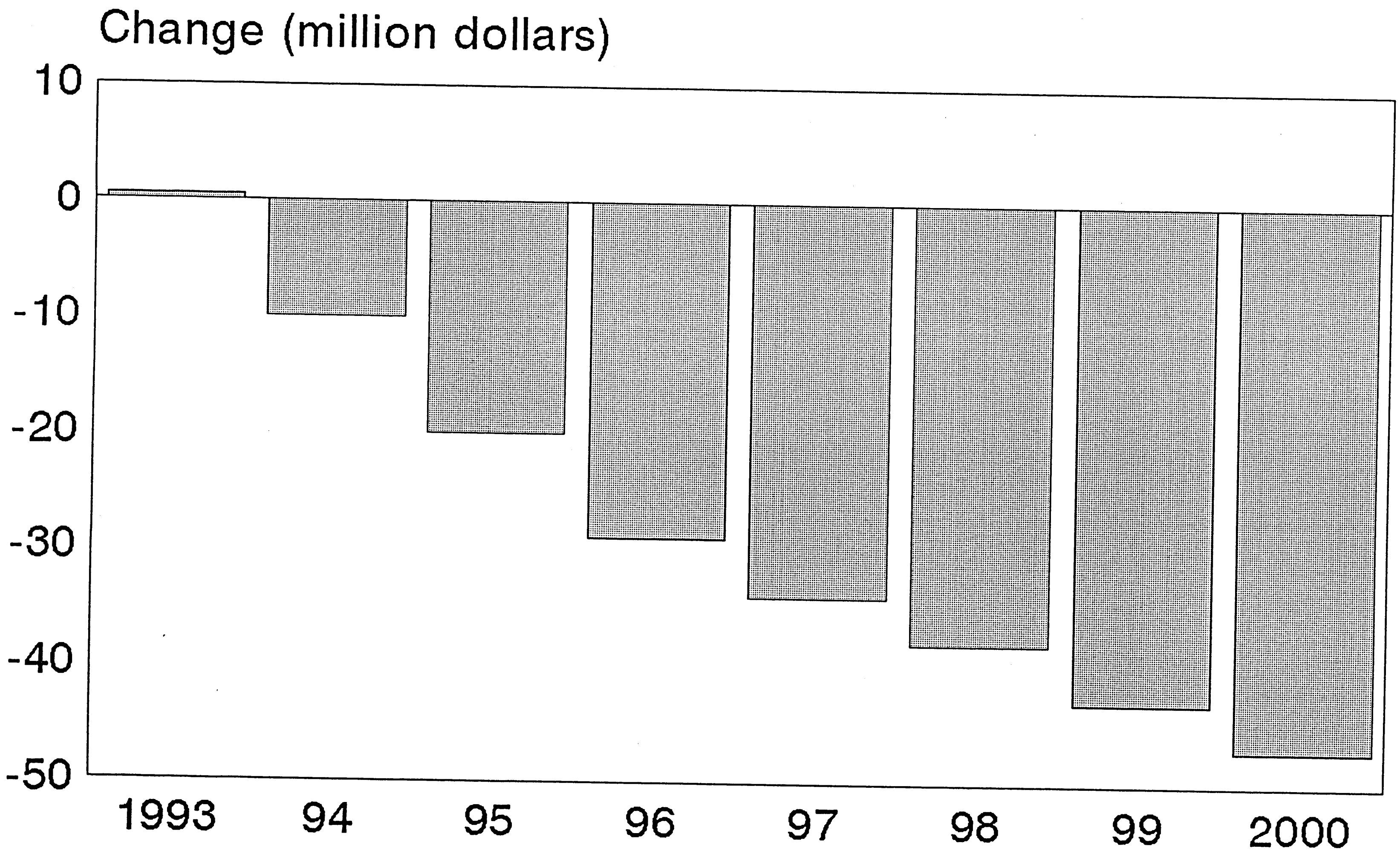


Excludes government payments to producers.

Figure 27 -- Change in AGSIM projection for

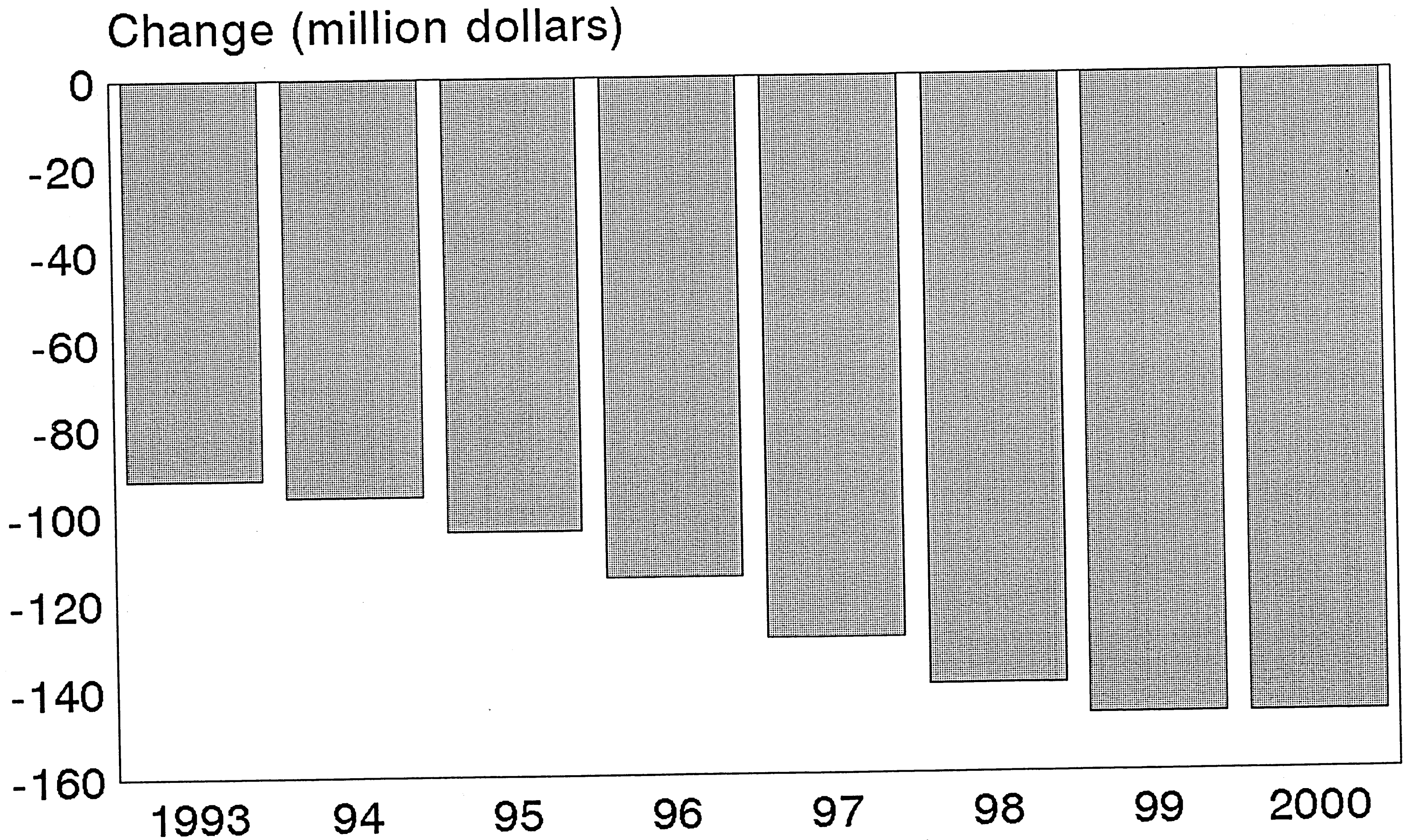
Excludes government payments to producers.

Figure 27 -- Change in AGSIM projection for livestock consumer surplus, 1993-2000, resulting from reduced N scenario



Ten livestock products.

Figure 28 -- Change in AGSIM projection for livestock producer surplus, 1993-2000, resulting from reduced N scenario



Eight livestock products.

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