2. # AgRISTARS

7. FC-LO-00493 CR-161022
JSC-16820

NOV 12 1980

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

Foreign Commodity Production Forecasting

6. October 1980

5. NAS9-15800

SEGMENT-LEVEL EVALUATION OF THE SIMULATED AGGREGATION TEST: U.S. CORN AND SOYBEAN EXPLORATORY EXPERIMENT

NASA CR-161022

3. S. A. Davidson

(E82-10061) SEGMENT-LEVEL EVALUATION OF THE SIMULATED AGGREGATION TEST: US CORN AND SOYBEAN EXPLORATORY EXPERIMENT (Lockheed Engineering and Management) 26 p
HC A03/MF A01
CSCL 02C G3/43

N82-19636
Unclas
00061

4. Lockheed Engineering and Management Services Company, Inc.
1830 NASA Road 1, Houston, Texas 77058

Lyndon B. Johnson Space Center
Houston, Texas 77058

FC-LO-00493
JSC-16820

SEGMENT-LEVEL EVALUATION OF THE SIMULATED AGGREGATION TEST: U.S. CORN AND SOYBEAN EXPLORATORY EXPERIMENT

Job Order 74-402

This report describes Accuracy Assessment Activities of the Foreign Commodity Production Forecasting project of the AgRISTARS program.

PREPARED BY

S. A. Davidson

APPROVED BY

M. D. Pore, Supervisor
Accuracy Assessment Section

B. L. Carroll, Manager
Commodity Forecasting Department

LOCKHEED ENGINEERING AND MANAGEMENT SERVICES COMPANY, INC.

Under Contract NAS 9-15800

For

Earth Observations Division

Space and Life Sciences Directorate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

October 1980

LEMSCO-15116

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FC-LO-00493; JSC-16820		

4. Title and Subtitle	5. Report Date
Segment-Level Evaluation of the Simulated Aggregation Test	October 1980
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
S. A. Davidson Lockheed Engineering and Management Services Company, Inc.	LEMSCO-15116
	10. Work Unit No.
9. Performing Organization Name and Address	
Lockheed Engineering and Management Services Company, Inc. 1830 NASA Road 1 Houston, Texas 77058	11. Contract or Grant No. NAS 9-15800
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Report
National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058 Tech. Monitor: R. O. Hill	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An evaluation of the corn and soybean proportion-estimation accuracy and dot labeling accuracy of the Simulated Aggregation Test, U.S. Corn and Soybean Exploratory Experiment, is presented. These results are in turn compared with the corn and soybean proportion-estimation accuracy and dot labeling accuracy of the Classification Procedures Verification Test.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
U.S. Corn and Soybean Exploratory Experiment Classification Procedures Verification Test, proportion-estimation accuracy, dot labeling accuracy, corn and soybean labeling procedure	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	25	

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The Simulated Aggregation Test (SAT): U.S. Corn and Soybean Exploratory Experiment was executed (1) to determine the labeling accuracy obtainable with the current corn and soybean labeling procedure and to determine the crop proportion-estimation errors of the resulting proportion estimates; (2) to compare the corn and soybean labeling procedure utilized in the SAT with that utilized in the Classification Procedures Verification Test (PVT) via a comparison of the labeling accuracy and the proportion-estimation errors of the two procedures; and (3) to test the aggregation logic for obtaining crop area and production estimates at state and regional levels. This report presents the results of (1) and (2).

The design of the SAT called for three analyst-interpreter (AI) groups (two from NASA and one from Lockheed) to label 50 to 70 Type I dots on each of 88 segments located in 5 agro-physical units (APU's) in 6 states of the U.S. Corn Belt. Each segment was to be labeled once only using a modified version of the corn and soybean labeling procedure utilized in the PVT (refs. 1 and 2).

Of the 88 segments labeled, 23 were a subset of the 29 blind sites processed in the PVT; 35 were additional blind sites; and the remaining 30 were nonblind sites. All the 23 segments in the SAT that were also processed in the PVT (hereafter referred to as Group 1 segments) had digitized ground truth available. Of the additional 35 blind sites (hereafter referred to as Group 2 segments), 18 had digitized ground truth available, and the remaining 17 had 400-dot ground truth available.

Since the NASA groups had already seen the ground truth for the Group 1 segments, it was stipulated that these 23 segments would be processed by the Lockheed group. Otherwise, there were no constraints on the assignment of segments to the AI groups. Table 1-1 shows the assignment of the blind sites to the APU's and AI groups.

2. ANALYSIS OF THE SIMULATED AGGREGATION TEST

Analyses were made to investigate the crop proportion-estimation accuracy and dot-labeling accuracy in the SAT as well as to compare the crop proportion-estimation accuracy and dot-labeling accuracy of the SAT with that of the PVT.

2.1 CROP PROPORTION-ESTIMATION ACCURACY IN THE SIMULATED AGGREGATION TEST

Initially, a linear model of the form

$$\hat{P}_{ijk} - P_{ijk} = u + A_i + G_j + (AG)_{ij} + \varepsilon_{(ij)k}$$

was assumed where

$\hat{P}_{ijk}$ = the proportion estimate of the crop of interest for the k^{th} segment of the i^{th} APU, labeled by the j^{th} group

P_{ijk} = the corresponding ground truth proportion

u = the overall mean difference

A_i = the effect of the i^{th} APU (fixed)

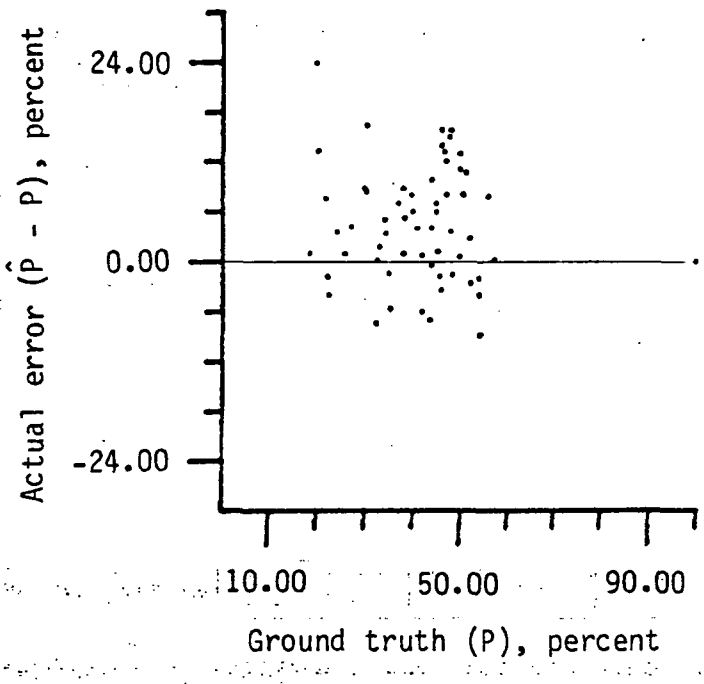
G_j = the effect of the j^{th} group (random)

$(AG)_{ij}$ = the interaction of the i^{th} APU and the j^{th} group (mixed)

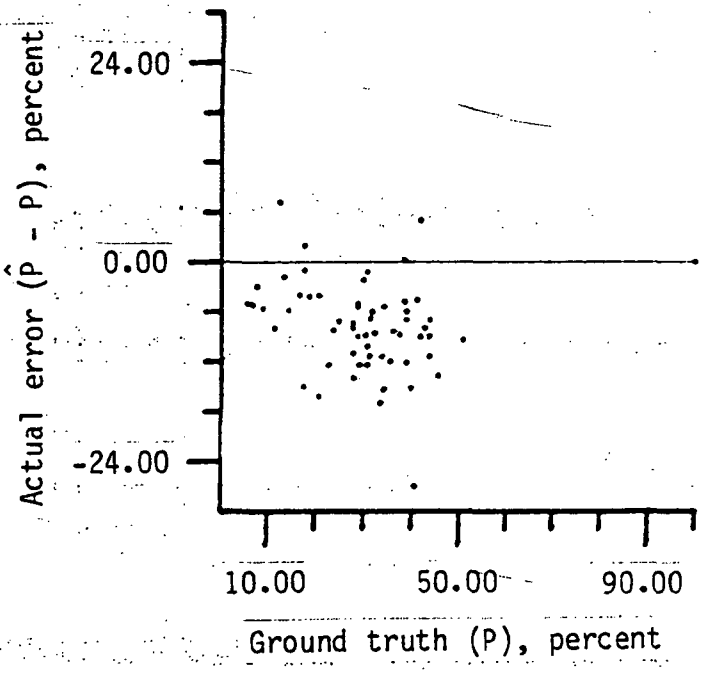
$\varepsilon_{(ij)k}$ = the random error resulting from the k^{th} segment of the i^{th} APU, labeled by the j^{th} group, assumed $NID(0,\sigma^2)$.

However, for the crops of interest (corn and soybeans), the model accounted for less than 29 percent of the observed variation. (Table 2-1 gives the coefficient of determination, R^2, for each crop.) Hence, the analyses were performed without regard to APU or group effects.

Plots of ground truth proportions (abscissa) versus crop proportion-estimation error (ordinate) are displayed in figures 2-1(a) for corn and 2-1(b) for soybeans. Overestimation of corn and underestimation of soybeans are clearly evident, a pattern that also emerged in the PVT (ref. 3).



(a) Corn.



(b) Soybeans.

Figure 2-1.- Crop proportion-estimation accuracy for the SAT.

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absolute value of the proportion-estimation error (absolute error) of each Group 1 segment with the mean absolute error of the corresponding PVT segment by means of the difference: mean absolute error minus absolute error.

The hypothesis of a mean difference of zero versus all alternatives was then tested ($\alpha = 0.05$). The results, displayed in table 2-4, show no significant difference in the proportion-estimation accuracy of corn; however, soybeans were underestimated to a significantly greater degree in the Group 1 segments (a mean difference of -2.60 percent).

2.2.2 COMPARISON OF THE GROUP 2 SEGMENTS WITH THE CLASSIFICATION PROCEDURES VERIFICATION TEST

The analysis for the comparison of the Group 2 proportion-estimation accuracy with the PVT proportion-estimation accuracy consisted of testing the hypothesis that the mean error of the PVT segments minus the mean error of the Group 2 segments was significantly different from zero ($\alpha = 0.05$) versus all alternatives. Table 2-5 displays the results of this test. Corn was overestimated to a significantly greater degree and soybeans underestimated to a significantly greater degree in the Group 2 segments.

2.3 LABELING ACCURACY OF THE SIMULATED AGGREGATION TEST

Tables 2-6(a) through 2-6(c) display, for all blind sites for the Group 1 segments and all blind sites for the Group 2 segments, the percentage of a given crop category labeled "corn," "soybeans," and "other" (neither corn nor soybeans). With errors of omission being essentially equal for corn and soybeans, the confusion errors for Group 1 and Group 2 together [table 2-6(a)] indicate that the AI groups could recognize corn signatures more readily than soybean signatures. This failure to discriminate soybeans from corn is due to late planting of soybeans, making the signatures of these late planted soybeans spectrally inseparable from corn. As a result, corn is overestimated and soybeans underestimated.

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TABLE 2-6.- DISTRIBUTION OF LABELS WITHIN EACH GROUND TRUTH CATEGORY

(a) All SAT blind sites

Ground truth	Label			Ground truth proportion, percent
	Corn, percent	Soybeans, percent	Other, percent	
Corn	92.58	1.62	5.80	43.36
Soybeans	6.87	87.58	5.54	30.25
Other	2.92	1.14	95.93	26.39

(b) Group 1 blind sites

Ground truth	Label			Ground truth proportion, percent
	Corn, percent	Soybeans, percent	Other, percent	
Corn	88.25	1.77	9.98	44.00
Soybeans	7.97	83.33	8.70	26.93
Other	3.69	2.35	93.96	29.07

(c) Group 2 blind sites

Ground truth	Label			Ground truth proportion, percent
	Corn, percent	Soybeans, percent	Other, percent	
Corn	94.89	1.54	3.56	43.03
Soybeans	6.39	89.46	4.15	31.99
Other	2.45	0.41	97.14	24.99

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reducing the underestimation of soybeans, indicating that committing soybeans with corn has a greater impact on soybean proportion-estimation accuracy than the mislabeling of soybeans as "other."

2.4 COMPARISON OF THE DOT-LABELING ACCURACY OF THE SIMULATED AGGREGATION TEST AND THE CLASSIFICATION PROCEDURES VERIFICATION TEST

Dot-labeling accuracy for the PVT, the Group 1 segments, the Group 2 segments, and the Group 1 and Group 2 segments combined is displayed in table 2-7. Overall, the labeling accuracy of the SAT improved over that of the PVT, with the labeling accuracy of the Group 2 segments contributing the most to this improvement. However, since dot-labeling accuracy data at the segment level was available only for the Group 1 segments, it was not possible to determine if the improvement in labeling accuracy for the Group 2 segments was significant.

The labeling accuracy of each Group 1 segment was compared with the mean labeling accuracy of the corresponding PVT segment by subtracting the Group 1 figures from the corresponding PVT figures. The null hypothesis of a mean difference of zero was tested against all alternatives ($\alpha = 0.05$). The results are given in table 2-8.

Since each of the 95 percent confidence intervals contains zero, the null hypothesis that the mean difference in labeling accuracy between the PVT segments and the SAT Group 1 segments is zero could not be rejected.

2.5 ANALYST-INTERPRETER LABELED, TYPE I DOT PROPORTION ESTIMATES

Crop proportion estimates of corn and soybeans were made for each blind site by using the proportion of dots labeled corn and the proportion of dots labeled soybeans. Figures 2-2(a) for corn and 2-2(b) for soybeans display plots of ground truth proportions versus the dot proportion-estimation error.

In table 2-9, the mean errors of the machine-classified estimates and the dot estimates are displayed. For both corn and soybeans, the Type 1 dots, as a random sample, produced smaller estimation errors, with the dot-estimation

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TABLE 2-9.- CLASSIFICATION ERRORS OF THE SAT

Source of classification	Corn			Soybeans		
	Mean error, percent	Standard deviation, percent	Mean square error	Mean error, percent	Standard deviation percent	Mean square error
Machine classification	[a]4.58	6.95	68.38	[a]-7.81	5.57	91.54
Type 1 dots as random sample	1.91	8.32	71.72	[a]-6.62	6.91	90.86

[a]Significantly different from zero ($\alpha = 0.05$).

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error for corn not significantly different from zero, although the estimate of soybeans is biased. However, the mean square errors for the two types of classification are not appreciably different, indicating that if the dot estimates are not better than the machine-classified estimates, then certainly they are no worse.

To compare the types of classification, two procedures were used. The first procedure, utilizing the binomial test, was to investigate whether or not one type of classification tended to yield superior estimation accuracy over the other. The first step in this procedure was determining the proportion of segments for which the dot estimates produced smaller, absolute deviations from ground truth. (See "Improved," table 2-10.) Then the null hypothesis that this proportion was not significantly different from 50 percent ($\alpha = 0.05$) was tested. For both corn and soybeans, the null hypothesis was not rejected. In other words, machine classification is no more likely to yield accurate estimates than a random sample of Type 1 dots.

To further qualify the comparison, the mean improvement of machine-classified estimates over dot estimates (see table 2-10) was obtained by finding the mean, on a segment-by-segment basis, of the absolute deviation from ground truth of the machine-classified estimate minus the absolute deviation from ground truth of the dot estimate. The null hypothesis of no significant improvement ($\alpha = 0.05$) was tested. The null hypothesis could not be rejected.

Thus, machine classification does not improve upon a random sample of Type 1, analyst-labeled dots whether measured as a reduction of mean square error, a likelihood of yielding more accurate estimates, or a mean difference in estimation accuracy.

3. SUMMARY OF RESULTS

The following results emerged from the evaluation of the SAT:

1. Corn was significantly overestimated on an average of 4.58 percent per segment (standard deviation, 6.95 percent), and soybeans were significantly underestimated on an average of 7.81 percent per segment [standard deviation, 5.57 percent (table 2-2)].

2. When comparing the proportion-estimation accuracy of the Group 1 SAT segments with the PVT segments, no significant difference emerged for corn; however, soybeans were underestimated to a significantly greater degree in the SAT segments (table 2-4).

3. When comparing the proportion-estimation accuracy of the Group 2 SAT segments with the PVT segments, corn was overestimated to a significantly greater degree and soybeans underestimated to a significantly greater degree in the SAT segments (table 2-5).

4. The labeling accuracy of the Group 2 segments was higher than that of the Group 1 segments as a result of fewer corn and soybean dots being mislabeled as "other" in the Group 2 segments [tables 2-6(b) and 2-6(c)].

5. In the SAT, more soybeans were labeled corn than corn, soybeans. This was caused by the spectral inseparability of late planted soybeans from corn [tables 2-6(a) through 2-6(c)].

6. The spectral inseparability of late planted soybeans from corn resulted in the overestimation of corn and underestimation of soybeans.

7. Since fewer corn and soybean dots were mislabeled "other" in the Group 2 segments (as compared with the Group 1 segments), the estimation of corn was further inflated, although the reduction in mislabeling had little effect on the soybean proportion estimates [tables 2-6(b) and 2-6(c)].

8. Overall, labeling accuracy in the SAT improved over that in the PVT. However, there was no significant difference in labeling accuracy between the PVT and Group 1 segments (tables 2-7 and 2-8).

4. RECOMMENDATIONS

An alternate machine classification technique should be developed since the procedure used in this experiment did not improve upon a random sample of analyst-labeled, Type 1 dots. Methods should also be developed to compensate for the adverse effect that late planted soybeans have upon corn and soybean proportion-estimation accuracy.

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FC-LO-00493
JSC-16820

"Segment-Level Evaluation of the Simulated Aggregation Test: U.S. Corn and Soybean Exploratory Experiment"

October 31, 1980

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