systems of crop rotation may be studied similarly. Comparative analysis of this kind, if done systematically and carefully, deserves to be called programming, although it would not lend itself to linear programming analysis.

Conclusion

Commercial broiler production presents a type of economic problem for which a special kind of arithmetic programming is more appropriate than is linear programming. The fact that linear programming proves to be the less efficient method in this particular problem should not be interpreted as a vote of no confidence. Rather it suggests the need for further comparative testing of alternative methods of programming as applied to each of many different types of economic problems which vary as to characteristics and in complexity. For some problems, linear programming will prove without doubt a more efficient procedure. But more testing needs to be done before we can be certain of their relative efficiencies in each set of circumstances. Eclecticism is a special virtue in this area. One of the special merits of linear programming is that the technique forces the analyst to list his assumptions in a systematic way, and, having done so, he is more likely to test them for reasonableness. This in turn helps in the selection of the most appropriate programming method.

Validity of Objective Estimates of Corn Yield

By Walter A. Hendricks

As part of an extensive research program, the Agricultural Estimates Division of Agricultural Marketing Service is investigating objective methods for estimating and forecasting corn yields. This paper is concerned only with one question: To what extent can differences in estimates of yield per acre, derived from weighing small samples of the crop just before harvest, be reconciled with yields reported by farmers and the official yield estimates derived from such reports? The present status of information on that question is given here without distracting attention from the main issue by including a mass of technical statistical detail. It should be emphasized, however, that the materials contained in this article represent only the preliminary findings of this particular research project, and that final conclusions with respect to the validity of official corn-yield estimates, compared with those obtained by other methods, cannot be made until the research program in this area has been completed and evaluated.

OFFICIAL yield estimates and yields reported by farmers for corn are generally lower than those obtained by weighing small preharvest samples of the crop and adjusting the average weight to a standard moisture content. To illustrate, statewide objective yield surveys conducted by the Crop Reporting Service and cooperating State agencies in Alabama in 1948, and in North Carolina and Virginia in 1949, gave the following results in relation to present official estimates:

	Objective estimate	Official estimate	Official estimate as percent of objective estimate
	Bu/Acre	*Bu/Acre*	*Percent*
Alabama (1948)	26	21. 0	81
North Carolina (1949)	41	31. 5	77
Virginia	55	42. 0	76

For Alabama, the objective estimate was in

terms of a 14-percent moisture content, whereas for North Carolina and Virginia it was in terms of a 15.5-percent moisture content. But converting the Alabama figure to a 15.5-percent moisture basis would raise the computed yield less than 0.5 bushel per acre. The official estimates are not defined rigorously, but they are generally assumed to be in terms of a moisture content at approximately that level.

Any technical discussion of the discrepancies between the objective estimates and the corresponding official estimates, which are based largely on data reported by farmers, is hampered by the lack of a clear-cut definition of the official estimate in other respects also. It is generally accepted that data reported by farmers refer to that part of the crop actually taken from the field in the harvesting operation.

To make the objective estimate comparable with the official estimate a "normal harvesting loss" should be deducted. No information on the size of that loss was available when these surveys were made, but it was not thought to be large enough to account for all of the observed differences. This forces us to inquire whether the objective estimate would be too high because of a bias in the small samples, even if proper allowance were made for harvesting loss, or whether data reported by farmers are at too low a level.

As often pointed out, biases can creep into objective estimates that are based on small harvested samples. It is also recognized that the official estimates are essentially at a level corresponding to yields derived from census data by dividing total reported production by total reported acreage. Even if production is properly reported, the derived yield per acre would not be comparable with the objective estimate if farmers reported gross field sizes instead of the net acreages on which corn was actually standing. Until recently we had no information on just what farmers include in their reported acreages.

Data From Research Project in 10 Southern States

As part of the Agricultural Estimates research program currently in progress, an objective yield estimate was computed by means of harvesting small samples of corn on a sample of fields spread over this 10-State region. Results were comparable with those found in previous work. The objective yield indication, at 15.5-percent moisture content, was 21.8 bushels per acre. The average of the present official estimates for the same States is only 16.4 bushels per acre. On a relative basis the official estimate is 75 percent as large as the objective estimate.

In this study a post-harvest gleaning of sample fields showed that an average of 2.0 bushels of corn per acre was left behind as harvesting loss. Assuming that such corn would not be included in a farmer's reported production, the objective yield indication should be reduced by that quantity. This gives an objective estimate of 19.8 bushels per acre.

A comparison was also made between farmers' reported field sizes and corresponding measurement data. This comparison indicated that the net acreage on which corn was actually standing for harvest amounted to 97.8 percent of the reported acreage.

This raises a question regarding the appropriate definition of yield per acre. If yields are defined in terms of the farmer's concept of acreage, the indication of objective yield relating to a net acreage should be reduced by 2.2 percent to make it comparable with that definition. On the other hand, if yield is defined in terms of net acreage, the official estimate should be divided by 0.978 to make it comparable with the objective estimate.

Convincing arguments could be advanced in favor of either of those two concepts, but the latter viewpoint was adopted here. The official estimate was converted to a "net-acreage" level. Such an adjustment raises the official yield to 16.4/0.978= 16.8 bushels per acre.

The objective yield estimate of 19.8 bushels per acre, obtained after adjusting for harvesting loss, and the official estimate of 16.8, obtained after adjusting for overstatement of acreage, should be comparable. But the official estimate is still only 85 percent as large as the objective yield estimate. We are left in the position of having to decide which of the two is closer to the truth.

Research at Iowa State College

For the last 2 years more detailed studies on forecasting and estimating corn yields have been conducted, in cooperation with the Statistical Laboratory of Iowa State College, on samples of

farms covering Crop Reporting Districts 2, 5, and 8 in Iowa. These districts cover the central third of the State, north to south.

In the 1953 studies the unadjusted objective yield indication was 79.3 bushels per acre. The yield computed from the farmers' reported acreage and production was only 58.3 bushels. The yield derived from the reported data is only 74 percent as large as the objective estimate. Here we find a harvesting loss of 7.8 bushels to be applied to the objective estimate. The net acreage for harvest, as determined by measurement, was 97.2 percent of the farmers' reported acreage for the same fields.

Those two statistics provide an adjusted objective yield of 79.3−7.8=71.5 bushels per acre and a comparable adjusted reported yield of 58.3/0.972=60.0 bushels. The comparable adjusted reported yield is still only 84 percent as large as the adjusted objective yield, even though both are supposedly on the same basis.

The similarity of these results, percentagewise, with those obtained in the 10 Southern States is striking, considering the large difference in levels of yield between the two regions. The ratio of the official estimate to the unadjusted objective estimate was 75 percent in the Southern States. The ratio of reported yield to the objective estimate was 74 percent in Iowa. Harvesting losses were estimated at 9 percent in the South and 10 percent in Iowa. Measured net acreage was 2.2 percent below reported acreage in the South and 2.8 percent below reported acreage in Iowa. Adjustments for harvesting loss and acreage corrections reduce the spread between the objective estimate and the judgment estimate to 15 percent in the South and to 16 percent in Iowa.

As the adjusted objective and judgment estimates are presumably comparable, this latter difference must be explained as a bias in the objective estimates, or as an understatement of yields reported by farmers, or both. To settle that question it would be helpful to have some objective data on total quantities of corn actually harvested by farmers for comparison with reported data. Such objective data are difficult to obtain. The nearest we have come to such data is a set of measurements of corn in the crib shortly after harvest, made by workers of Iowa State College as part of a research study, in 1954.

That year the objective yield estimate for the same area covered in 1953 was 74.0 bushels per acre, with an average of 55.7 bushels per acre reported by farmers on a gross acreage basis. The reported figure is again only 75 percent as large as the objective indication. The net acreage on which corn was actually standing for harvest was 2.2 percent below the reported gross acreage. Measured harvesting loss amounted to 8.3 bushels per acre.

We thus have adjustments similar to those made previously: the objective estimate becomes 74.0−8.3=65.7 bushels per acre and the judgment estimate becomes 55.7/0.978=56.9 bushels per acre. The adjusted judgment estimate is still only 87 percent of the adjusted objective estimate.

But in this study we have, for the first time, an objective indication of the quantity of corn actually harvested by the farmers. The volume of corn in cribs was measured on 50 of the farms and the results were compared with the farmers' estimates of bushels of corn in the cribs.

If the farmers' estimates were correct, they would imply an average conversion factor for the corn in these cribs of 2.87 cubic feet per bushel. A significantly different estimate of the number of bushels is obtained if the standard conversion factor [1] of 2.50 cubic feet per bushel is used. Applying that factor to the measured volume of corn in the farmers' cribs gives an indication that the bushels of corn in the cribs was understated by 15 percent.

The adjusted judgment yield of 56.9 bushels per acre, corrected for that understatement, becomes (1.15)(56.9)=65.4 bushels. This agrees almost perfectly with the objective indication of 65.7 bushels, obtained after applying the deduction for harvesting loss.

Conclusions

The evidence so far thus indicates that objective corn-yield estimates, adjusted for harvesting loss under farm operating conditions, can be accepted as valid estimates of yield per acre.

[1] It should be pointed out that the standard factor is in the nature of a national average which may not be fully applicable to corn in different locations at different times of the year, particularly with respect to moisture content. Work planned at Iowa includes an effort to ascertain the most appropriate factors to be used for such conversion.

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Yield per acre is defined in terms of net acres on which corn is standing for harvest. The harvesting loss appears to be of the order of 10 percent of the unadjusted objective indication of yield.

Estimates of yield per acre, derived from data reported by farmers, need to be adjusted to a net acreage level to compensate for parts of the field upon which no corn is standing for harvest, but which presumably are included in the acreage customarily reported by farmers. In round numbers, the reported acreage appears to be about 2.5 percent too high.

In addition to the acreage adjustment, it appears that there may be an understatement of as much as 15 percent in farmers' reported data on production. This factor admittedly applies to corn that is already in the crib. For corn that is not cribbed, the accuracy of that factor may be questioned. But it is perhaps reasonable to infer that if cribbed corn is understated by that amount, uncribbed corn is probably understated by at least that much.

To summarize, let us apply these average adjustments to all of the objective and judgment estimates of yield discussed in this paper in one table. The results are as follows:

Comparison of Objective and Judgment Yield Estimates

Area	Objective Estimate		Judgment Estimate	
	Unadjusted	Adjusted for harvesting loss	Unadjusted	Adjusted for acreage and understatement of production
	Bu/Acre	*Bu/Acre*	*Bu/Acre*	*Bu/Acre*
Alabama (1948)	26	23. 4	[1] 21. 0	24. 8
North Carolina (1949)	41	36. 9	[1] 31. 5	37. 2
Virginia (1949)	55	49. 5	[1] 42. 0	49. 6
Southern States (1954)	21. 8	19. 6	[1] 16. 4	19. 4
Central Iowa (1953)	79. 3	71. 4	[2] 58. 3	68. 8
Central Iowa (1954)	74. 0	66. 6	[2] 55. 7	65. 7

[1] Official estimate. [2] Reported data.

It is clear that even the use of fixed adjustment factors does a creditable job of reconciling the objective and judgment yield estimates, particularly when it is remembered that some divergence between the two can be charged to sampling error.