is considered, however, the measures of relative contribution change to 56 percent for acreage changes and 44 percent for yield changes. The reason is that, owing to a sharp cut in allotments in 1933, harvested acreage dropped from 421,000 to 311,600 acres, a decline of 26 percent. Average yield per acre changed only 5 percent, declining from 1,556 pounds to 1,513 pounds.

Illustration of Use of Proposed Method

Method 2 was used to ascertain the relative effects of acreage and yield changes on year-to-year changes in production of cotton, wheat, and soybeans during the periods 1921-23 and 1930-36. The crops and the periods were selected to illustrate application of the proposed computational method; analysts who are working in these commodity areas may wish to examine other periods. Results of the analysis are shown in table 2.

Results for wheat confirm Meinken's finding that yield changes exerted the predominant influence on yearly changes in production in the period 1920-23. For the period following 1938, however, results show a greater influence of acreage changes than was found by Meinken, probably because of inclusion of 1933, when harvested acreage declined substantially from the previous year.

The analysis of cotton showed that in the period 1921-38 approximately 60 percent of the annual changes in production was attributable to changes in yield. In 1939-56, this contribution dropped to about 30 percent, whereas that of acreage changes rose to about 70 percent. During the more recent period, there were sharp fluctuations in harvested acreage of cotton, particularly in 1944, 1949, 1950, 1951, and 1952, when annual changes ranged from 20 to more than 50 percent. These sharp changes were chiefly the result of a postwar expansion in acreage and the operation of acreage controls in 4 of the 7 years 1950-56.

In the case of soybeans, the analysis showed that in both periods acreage changes were the predominant influence on changes in yearly production, but that the relative contribution of changes in yield was greater in the more recent period than in the earlier one.

---

Preliminary Report on Objective Procedures for Soybean Yield Forecasts
By Bruce W. Kelly

As part of its expanded research program, the Agricultural Estimates Division of AMS is exploring the possibilities of objective forecasts of yield for several crops. This paper summarizes results obtained from the first year's work on soybeans. Although these results must be regarded as tentative until more data become available, they nevertheless illustrate how the problem is being attacked.

To develop techniques for forecasting the yield of a crop, it is convenient to study individual components of yield separately. In our study of soybeans, the components considered were the number of plants per acre, the number of pods per plant, and the weight of beans per pod.

This preliminary report is restricted to forecasting the number of pods per plant that will reach maturity and be present on the plants at harvest time, based on 1956 data. As the number of plants per acre can be estimated from sample plots within fields, this is equivalent to forecasting the number of pods per acre.

As for cotton, a forecast made early in the season must allow for fruit not yet on the plants. This is the situation with soybeans on August 1, which is the earliest forecast date considered here. The general approach used in this study was the same as for cotton—namely, to count the pods already present on August 1 and to seek an observable syndrome of plant characteristics that indicates what fraction of a 100-percent load is represented by that count. Again, as with cotton, all pods that will contribute to the final yield have

been formed by September 1. On and after that
date, the problem is reduced to estimating the
fraction that will survive and reach maturity.
(The problem of estimating normal harvesting
losses is not considered in this report.)

Two sets of data were available for this study.
For the first set, intensive counts of bloom and pod
were made at frequent intervals between June 28
and September 11, 1956, on 3 plants in each of
12 Illinois soybean fields near Springfield. This
field work was done under direction of the State
statistician's office in Springfield. These counts
were used to study the growth and fruiting habit
of the soybean plant, and to set up a forecasting
model. A second set of fruit counts was available
from a probability sample of 150 soybean
fields dispersed over the producing area in the
North Central States. In those fields, counts
were made at monthly intervals during 1956 from
August 1 until harvesttime. (Only half of these
fields were used on August 1.) Relationships
derived from the Illinois data were applied to data
from the more extensive surveys in the North Central
States to test the accuracy with which the final
mature pod count could be forecast at the official
monthly forecast dates, starting with August 1.

Relationships Observed in Illinois's Data

For each plant on which detailed counts could
be made throughout the entire growing season, the
number of pods present on each date was expressed
as a percentage of the maximum number formed
on any later date. As there was some variation
in the date on which the maximum pod load was
attained, the time scale was adjusted so that August
5 was arbitrarily substituted for the actual
date. The dates of the other observations were
adjusted accordingly. This had the effect of put-
ting the pod counts on a comparable age-of-plant
basis. Average percentage of maximum pod load
by adjusted dates after these adjustments were
made is shown in table 1.

Plotting the relative pod load against time on
a chart shows that the decline in pod load pro-
ceds in almost linear fashion after the maximum
is reached. The rate of pod formation up to the
maximum count follows a typical sigmoid growth
curve. The problem in that part of the fruiting
history of the plant is to find some observable
plant characteristics that are related to the relative
pod load so that when pods are counted it will
also be possible to ascertain the fraction of a full
load that the count represents.

The Illinois data indicate that plants have their
maximum number of blooms about 2 weeks after
blooming begins. Pods begin to set at that time.
About 2 weeks later, plants carry about half of
their fruit as blooms and half as pods. The older
pods have already reached full length. In terms
of blooms and pods combined, the plant has its
maximum fruit load 1 week later, and the presence
of beans can be detected in the older pods. An-
other week later—this would be 4 weeks after pods
begin to set—the plant is carrying its maximum
number of pods. By the time flowering ceases—
about 3 weeks after the maximum pod load has
been attained—the plant has shed 13 percent of its
pods. Another 10 percent of the pods disappear
between cessation of blooming and maturation of
pods, so that only about 71 percent of the pods
present at the date of maximum pod load are pres-
ent at harvesttime.

On the basis of these observations, it was con-
cluded that plants on which no pods have yet
begun to set at the time of an early-season forecast
date, such as August 1, have 0 percent of their
maximum pod load; the average plant carrying
more blooms than pods has 15 percent of that
maximum; the average plant carrying more pods
than blooms, but no pods yet showing bean forma-
tion, has 75 percent of its maximum; and the
average plant showing pods with beans, even if
blooms are also present, already has 100 percent
of its maximum total per load.

This tentative relationship between observable
plant characteristics and relative pod load was
applied to August 1 data from extensive surveys
conducted over the soybean-producing areas of 11
North Central States. Losses of pods between the

<table>
<thead>
<tr>
<th>Date</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 28</td>
<td>0.0</td>
</tr>
<tr>
<td>July 11</td>
<td>6.2</td>
</tr>
<tr>
<td>July 17</td>
<td>20.2</td>
</tr>
<tr>
<td>July 23</td>
<td>81.0</td>
</tr>
<tr>
<td>August 5</td>
<td>100.0</td>
</tr>
<tr>
<td>August 28</td>
<td>87.5</td>
</tr>
<tr>
<td>September</td>
<td>75.1</td>
</tr>
</tbody>
</table>

Table 1.—Pod load on soybean plants as percent-
age of maximum load (Illinois data)
data on which the maximum count was reached and harvesttime were also assumed to be of the same relative size as in the Illinois data.

Analysis of Data From North Central States

Observations in the North Central States were made at monthly intervals on two sample plots in each sample field. Each plot consisted of two adjacent row sections, 3 feet in length. All soybean plants were counted in each plot, but pods were counted on only 1 of the 2 row sections in each plot. Detailed counts of blooms, pods, nodes, and lateral branches were made on one plant adjacent to each row section on which pods were counted. These detailed counts were used to classify fields by stage of maturity into the categories suggested by the Illinois data. This classification was used to estimate the percentage of the maximum pod load that was represented by the August 1 pod count.

The classification of fields, the relative pod load for each class, and the weighted average relative pod load for all fields in the survey, are shown in table 2.

In the August 1 survey, the average pod count was 708 per 6 feet of row. The corresponding counts on later surveys were 1,198 on September 1 and 946 on October 1.

As of August 1, the maximum pod count that would be obtained can be forecast by dividing the observed count on that date by the fraction of a full load represented by that count: 708/0.594 = 1,198. This is larger than the number observed on September 1, but the Illinois data indicate that about 13 percent of the maximum pod load is lost between August 1 and September 1. The number of pods expected to be present on September 1 should be (0.87) (1,343) = 1,189 per 6 feet of row. This agrees remarkably well with the 1,198 actually observed on September 1. Again, according to the Illinois data, the number of pods found on October 1 should be about 20 percent less than the maximum: (0.71) (1,343) = 954. This also agrees closely with the 946 actually counted on October 1.

It thus appears that a forecast of the number of pods that will be present at harvest time can be made as early at August 1. That forecast is obtained in two stages. First, the maximum potential pod load is computed from the number already present and the indicated percentage of a full load represented by that count. The number of these pods that will be present at harvest time is then computed from the average survival rate.

By September 1, most plants have stopped blooming, very few new pods are being formed, and beans are developing in most pods on the plants. For a September 1 forecast of pods present at harvesttime the problem is mainly to estimate subsequent losses. These losses can be estimated from trends such as those observed in the Illinois data. But there may be other possibilities. For example, it was observed that for plants that have stopped blooming by September 1, the ratio of the October 1 pod count to the September 1 count was identical with the ratio of the September 1 count of pods with beans to the September 1 total pod count. For the region as a whole, the October 1 pod count was 70.0 percent of the September 1 count. The September 1 ratio of pods with beans to total pods was 80.0 percent. The agreement is also fairly good when considered State by State. This implies that plants mature enough to stop blooming at that stage, are carrying all pods that will produce beans and that pods in excess of that number are likely to be shed by the plants.

Experimental work is continuing to test the validity of the relationships described here and to seek possible refinements. For the August 1 forecast, some other basis for classifying plants according to maturity may be more suitable. For the September 1 forecast, the behavior of some plants that are still setting pods needs to be studied. Weight of bean is receiving attention. Harvesting losses are being estimated by gleaning sample fields after harvest.

<table>
<thead>
<tr>
<th>Number of pods</th>
<th>Relative number of fields</th>
<th>Percentage</th>
<th>Percentage of maximum pod load</th>
<th>Weighted average</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
<td>1.0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>More than pods</td>
<td>2</td>
<td>25</td>
<td>53</td>
<td>28</td>
</tr>
<tr>
<td>Same pods than blooms</td>
<td>37</td>
<td>73</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>Some pods having beans</td>
<td>28</td>
<td>100</td>
<td>100</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pods</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>More than pods</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Same pods than blooms</td>
<td>37</td>
<td>73</td>
</tr>
<tr>
<td>Some pods having beans</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td>Weighted average</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

---

Table 2.—Computation of average percentage of full load present on August 1