Alternative Methods for Estimating Changes in Production From Data on Acreage and Condition

By Richard J. Foote and Hyman Weingarten

Reports on prospective plantings are designed to aid farmers in deciding among alternative crops before the planting season. In this connection, they are a useful guide only insofar as they assist the farmer in forecasting probable levels of, or changes in, relative prices. Prices during the ensuing marketing year for each of the crops that a farmer can grow depend on the particular supply and demand conditions that affect them. Two assumptions usually are made implicity with respect to factors of demand: (1) That possible changes in demand will affect the several alternative crops about the same and in such a way that they will affect the ratio of one price to another very little, and (2) that any differential effects of changes in demand can be forecast by economic analysis. Changes in production, however, frequently have important effects on relative prices and, in general, cannot be forecast by economic analysis. Hence, a survey of farmers' intentions is used instead. As farmers cannot forecast probable yields before planting, the survey is confined to intentions with respect to acreage. This article explores alternative ways of translating the acreage intentions data into the more meaningful decision-making variable, prospective changes in production for specified crops and, as a byproduct, indicates how useful the data are for this purpose. If a majority of farmers change their minds with respect to plantings after the report is issued, then the data regarding intentions to plant would give a poor forecast of production. But these analyses indicate that, on the average, for many crops data on intentions to plant are a useful guide to forthcoming production. Included also are analyses of the usefulness in forecasting production of data on acreage seeded to winter wheat and rye published before harvest in December, of data on acreage of cotton in cultivation in July, and of data on condition of specified crops.

IN MARCH, the Crop Reporting Board issues annually a report on farmers' planting intentions as of March 1 for most field crops.[1] In addition to tabular data on indicated planted acreages by States, text statements for the more important crops are given with respect to the total production in the United States that would result if yields per planted acre should equal a specified average and the acreage planted equals that indicated by farmers as of March 1.

A cautionary statement is included in each report; the statement in the 1957 report (page 5) is as follows:

> The purpose of this report is to present information on planting prospects at an early date for use by growers and others in advance of final planting decisions. Commodity comments which follow mention many factors for the different crops which may result in changes, thus stressing the fact that many of the plantings referred to are still to be accomplished. Production computations in comments generally involving 5-year average yields are offered as convenient added information and not as true estimates of probable production. Actual production forecasts will be made by the Crop Reporting Board after determination of acreage for harvest and accumulation of evidence on per acre yields.

Despite the fact that the data on intentions to plant are in a different category from the regular production reports issued by the Crop Reporting Board, they do have forecasting implications. Thus, it is desirable to explore the extent to which the information provided in the prospective plantings report can be used as a guide to probable changes in production. Similar analyses are given for certain indications of acreage and for estimates of condition as a percentage of normal, which are published for some crops before the first forecast of production.

In the early years of crop reporting, reports on acreage intentions were not issued uniformly as they are now. Since 1938, these intention figures

[1] Crop forecasts appear in *Crop Production*, a monthly publication issued by the Crop Reporting Board, U. S. Department of Agriculture, Washington, D. C.

have been reported consistently on a planted acreage basis for most crops. Planted acreages also are reported in December for these crops. To insure valid conclusions, analyses that involve data on acreage intentions begin with 1938 wherever possible. Of necessity, however, shorter periods are studied for some crops, because of a lack of data. All of the studies discussed here refer to national aggregates, as such data provide the most important single figure for each crop from either a price-forecasting or a national policy standpoint. As data are given in the published reports by States, similar analyses on a State basis appear to be desirable.

Alternative Methods

We first list several alternative ways by which information on farmers' intentions to plant or other available information might be used to forecast changes in production. Emphasis is placed on year-to-year changes in production rather than the absolute level, because most outlook statements on either prices or supply are given in these terms. A comparison is made with the estimate of production issued in the December following harvest, rather than the final figure, because the latter is based partly on information regarding marketings or other check data in addition to that on acreage and yields *per se*. We show first the results of applying these methods to three crops—corn, flaxseed, and spring wheat. A summary is then given of the results for all field crops.

The three crops were chosen for special attention for the following reasons: (1) Changes in acreage on a percentage basis for corn normally are small, whereas percentage variations in yield frequently are 25 percent or more. Thus corn is one of several crops for which, on the average, the acreage-intentions report may be of little value in indicating probable changes in production. (2) For spring wheat, changes in acreage frequently have decided effects on total production. Winter wheat, of course, is not included in the intentions-to-plant report because by March it is already growing. (3) Flaxseed is an item for which variation in yield is relatively small in percentage terms, and the variation in acreage is frequently large. The latter reflects (a) weather conditions that may affect the acreage planted to spring wheat, the principal alternative crop to flaxseed and one which normally must be planted in advance of flaxseed, or (b) changes in the prospective price of flaxseed relative to that for spring wheat, which in some years have been substantial. Thus, spring wheat and flaxseed are among those crops for which the acreage intentions report might be of considerable value, on the average, as an indication of prospective changes in production.

The following alternative methods of obtaining an indicated change in production are considered:

1. Direct use of the indicated change in intentions to plant from the planted acreage of the preceding year, in percentage terms, as an indication of the prospective percentage change in production. A more sophisticated way of doing this statistically is to use the indicated change in acreage as the independent variable in a regression analysis for which the change in production is the dependent variable, and this is the method used. If the constant term in the regression analysis does not differ significantly from zero and the regression coefficient does not differ significantly from one, the direct method and that based on the regression analysis are identical for practical purposes.

2. Use of the change in intentions to plant from the harvested acreage of the preceding year as the independent variable in a regression analysis for which the change in production is the dependent variable. Contrary to what might be expected on first thought, use of the harvested acreage for the previous year for some crops provides a more reliable guide than does use of the planted acreage for the preceding year. (See table 3.)

3. Use of (a) the figure given in the text or (b) its approximate equivalent based on multiplying the intentions to plant by an average yield per planted acre as an indication of prospective production. The years used in computing the average yield in the latter case were those specified in the text. To be consistent with the other analyses, the indicated change in production from the preceding year based on this figure is used as the independent variable in a regresssion analysis for which the actual change in production is the dependent variable.

4. Use of an average production for the same years as those used in computing the average yield in method (3b) as an indication of prospective production. This indication is used in the same way as those from methods (3a) and (3b).

5. Obtaining an indication of prospective production by multiplying an average yield per planted acre by the acreage planted in the preceding year as shown in the December crop report. This is similar to method (4) except that acreage in the preceding year is used instead of, in effect, an average acreage.

6. Use of a mechanical projection of a moving average of yield times either (a) last year's acreage or (b) intended acreage as an indication of production. The mechanical projection is similar to that used by the Bureau of the Census in its method of measuring shifts over time in normal seasonal variation as programmed for UNIVAC.

Methods (4), (5), and (6a) are designed to measure how closely changes in production can be forecast by using information available prior to the acreage-intentions report and thus to indicate how much additional information is obtained from that report. Methods (1), (2), (3a), (6a), and (6b) were applied also to winter wheat and rye, with the data on seeded acreage as published in December used in the same way as the intentions-to-plant data for other crops.

Results for the Three Crops

Corn.—The qualified estimates given in the text turn out to be more closely correlated with production than were the estimates obtained by any other method tested. For 1943–54, 63 percent of the year-to-year variation in production was associated with the estimate published in March. From 50 to 52 percent of the variation, however, was associated with estimates based on an average or projected yield multiplied by the acreage planted in the preceding year. Thus, the explained variation was increased by 11 to 13 percentage points by making use of data obtained from the acreage-intentions report.

Spring wheat.—As for corn, the best results are obtained by using the qualified estimate given in the text, although for this item the percentage of associated variation is only 49 percent for 1945–54. But for spring wheat, only 13 percent of the variation is associated with estimates in which the intentions data are not used. For Durum and other spring wheat, no estimates are given in the text. The best method of forecasting for Durum is a projected yield multiplied by the acreage intentions; this was associated with 32 percent of the variation in production. For "other" spring wheat, the best method was an average yield times the intended acreage; here the associated variation was 61 percent. For each of these classes, substantial improvement is obtained by making use of the data on intentions. As discussed later (see table 2), further improvements in accuracy are obtained by making use of the condition figures published in June.

TABLE 1.—*Alternative methods of forecasting production from past yields and indicated acreage: Method that gives the highest percentage of variation associated with actual production, this percentage, and related data, specified crops, 1938–54* [1]

Crop	Method that gives the highest percentage		Difference between highest percentage and that for—	
	Method	Percentage	Best method that does not use indicated acreage	Qualified estimate in text
Included in intentions report:		*Percent*	*Percent*	*Percent*
Corn	3a	63	11	0
Spring wheat:				
Durum	6b	32	30	-------
Other	3b	61	22	-------
All	3a	49	22	0
Oats	3a	71	20	0
Barley	3a	88	38	0
Flaxseed	3a	82	49	0
Rice	6b	88	88	33
Sorghums	1	69	35	28
Potatoes	3a	68	36	0
Sweetpotatoes	1	70	52	17
Beans, dry edible	4	46	0	42
Peas, dry field	2	59	48	37
Soybeans	3a	51	17	0
Peanuts	2	59	30	25
Hay, all	6b	45	18	18
Sugar beets	6b	94	76	44
Tobacco:				
Flue-cured	3a	76	48	0
Fire-cured	3b	69	29	-------
Burley	3b	83	46	-------
Maryland	6b	78	23	-------
Dark air-cured	3b	79	38	-------
Cigar—				
Filler	6b	69	39	-------
Binder	2	47	37	-------
Wrapper	6b	49	18	-------
Based on acreage estimates as of preceding December:				
Winter wheat	2	45	25	2
Rye	6b	70	44	-------

[1] For some analyses, fewer years were used. Details are shown in table 3.

5. Obtaining an indication of prospective production by multiplying an average yield per planted acre by the acreage planted in the preceding year as shown in the December crop report. This is similar to method (4) except that acreage in the preceding year is used instead of, in effect, an average acreage.

6. Use of a mechanical projection of a moving average of yield times either (a) last year's acreage or (b) intended acreage as an indication of production. The mechanical projection is similar to that used by the Bureau of the Census in its method of measuring shifts over time in normal seasonal variation as programmed for UNIVAC.

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	Method	Percentage	Best method that does not use indicated acreage	Qualified estimate in text
Included in intentions report:		*Percent*	*Percent*	*Percent*
Corn	3a	63	11	0
Spring wheat:				
Durum	6b	32	30	-------
Other	3b	61	22	-------
All	3a	49	22	0
Oats	3a	71	20	0
Barley	3a	88	38	0
Flaxseed	3a	82	49	0
Rice	6b	88	88	33
Sorghums	1	69	35	28
Potatoes	3a	68	36	0
Sweetpotatoes	1	70	52	17
Beans, dry edible	4	46	0	42
Peas, dry field	2	59	48	37
Soybeans	3a	51	17	0
Peanuts	2	59	30	25
Hay, all	6b	45	18	18
Sugar beets	6b	94	76	44
Tobacco:				
Flue-cured	3a	76	48	0
Fire-cured	3b	69	29	-------
Burley	3b	83	46	-------
Maryland	6b	78	23	-------
Dark air-cured	3b	79	38	-------
Cigar—				
Filler	6b	69	39	-------
Binder	2	47	37	-------
Wrapper	6b	49	18	-------
Based on acreage estimates as of preceding December:				
Winter wheat	2	45	25	2
Rye	6b	70	44	-------

[1] For some analyses, fewer years were used. Details are shown in table 3.

Flaxseed.—A similar situation holds for flaxseed, except that the percentage of associated variation is considerably higher than for either of the other test crops. Here the qualified estimate given in the text is associated with 82 percent of the variation in production, and figures of 78 percent or above are given for three other methods. Methods in which the intentions data are not used at best are associated with only 33 percent of the actual production.

A Summary of the Usefulness of Acreage Data in Forecasting Production

Detailed figures on the results that relate to acreage are given in table 3; significant aspects are summarized in table 1.

For all the crops except one, methods that utilize the indicated acreage data explain a higher percentage of the variation in production than do those that do not utilize this information; the exception is dry edible beans. For this crop, the use of average production yields the best estimate for 1944–54. Differences between the highest figure that utilizes this information and the highest figure that does not utilize it for the other crops range from 11 percent for corn to 88 percent for rice. For 16 of the 27 items, the improvement equals or exceeds 30 percentage points. Thus the intentions-to-plant data appear definitely to be useful in making forecasts of future production.

Naturally, estimates based on the acreage information, combined with an average or projected yield, are not perfect forecasters of future production. Percentages of variation associated with actual production for the best method range from 32 percent for Durum wheat to 94 percent for sugar beets. For 20 of the 27 items, the percentage equals 50 percent or better, and for 11 items, the percentage is 70 percent or better. For a few crops, the best estimate based on acreage data is closer on the average to actual production than is the first or even later production forecasts isued by the Crop Reporting Board.

Of the crops for which a qualified estimate is given in the text, the percentage of variation associated with actual production, based on this figure, ranges from 4 percent for dry edible beans to 88 percent for barley, with 10 of 17 items equal to or exceeding 50 percent. For approximately half of the items for which a qualified estimate is given, this is the best estimate; for the other half, one of the other methods tested is an improvement.

It appears to be desirable to examine carefully the items for which a method other than the qualified estimate in the text gives the best forecasts.

TABLE 2.—*Alternative methods of forecasting production when use is made of data on condition: Percentage of variation associated with year-to-year changes in actual production, specified crops, 1938–54*

Result for—	Crop			
	Spring wheat [1]		All hay [2]	Rye
	Durum	Other		
Best method based only on indicated acreage and past yields	*Percent* 32	*Percent* 61	*Percent* 45	*Percent* 70
Seeded acreage times condition when condition relates to—				
December	------	------	------	[3]
April	------	------	------	[3]
Average yield times indicated acreage times condition when condition relates to—				
May	------	------	[3]	------
June	38	66	16	------
Logarithmic multiple regression for seeded acreage and condition when condition relates to—				
December and seeded acreage is related to preceding—				
Planted acreage	------	------	------	39
Harvested acreage	------	------	------	49
April and seeded acreage is related to preceding—				
Planted acreage	------	------	------	28
Harvested acreage	------	------	------	43
Logarithmic multiple regression for average yield, indicated acreage and condition when condition relates to—				
May and indicated acreage is related to preceding harvested acreage	------	------	25	------
June and indicated acreage is related to preceding—				
Planted acreage	78	58	------	------
Harvested acreage	74	61	38	------

[1] Based on 1946–54.
[2] Based on 1948–54.
[3] A negative correlation that does not differ from zero by a statistically significant amount was obtained.

TABLE 3.—*Alternative methods of forecasting production from past yields and indicated acreage: Percentage of variation associated with year-to-year changes in actual production, specified crops, 1938–54*

Method		Indicated acreage based on intentions to plant													
Description	Number	Corn	Spring wheat			Oats	Barley	Flaxseed	Rice	Sorghums	Potatoes	Sweet potatoes	Beans, dry edible	Peas, dry field	Soybeans
			Durum	Other	All										
When use is made of indicated acreage for the current year:															
Indicated acreage in relation to preceding—		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Planted acreage	1	14	13	24	21	49	57	79	[1] 75	[2] 69	64	[3] 70	35	[1] 44	37
Harvested acreage	2	20	22	38	35	25	45	78	[1] 81	[2] 64	66	[3] 69	26	[3] 59	27
Year-to-year change in—															
Qualified estimate in text	3a	[3] 63	-------	-------	[4] 49	[3] 71	[3] 88	[3] 82	[3] 55	[1] 41	[3] 68	[3] 53	[3] 4	[3] 22	[1] 51
Product of indicated acreage and—															
Average yield	3b	[3] 60	[4, 5]	[4] 61	[4] 48	[3] 64	[3] 70	[3] 74	[3] 48	[1] 40	[3] 54	[1] 47	[1] 5	[3] 27	[1] 44
Projected yield	6b	[3] 52	[3] 32	[3] 47	[3] 17	[3] 55	[3] 63	[3] 80	[1] 88	[3] 39	[3] 50	[3] 69	[3] 16	[1] 57	[3] 16
When use is not made of such information:															
Year-to-year change in—															
Average production	4	[3] 48	[4, 5]	[4] 39	[4] 27	[3] 51	[3] 50	[3] 33	[3, 5]	[1] 34	[3] 32	[1] 18	[1] 46	[3] 0	[1] 33
Product of acreage planted in preceding year and—															
Average yield	5	[3] 52	[4, 5]	[4] 21	[4] 13	[3] 47	[3, 5]	[3] 2	[1, 5]	[1] 21	[3] 10	[1] 7	[1, 5]	[1] 11	[1] 34
Projected yield	6a	[3] 50	[3] 2	[3] 4	[3, 5]	[3] 30	[3, 5]	[3, 5]	[1, 5]	[3] 4	[3] 21	[3] 0	[3, 5]	[1] 0	[3] 17

Method		Indicated acreage based on—													
		Intentions to plant											Seeded acreage		In cultivation, July 1, for cotton
					Tobacco										
Description	Number	Peanuts	All hay	Sugar beets	Flue-cured	Fire-cured	Burley	Maryland	Dark air-cured	Cigar			Winter wheat	Rye	
										Filler	Binder	Wrapper			
When use is made of indicated acreage for the current year:															
Indicated acreage in relation to preceding—		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Planted acreage	1	51	-------	[2] 88	-------	-------	-------	-------	-------	-------	-------	-------	23	5	78
Harvested acreage	2	59	[3] 9	[2] 90	71	39	47	60	35	46	47	45	45	3	80

Year-to-year change in—															
Qualified estimate in text	3a	[1] 34	[3] 27	[1] 50	[1] 76	------	------	------	------	------	------	------	43	------	------
Product of indicated acreage and—															
Average yield	[1] 3b	21	11	76	74	69	83	71	79	56	43	48	------	------	------
Projected yield	6b	[3] 41	[6] 45	[3] 94	[3] 70	[3] 62	[3] 82	[3] 78	[3] 69	[3] 69	[3] 46	[3] 49	[3] 44	[3] 70	[3] 78
When use is not made of such information:															
Year-to-year change in—															
Average production	4	([1, 5])	[1] 24	[1] 18	28	[1] 31	[1] 25	[1] 55	[1] 22	[1] 6	[1] 7	[1] 10	------	------	------
Product of acreage planted in preceding year and—															
Average yield	[1] 5	12	27	5	2	40	33	53	26	40	10	31	------	------	------
Projected yield	6a	[3] 29	[6] 18	([3, 5])	([3, 5])	[3] 34	[3] 37	[3] 55	[3] 41	[3] 30	([3, 5])	[3] 25	[3] 20	[3] 26	[3] 18

[1] Based on 1944–54. [2] Based on 1942–54. [3] Based on 1943–54. [4] Based on 1945–54.
[5] A negative correlation that does not differ from zero by a statistically significant amount was obtained.
[6] Based on 1946–54.

As shown in the last column of table 1, the items that show substantial differences are rice, sorghums, sweetpotatoes, dry edible beans, dry field peas, peanuts, all hay, and sugar beets. Except for hay, all of these are rather specialized crops. Either method (1) or (2) gives the best estimates for sorghums, sweetpotatoes, peas and peanuts, with two of the four items being best for each approach. These methods assume that the change in production is a direct function of the indicated change in acreage. They tend to be of value when average yield is a poor indicator of actual yield. Method (6b) is best for rice, hay, and sugar beets. Here projected yields, based on a formula that gives heaviest weight to the later years, are used in connection with the data on intentions to plant. Method (4) is best for dry beans. This method merely states that average production over a recent period is the best indicator of forthcoming production. These methods gave best results over a relatively short period. Whether they would give better results in future than the methods currently used by the Crop Reporting Board in making their qualified estimates in the text is a matter of conjecture. The Board might well consider use of these alternative estimating procedures when conditions are such as to suggest that they might give improved results.

Similar analyses, based on the estimate of the acreage in cultivation published in the July prior to harvest, were made for cotton, using methods (1), (2), (6a) and (6b). Three of these methods, that is, all except (6a), give percentages of associated variation that range between 78 and 80 percent. As for most other crops, the acreage information contributes substantially to the accuracy of production forecasts.

Results When Information on Condition Is Used in Conjunction With That on Acreage

Table 2 shows the results from various analyses that make use of data on condition, in addition to information on indicated acreage. For purposes of comparison, the percentage of variation associated with production is shown in the first line for the best method based on information that relates only to past yields and indicated acreage.

Information on condition as a percentage of normal is given in the December and April crop reports for rye, in the May report for all hay, and in the June report for (a) Durum and (b) other spring wheat and for (a) alfalfa, (b) clover and timothy, and (c) all hay. These representations of farmers' composite opinion of the crops relate essentially to yield, and this information can be combined with information on indicated acreage to arrive at a forecast of production. It should be noted that a production forecast for all spring wheat is included in the June report. Thus the analyses discussed here for Durum and other spring wheat are chiefly of value in breaking down this total.

The following methods made use of this information:

1. Obtaining a composite indication of prospective production by use of average yield per planted acre multiplied by condition multiplied by indicated acreage.

2. Running a multiple regression analysis for which the change in actual production is the dependent variable and year-to-year changes in each of the following are used as independent variables: (a) Condition, (b) average yield, and (c) indicated acreage. As with methods (1) and (2) on acreage (see p. 21), indicated acreage can be related either to (a) planted acreage or (b) harvested acreage in the preceding year. When published data on planted acreages were available both approaches were used. The analysis is run in logarithms, as this is believed to be a multiplicative relation.

In computing an average yield, the same years were used as those specified in the report on intentions to plant. As no such years are specified for rye, an average yield was not used. Instead, seeded acreage times condition was used as an indication of prospective production, and these two factors also were used separately as independent variables in a logarithmic multiple regression analysis.

In method (1), the composite is computed and then year-to-year changes in this are used in the analysis. In method (2), year-to-year changes in each of the components are used in the analysis. From a statistical standpoint, the two approaches are quite different.

For some items, results shown in table 2 are rather surprising. Those obtained for Durum wheat are in line with expectations; that is, analyses that make use of the information on condition

yield better estimates of year-to-year changes in production than do those that do not make use of such information. Here, the best method is that based on a multiple regression analysis in which the indicated acreage is related to the planted acreage in the preceding year; this analysis, which includes an estimate of condition made in June, explains 78 percent of the year-to-year variation in production compared with only 32 percent associated with the best method that does not make use of information on condition. For "other" spring wheat, the several analyses yield similar results and little is gained from making use of the June information on condition.

For all hay and for rye, the analyses that make use of information on condition are less reliable as indicators of production than is the best analysis that does not make use of this information. For hay, this results because the best analysis is based on a projected rather than an average yield. The multiple regression analysis based on average yield, condition, and the change in indicated acreage from the harvested acreage in the preceding year was the most reliable of the several studies based on condition. It explained 38 percent of the year-to-year variation in production, compared with 27 percent for the best noncondition analysis that did *not* make use of a projected yield. A similar situation holds for rye. Here the best analysis that made use of information on condition was the multiple regression based on December condition and the seeded acreage related to harvested acreage in the preceding year. This explained 49 percent of the variation in production, compared with 5 percent for the best noncondition analysis not based on a projected yield. Apparently, information on condition of rye in April is less reliable as an indicator of production than is the information that is available in the preceding December.

Book Reviews

Economic and Technical Analysis of Fertilizer Innovations and Resource Use. Edited by E. L. Baum, Earl O. Heady, John T. Pesek, and Clifford G. Hildreth. The Iowa State College Press, Ames, Iowa. 393 pages. 1957. $4.50

THE NEXUS between research in farm management, or agricultural production economics, and research in the physical sciences has long been recognized. But the Tennessee Valley Authority and its cooperators have an outstanding record of promoting actual teamwork approaches to interdisciplinary problems. This volume, and a previous one, "Methodological Procedures in the Economic Analysis of Fertilizer Use Data" (Iowa State College Press, 1956), are indispensable references for economists, agronomists, and soil scientists who are concerned with research on fertilizers. The scope of the present work is much broader than the field of soil fertility. The book will be useful in the planning of any agronomic-economic project.

Here are 29 papers presented by agronomists, economists, and statisticians at a seminar held in Knoxville, Tenn., in 1956 under the auspices of TVA. They are grouped under the following headings:

1. Physical and economic aspects of water solubility in fertilizers.
2. An examination of liquid fertilizers and related marketing problems.
3. Methodological procedures in the study of agronomic and economic efficiency in rate of application, nutrient ratios, and farm use of fertilizer.
4. Farm planning procedures for optimum resource use.
5. Agricultural policy implications of technological change.

The early sections are devoted to specific new problems in fertilizer manufacture and use. Later sections are devoted to progressively more general problems in resource use and agricultural policy. The last two sections deal with fertilizer research only incidentally.