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ESCS Objectives for Yield Forecasting Models
and Method of Evaluation: Example GOSSYM

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I. Method Of Model Evaluation For A New Indication

The Economics, Statistics and Cooperatives Service "has the responsibility for making (1) forecasts of crop production from current crop conditions during the growing season and (2) annual estimates of crop production. These are two separate and distinct functions. We use 'estimate' to indicate a measure of accomplished fact, such as at harvest time or later; the term 'forecast' is used to refer to expectations of what is likely to be accomplished at some time in the future." |1|

To produce yield forecasts for corn, cotton, soybeans, wheat, and potatoes, we use farmer reported crop condition, farmer projected yield, and field measured plant characteristics. The field measured plant characteristics are employed in plant and fruit related regression models with crop production feedback to provide state, regional, and national indications. Coverage in the statistical sample used in this objective yield technique is described in Table 1 below.

Table 1: Objective Yield Sample by Crop

Crop	No. States In Program	% Of U.S. Crop Coverage	Total Samples Laid Out	Combined Sample Unit Acreage
CORN	18	94	3,200	13.2
COTTON	12	98	2,390	7.2
SOYBEANS	17	95	1,915	1.8
WHEAT	17	85-90	2,510	.47
POTATOES	12	95	2,175	6.0

Using this objective yield crop cutting technique we can estimate final yield with a one to two percent error at the national level. For this reason we are primarily interested in improvements to forecasting models.

Before we can employ a new model it must satisfy the following model criteria and survey constraints. A forecasting model must:

- converge to the biological yield produced;
- be consistent and reliable both within and between years;
- be causally related to plant growth and development even though the process may not be completely understood;
- contain a limited number of input variables; and

permit parameter estimability, in the statistical sense for the population of plants, with a limited set of yearly data.

The survey constraints which must be satisfied are:

Model concepts and inputs must be operationally definable in terms of specific data collection tasks.

Input data collection can be sucessfully completed by a part-time enumerator corps with marginal expertise and training.

Data collection can be completed in a reasonable time and in a cost effective manner.

Model output can be produced for required reporting dates.

A detailed sensitivity analysis relating input variables to both modeled and measured output is necessary for the user.

To apply these model criteria and survey constraints in model evaluation usually requires four or five years of study. Only a few fields are employed in the first year of study. During the first year, the primary purpose is to translate model concepts and inputs into definable data collection procedures. Data analysis is devoted to the quality of the input data collected as well as a review of each data collection procedure. Each enumerator and the state office supervisor are asked to comment on each data collection procedure. Review of these comments can lead to the discovery of nonsampling errors. From this preliminary analysis a few input variables are selected as basic to the study. In all subsequent studies, survey design will be developed to collect these selected variables with the greatest reliability.

The second year of study is again limited to a few fields. It is designed to produce, at reasonable levels of error, field level estimates as well as obtain actual farmer yield. Such estimates usually require a minimum of twenty or more plots in a field.

From this second study some basic questions concerning model criteria can be answered. These relate to model convergence to biological or farmer yield, consistency and reliability within year, and estimability of marginal driving parameters that can be produced within a growing season.

Again in the data analysis, the quality of the input data is examined first. Model parameters are next estimated. Model output is then compared to the biological and farmer yields produced for the field. Comparisons, at this point, are made at both field and plot level. If the analysis proves favorable one of two study directions are pursued.

If earlier studies have not produced cost effective input data collection methods, then subsequent effort will be in model modification or double sampling. For our purposes data employed in any model must be available from an unimpeachable external source or be obtained by a trained enumerator in the field. The field enumerators are part-time employees; so data collection procedures must be specified by precise instructions, require easy to use and inexpensive equipment, and require a limited amount of time in the field. In our current objective yield only 35 percent of the total cost is for equipment and the actual data measurements made. Unless cost effective data collection techniques can be developed the model has failed.

On the other hand, if cost effective procedures have been developed, the research is now expanded to a few plots in many fields over a large area. Forecasts and estimates from the model for this large area are now compared to our own objective yield models and where possible actual farmer yield. Performance of the forecasts and estimates will be examined relative to the final yields produced. At this point model criteria as well as the first three survey constraints will be re-evaluated.

Favorable results would suggest that all operational problems have been resolved. Thus a pilot study would be conducted in several states. This study is treated as part of the operational program. All training schools, data collection efforts, data summary, and data utilization must be scheduled to conform to required crop reporting dates.

The major deviation from an operational program is that all users need to be instructed in how to evaluate and use model output. This usually means providing a limited sensitivity analysis of input data. It should be pointed out that the sensitivity constraint is usually only satisfied through model acceptance and use. This is because the analysis must not only relate how input variables influence model output but what real outputs were finally realized. With this analysis the user develops an understanding of what input changes will do to output.

At the end of this pilot study all criteria and constraints are re-evaluated. If all are satisfied and if the model produces either improved estimates or provides better early season forecasts, the recommendation will be made to adopt the model for producing yield indications.

The final hurdle is to obtain funding for the operational project. Once a model becomes operational, one to three years are usually required to institute the program in all necessary states. Thus testing, evaluating, and executing a model for operational use usually requires at a minimum five years and a maximum of eight. The longer periods sometimes occur due to funding or unforeseen complications in the data analysis.

II. Overview of GOSSYM Evaluation Study

Last year a data collection study was conducted in commercial fields in Mississippi to supplement other evaluations of GOSSYM. The sample consisted of three purposefully selected fields planted to row cotton. Two of the fields were located near Stoneville in Washington County and the other near Pontotoc in Pontotoc County. Each field contained two plots randomly located from each of four specified corners for a total of eight plots. Data collection began during the third week of June after a one day enumerator training school. Approximately 22 visits were made to each field during the study. Semi-weekly visits were made initially, switching to weekly visits at mid July, and biweekly visits at the end of August.

Data collected daily near the three fields included PAR, maximum temperature, minimum temperature and precipitation.

Data collected during each enumerator visit in each plot consisted of the following:

detailed plant mapping of four plants;

height measurements of eight plants;

counts in a three foot by two row unit of the number of plants which have squared, flowered, set bolls, and opened bolls to establish 50% dates of these stages of development;

measurements in a four foot by two row drop count unit to establish the amount of canopy cover;

counts of fruit loss due to insect damage in the drop count unit; and

estimates of the average plant height in the drop count unit using a sighting technique.

Other data collection activities in the field included:

obtaining the total precipitation since the previous visit;

drawing one soil core per plot at the beginning of the season to establish available soil moisture;

performing analysis of the soil cores to establish the initial nutrient profile;

selecting one plant per plot of average height for plant partitioning measurements;

harvesting all fruit on the individually mapped plants to establish the amount of dry matter in the fruit and the biological yield for the plant;

counting all fruit in the plot immediately before harvest to establish the biological yield of the plot;

obtaining harvest loss counts immediately after harvest;

obtaining final yield for each field as reported by the farmer; and

obtaining information on farm management practices.

III. Initial Data Analysis

The initial data analysis examines confidence interval widths and relative standard errors of the estimates. The relative standard error is defined as the standard error divided by the mean converted to a percent.

Thus far we have examined the 50% date of squaring, flowering, boll set, and boll opening; plant heights; canopy coverage; plant mapping; and insect damage. Other variables are currently being examined. Field 2 data has not yet been summarized due to data collection problems, except for plant mapped data.

50% Dates

The dates when 50% of the plants in the field had flowered, set bolls, and opened bolls were estimated using several different methods which all produced similar results as shown in Table 2. Squaring dates were not estimated since this event had already occurred.

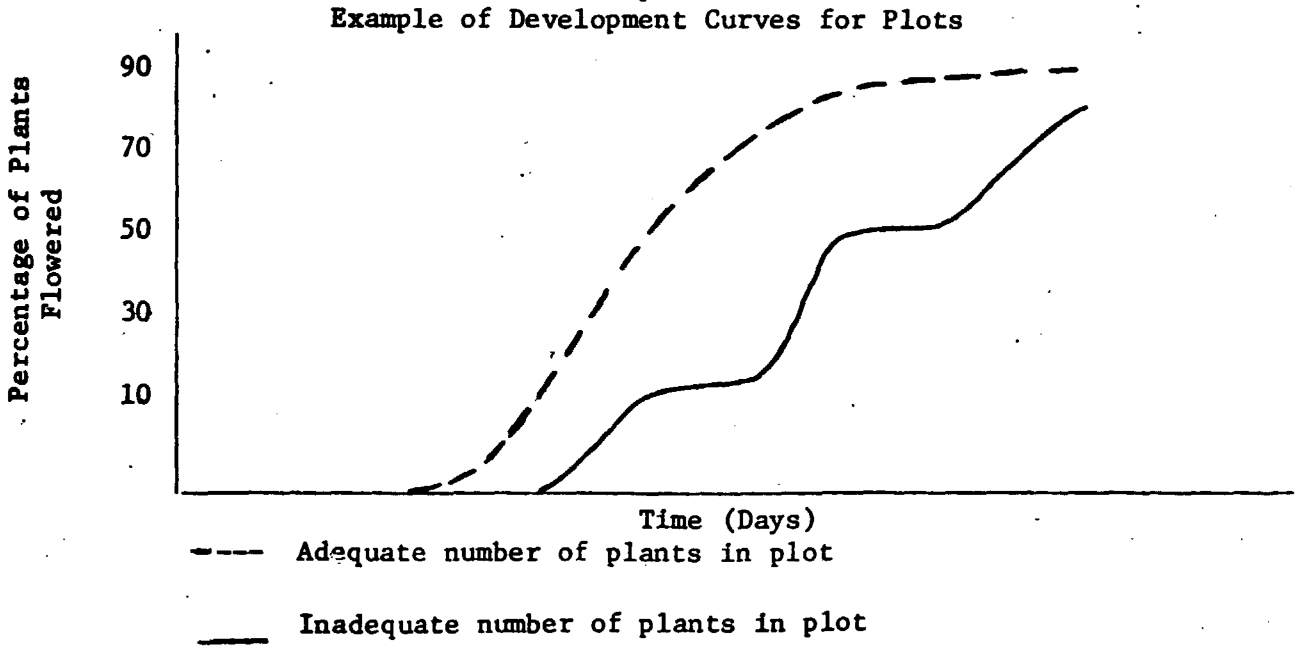
Table 2: Comparison of Estimated 50% Dates Using Six Different Methods

Method	Flowering		Setting Bolls		Open Bolls	
	Field 1	Field 3	Field 1	Field 3	Field 1	Field 3
1	July 6	July 1	July 7	July 3	Aug 18	Aug 17
2	July 6	July 2	July 7	July 3	-	Aug 17
3	July 6	July 1	July 7	July 2	Aug 19	Aug 16
4	July 5	July 1	July 7	July 2	-	Aug 16
5	July 5	July 2	July 7	July 3	Aug 19	Aug 18
6	July 5	July 2	July 7	July 3	-	Aug 18

The approximate 95% conficence interval widths for the field 1 estimated dates are about ± 2 days. The field 3 interval widths are about ± 4 days for flowering and setting of bolls and ± 6 days for opening of bolls.

One possible reason for the higher variability in field 3 is that the plant population in field 3 is about half that of field 1. This suggests that sparce fields are more variable or that the plots did not contain an adequate number of plants. If the plant count is low, irregular development curves are produced as shown in graph 1. At least 25 plants/plot are needed to smooth the curve and produce better estimates of the 50% dates.

Graph 1
Example of Development Curves for Plots



A further reduction in the interval widths may be produced by increasing number of plots as shown in Table 3, which assumes a 95% confidence interval width of ± 4 days with 8 plots.

Table 3: Plot Number Requirements to Reduce CI Width to ± d (=days) for 50% Dates

n	d
12	3.4
15	3
34	2
59	1.5
133	1

Weekly visits were considered versus the semi-weekly visits used in the 1977 study as a cost reduction method. Estimated 50% dates using the weekly data were no more than one or two days different from the original estimates and the standard errors were very similar. Weekly visits are being planned for the continuation of the study.

Plant Heights

Estimates of average plant height were made based on eight plants measured in each plot on each visit to the field. The relative standard error for the field 1 estimates were consistent at about 7% for all visits. In field 3, the relative standard error decreased from almost 12% for the first visit to 4% for the visits later in the season. Assuming variability similar to that of field 1, Table 4 shows how varying plot numbers would change the relative standard error.

Table 4: Number of Plots vs. Relative Standard Errors of Mean Plant Height

n	Relative St. Error%
12	6
16	5
24	4

If cost cutting is again considered the analysis showed that the number of plants measured could be reduced from eight to four without greatly influencing the standard error of mean height. Another method of obtaining plant height data for less cost did not succeed. The enumerators were trained to estimate the average plant height in a subplot by observation. However, plant heights estimated by field enumerators through observation tested to be significantly higher than the measured plant heights in both fields. Another year of data will be collected to further test the sighting technique.

Canopy Coverage

The amount of canopy coverage or shadow cover was estimated at each visit using a grid covering the area in a two row by 4 foot unit. The field 3 canopy coverage data appeared to be of reasonably good quality. Table 5 shows that the percent of ground cover did gradually increase through the season as the plants obtained more leaves; however, complete canopy coverage was never reached. The relative standard error of these percent coverage estimates decreases from 19% for the first visit to about 4% later in the season.

Table 5: Percent Canopy Coverage in Field 3 by Visit

Visit	Estimate	Standard Error	Relative St. Error%
1	33	6.3	19
2	37	4.8	13
4	50	4.0	8
5	48	2.2	5
6	48	2.9	6
7	54	2.1	4
8	56	2.6	5
9	59	2.3	4
12	68	2.3	3
14	65	6.0	9

For the 1978 study additional emphasis will be made on collecting the data at approximately 12-1 o'clock on every visit. The enumerator in field 1 did not follow this rule.

Plant Mapping

The plant mapping data consists of estimates of the average number of branches, squares, open bolls, etc. on a plant in the field by visit. The specific variables summarized consist of those shown in Table 6. The results are shown in Table 7.

Table 6: Variables Estimated Using Plant Mapping Data

Variable	Description
Branches	fruiting branches
Squares	nodes that produced squares
Sqs-Abs	squares that abscised
Sqs-Boll	squares that produced a boll
Open-Boll	set bolls that opened
Boll-Abs	set bolls that abscised
Boll-Hrv	bolls harvested by hand (including large unopen and partially open bolls)
Veg-Brch	vegetative branches

Table 7: Plant Mapping Estimates and Relative Standard Errors

	Field 1			Field 2			Field 3		
Variable	Est.	Std. Error	Rel. Std. Error%	Est.	Std. Error	Rel. Std. Error%	Est.	Std. Error	Rel. Std. Error%
Branches	6.31	0.44	7	10.41	0.72	7	11.06	0.54	5
Squares	9.31	0.84	9	21.31	2.36	11	22.03	2.04	9
Sqs-Abs	2.44	0.20	8	12.63	1.73	14	5.88	1.33	23
Sqs-Boll	6.25	0.79	13	6.84	0.94	14	12.84	0.87	7
Open-Boll	1.78	0.26	15	0.84	0.16	19	1.13	0.51	45
Boll-Abs	2.44	0.43	18	3.56	0.48	13	4.97	0.65	13
Boll-Hrv	3.19	0.42	13	3.06	0.50	16	6.97	0.66	10
Veg-Brch	0.28	0.11	39	0.75	0.15	20	0.91	0.19	21

Data collection problems had some effect on the estimates made from plant mapping data last year. This is especially true of the estimated number of open bolls, which is lower than expected in all three fields. Regardless, the data still provides estimates of the variability associated with these estimates which is of primary concern at this time. The relative standard errors associated with these estimates are high compared to the other data collected in the study. Table 8 shows the reduction in the relative standard error as the number of plots is increased. This assumes a relative standard error of 15 % with 8 plots in the field which is an average taken from last year's data.

Table 8: Number of Plots vs. Relative Standard Error for Plant Mapping Data

n	Relative Standard Error%
12	12
16	11
24	9
36	7

Insect Damage Counts

Estimates of an abscission rate per plant due to insect damage for squares, unopen bolls and open bolls were also made. These estimates along with approximate 95% confidence intervals are shown in Table 9. The estimate of total square abscission from these counts is low compared to the abscission rate from the plant mapping data. It is highly unlikely that field enumerators could find all of the small squares that had fallen on the ground. Thus, the estimated abscission rate due to insect damage may also be low.

Table 9: Estimated Abscission Rates per Plant Due to Insect Damage and Approximate 95% Confidence Interval

	Squares	Unopened Bolls	Opened Bolls
Field 1	0.226 ± 0.137	0.068 ± 0.047	0
Field 3	0.336 ± 0.258	0.215 ± 0.215	0

The confidence intervals are relatively wide in terms of the magnitude of the estimate. It would take much larger plots than we are able to use, for cost reasons, to obtain relatively accurate estimates. These estimates do provide an idea of the amount of abscission due to insect damage. In last year's study this loss appears to be small in all cases.

IV Plans for 1978

The evaluation study will be continued in 1978 in three Mississippi cotton fields. Based on the review of last year's data and cost constraints, twenty-four plots, to be visited weekly, will be located in each field. These plots will be at two levels of intensity.

In the twelve intensive plots, data will be collected to estimate all the variables in the study. Several major sampling changes will be made in the procedure from last year. In order to observe an adequate number of plants in each plot to permit reliable 50% date estimates, plot size will be variable. To reduce the variability in the field level plant estimates, only plant mapping data will be collected in the remaining twelve plots. These modifications should permit a complete and reliable data set to be collected.

REFERENCE

[1] Kelly, B. W. and Kirkbride, J. W., Forecasting Crop Yields, presented at Seminar on Weather and Our Food Supply, sponsored by the Center for Agricultural and Economic Development, Iowa State University, Ames, Iowa, May 4-6, 1964.