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Inventory Technology Development

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
April 15, 1982

SEM:-ANNUAL PROGRAM REVIEW PRESENTATION TO LEVEL 1, INTERAGENCY COORDINATION COMMITTEE

Lyndon B. Johnson Space Center
Houston, Texas 77058
THIS IS THE FIFTH SEMI-ANNUAL PRESENTATION OF THE INVENTORY TECHNOLOGY DEVELOPMENT (ITD) PROJECT STATUS TO AGRISTARS LEVEL 1, INTERAGENCY COORDINATION COMMITTEE ON APRIL 19-20, 1982. IT REPRESENTS ACCOMPLISHMENTS FROM OCTOBER 1, 1981 THROUGH MARCH 30, 1982.

JON D. ERICKSON
ITD PROJECT MANAGER
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OVERVIEW OF AN EXTREMELY SUCCESSFUL FCPF PERIOD
(APRIL-SEPTEMBER 1981)

FCPF DEVELOPED PROCEDURES WERE SHOWN IN PILOT TESTS

- TO BE HIGHLY EFFICIENT ("USER ACCEPTABLE") WHILE PRODUCING POST-HEADING U.S./CANADIAN SSG'S CROP ESTIMATES WITH ACCURACIES (WITHIN 3-1/2 TO 9% OF USDA) COMPARABLE TO THE BEST PREVIOUS SSG'S PROCEDURE.
- TO PRODUCE ACCURATE POST-TASSELING SUMMER CROP ESTIMATES IN CENTRAL U.S. CORN BELT WITH SIGNIFICANT BIAS FOR CORN AND SOYBEANS ONE OF TWO YEARS.

PROGRESS IS BEING MADE ON KEY TECHNICAL PROBLEMS

- MODELING OF CROP SIGNATURES (SPATIAL/SPECTRAL/MULTI-TEMPORAL)
- TREATMENT OF BOUNDARY PIXELS
- ASSESSMENT OF LONG-TERM EFFECTS OF CLOUD COVER AND SATELLITE FREQUENCY
- YEAR-TO-YEAR AREA CHANGE DETECTION METHODOLOGY
- FOREIGN PERFORMANCE PREDICTION MODELING AND SIMULATION

IMPORTANT UNDERSTANDING OF FOREIGN CROP REGIONS BEING OBTAINED FOR

- AUSTRALIA
- ARGENTINA
- BRAZIL
OVERVIEW OF ITD ACCOMPLISHMENTS AND CHANGES  
(October 1981-March 1982)

- ITD continued to build on accomplishments of previous period
  - Further quantified major source of SSG errors to be in acquisition selection - associated with satellite overpass frequency and cloud cover.
  - Significant improvement made in accuracy and efficiency of post-tasseling corn and soybeans procedures.
  - Began to extend technology to include winter small grains for USSR applicability.

- Progress continues to be made on key technical problems.

- Promising preliminary results have been obtained for new approaches to area estimation
  - Early season
  - Change estimation

- The goals of foreign applicable technology and understanding to support satellite and sensor systems definition have been retained.

- Testing over regions and years of significant variability, which was believed to be important to understanding the direction of reliable technology development, has been reluctantly deleted.
CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT

- SMALL GRAINS

  + SENSITIVITY STUDIES OF SSG 3B/3C AND SSG4 IN PROGRESS

  - QUANTIFIED IMPACT OF ACQUISITION SELECTION AND SSG3B/C PERFORMANCE
    - IMPROVED ACQUISITION SELECTION DECREASED MAE FROM 8.5% TO 5.1%
      AND INCREASED R^2 FROM .68 TO .89 RELATIVE TO GROUND TRUTH
      PROPORTIONS. R^2 FOR PROBLEM YEAR (1979) INCREASED FROM .35
      TO .79
    - PROCESSABILITY UNCHANGED (REMAINS HIGH 58%)
  - QUANTIFIED IMPACT OF MINOR SOFTWARE PROBLEMS ON SSG4 TEST RESULTS
    - DECREASE MAE FROM 8.7% TO 8.4% AND R^2 FOR PROBLEM YEAR 1979
      INCREASED FROM .41 TO .68.
    - EFFECT OF IMPROVED ACQUISITION SELECTION ON SSG4 NOT STUDIED,
      BUT ASSUMED TO BE SIMILAR TO SSG 3P/C
  - DATA BASES FOR 2 REMAINING SENSITIVITY STUDIES COMPLETE
    - DETAILED LABELING STUDIES
    - 4 PROCEDURE AGGREGATION STUDY (ALL 32 AGGREGATIONS COMPLETED)
  - ALL OTHER PLANNED SENSITIVITY STUDIES DELETED
SMALL GRAINS

- DEVELOPED INITIAL APPROACH AND COMPLETED FEASIBILITY TESTS FOR AN EARLY SEASON (PRE-TILLERING) DIRECT SPRING SMALL GRAINS PROPORTION ESTIMATOR (SSG5)

- 45 SEGMENTS OVER 3 YEARS (76, 78, 79)
- PERFORMANCE CHARACTERISTICS COMPARABLE WITH AT HARVEST RESULTS, OBTAINED IN SPRING SMALL GRAINS PILOT (RME = 4.9%, STANDARD DEV. = 9.1%, $R^2 = .68$)
- APPROACH AMENABLE TO CURRENT FCCAD ENVIRONMENT

- INITIATED DEVELOPMENT OF SG1 AND MC3 - EXTENSIONS OF THE PREVIOUSLY REPORTED SSG3 AND SSG4 AUTOMATED LABELING AND PROPORTION ESTIMATION PROCEDURE TO INCLUDE WINTER SMALL GRAINS.
CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

CORN/SOYBEANS/SUMMER CROPS

+ C/S 1B - A SEMIAUTOMATED ERIM EXTENSION OF C/S 1

- (78-79) DEFINITION TEST (20 SEGMENTS) INDICATED DESIRED ACCURACY IMPROVEMENTS
- 1980 SENSITIVITY TEST (IOWA-69 SEGMENTS, 27 WITH GT) RESULTS WITHIN 11% RME FOR CORN, SOYBEANS AND SUMMER CROPS (STANDARD ERROR ALSO LOW: 3 TO 9%)
- EFFICIENCY MUCH IMPROVED
- PROCESSABILITY REMAINS HIGH (64%)
- AUTOMATION OF REMAINING STEPS IN DEVELOPMENT
- EVALUATION OF ALTERNATIVE LABELING TARGET DEFINITION (BLOB DOT RELOCATION, MIXTURE DECOMPOSITION) UNDERWAY
CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- CORN/SOYBEANS/SUMMER CROPS (CONTINUED)

  - MC2B - FULLY AUTOMATED (LEMSCO) ADAPTATION OF SSG 4 TYPE TECHNOLOGY
    - 78-79 DEFINITION TEST COMPLETE
    - 1980 SENSITIVITY TEST (IOWA) RESULTS SHOWED LARGE SUB-REGIONAL BIAS PREVIOUSLY UNDETECTED IN 78-79 RESULTS

  - SEMIAUTOMATED CS1B TECHNOLOGY SELECTED FOR FURTHER (ILLINOIS, INDIANA 1980 DATA) SENSITIVITY TESTING

  - CONDUCTED AN ASSESSMENT OF SR CS4 TECHNOLOGY IMPLEMENTATION STATUS AND RECOMMENDED ISSUES TO SR FOR RESOLUTION
CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- LARGE UNIT PROPORTION ESTIMATION
  
  + ALTERNATE APPROACH BEING INVESTIGATED
    
    - BASED ON SSG 4 TYPE TECHNOLOGY EXTENDED TO AGRICULTURAL REGIONS (RATHER THAN FIELDS) FOR WINTER/SPRING SMALL GRAINS AND SUMMER CROPS
    
    - APPROACH AMENABLE TO CURRENT FCCAD ENVIRONMENT
      
      . PRECISE REGISTRATION NOT REQUIRED
      . USES SKIP SAMPLED FULL FRAME DATA
FEATURE IDENTIFICATION/SIGNATURE CHARACTERIZATION

- SMALL GRAINS
  - SPECTRAL AND METEOROLOGICAL DATA SETS DEFINED FOR AUSTRALIA AND USSR RESEARCH
    - GROUND TRUTH FROM 2 CROP YEARS NOW AVAILABLE FOR AUSTRALIA
      (ALSO SELECTED OBS FROM 2 OTHER YEARS)
  - FSR DATA SETS SELECTED FOR SG1 AND MC3 DEVELOPMENT
  - SOFTWARE DEVELOPED TO FIND EXPECTED TEMPORAL/SPECTRAL CROP SIGNATURES AND THEIR VARIANCES
FEATURE IDENTIFICATION/SIGNATURE CHARACTERIZATION (CONTINUED)

- CORN/SOYBEANS
  + INVESTIGATION ACCOMPLISHED FROM SR FIELD MEASUREMENTS DATA BASE ON RELATIONSHIP OF CORN AND SOYBEANS PROFILE FEATURES TO CROP DEVELOPMENT STAGE CULTURAL FEATURES, AND STRESS (ERIM)
    - CORN EXHIBITS A GREENNESS PLATEAU DURING THE CROP YEAR NOT SEEN IN SOYBEANS OR SMALL GRAINS
    - CORN ACHIEVED PEAK GREENNESS PRIOR TO PEAK LAI, TASSELING, EXPLAINABLE BY CANOPY STRUCTURE
    - SOYBEAN PROFILE FEATURES MORE CORRELATED WITH CANOPY CLOSURE THAN VEGETATIVE STAGES. THIS IS PROBABLY DUE TO INDETERMINATE NATURE OF PLANT REPRODUCTIVE CYCLE.
  + EXCELLENT DISCRIMINATION BETWEEN CORN AND SOYBEANS ACHIEVED BY USE OF A PEAK GREENNESS FEATURE AND THE PLATEAU IN GREENNESS OF CORN (FIELD MEASUREMENT DATA)
    - ANALYSIS OF EXTENSION TO LANDSAT MSS INITIATED
  + EXAMINATION OF LIMITED U.S. DATA INDICATES RELATIVE BRIGHTNESS APPEARS TO PLAY IMPORTANT ROLE IN SUNFLOWER SEPARABILITY (UCB)
    - ARGENTINA LANDSAT AND GROUND DATA NOW AVAILABLE FOR STUDY.
AREA CHANGE ESTIMATION METHODOLOGY

- COMPLETED PRELIMINARY STUDY/ANALYSIS IN USSR INDICATING THE LEVEL OF PERFORMANCE (VARIANCE) IN CHANGE ESTIMATION AS A FUNCTION OF SAMPLE SIZE
  - APPROACH TAKES ADVANTAGE OF YEAR-TO-YEAR CORRELATION
  - APPROXIMATELY 25% TO 30% REDUCTION IN NUMBER OF REQUIRED SEGMENTS FOR CHANGE ESTIMATOR

+ DEVELOPED PROFILE CHANGE APPROACH
  - APPROACH MEASURES YEAR-TO-YEAR CHANGE IN VEGETATIVE AREA TO ESTIMATE CROP AREA
  - INITIAL FEASIBILITY STUDY ENCOURAGING: COMPARISON WITH SSG 4 OVER 9 COMMON SEGMENTS INDICATED MEAN ERROR IN ESTIMATED CHANGE REDUCED FROM +6.2% TO -1.2%; STANDARD DEVIATION REDUCED FROM 16.1% TO 3.6%. 

1-10
SAMPLING AND AGGREGATION TECHNOLOGY DEVELOPMENT

+ INITIATED EVALUATIONS OF ADVANCED AGGREGATION TECHNOLOGIES (FOUR AGGREGATION PROCEDURES.
  - SINGLE YEAR VS. MULTIYEAR; SIMPLE RATIOING FOR MISSING STRATA VS. MATHEMATICALLY OPTIMAL ADJUSTMENT
  - AGGREGATIONS COMPLETED, EVALUATIONS UNDERWAY

+ DEVELOPED PARTIAL RESPONSE MODEL (TAMU)
  - ALLOWS AGGREGATION OF SEGMENTS HAVING CROP GROUP ESTIMATES WITH THOSE HAVING CROP TYPE ESTIMATES
  - RECOVERS APPROXIMATELY 50% OF THE VARIANCE INCREASE PREVIOUSLY DUE TO DELETION OF CROP GROUP ONLY ESTIMATES
  - COMPLETION OF VARIANCE ESTIMATOR DELAYED

+ INITIATED INVESTIGATION OF A PROCEDURE FOR AUTOMATED DYNAMIC STRATIFICATION ORIENTED TO DETECTION OF CHANGE AND CONDITION ASSESSMENT.
FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION

+ AGRICULTURE INFORMATION SYSTEM SIMULATOR
  - COMPLETED DEFINITION TESTING OF ACQUISITION HISTORY SIMULATION MODULE
  - TESTED OVER U.S. NORTHERN GREAT PLAINS FOR 76-77
  - 143 SEGMENT/LOCATIONS
  - SIMULATION APPEARS HIGHLY REALISTIC

  - INITIATED DEVELOPMENT OF SEGMENT LEVEL PROPORTION ESTIMATION AND
    PROPORTION ESTIMATION ERROR SIMULATION MODULES
  - DELETED DEVELOPMENT OF SEGMENT LEVEL MSS SIMULATOR

+ MULTI-SATELLITE/SENSOR INFORMATION CONTENT SIMULATOR
  - IN USE TO INVESTIGATE COMBINATIONS OF ORBITS/SENSORS BEST SUITED TO
    DETECT AND QUANTIFY AGRICULTURAL PARAMETERS (ERIM)

+ PREPARED AND SUBMITTED TM PROPOSAL, PARTICIPATED IN APPLICATIONS NOTICE
  PROPOSAL EVALUATIONS AND SCOPE ITD TM DATA REQUIREMENTS

+ FORMED ITD LANDSAT-D WORKING GROUP (JSC/ERIM/UCB/LEMSCO) TO DEVELOP
  IMPLEMENTATION PLAN FOR ERAD LANDSAT-D/TM PROPOSAL
FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION (CONTINUED)

+ EXPLORATION OF COMBINED LANDSAT/SEASAT USE FOR CROP INVENTORY UNDERTAKEN (ERIM)

- SCIENTIFIC BREAKTHROUGH IN REMOVAL OF SPECKLE FROM SAR DIGITAL DATA

- ARTIFICIAL INTELLIGENCE APPROACH USED TO DETERMINE KEY RADAR FEATURES.
  FEATURES CALLED TONE AND TEXTURE FOUND TO BE CORRELATED TO CORN AND SOYBEAN CANOPY STRUCTURAL FEATURES.

- TECHNICAL BREAKTHROUGH IN ABILITY TO EXTRACT TEXTURE INFORMATION WITHOUT LOSS OF SPATIAL RESOLUTION

- COMBINED LANDSAT/SEASAT DATA PERMIT CORN/SOYBEAN DISCRIMINATION 6 WEEKS PRIOR TO DISCRIMINATION WITH LANDSAT ALONE

+ CONDUCTED A PRELIMINARY SHUTTLE IMAGING RADAR-A (SIR-A) ANALYSIS IN AUSTRALIA AND COLLECTED COMPLEMENTARY GROUND OBSERVATIONS.

- SIGNIFICANT AGRICULTURE INFORMATION APPARENT, FURTHER STUDY PLANNED.
FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION (CONCLUDED)

* INITIATED INVESTIGATION OF USE OF ENVIRONMENTAL SATELLITE TYPE DATA FOR AREA ESTIMATION (COORDINATED WITH NOAA LIAISON MANAGER AND EW PERSONNEL)
  - FREQUENT COVERAGE MAY BE ADVANTAGE IN ESTIMATION OF CROP EMERGENCE AND CHANGE DETECTION
  - FOR USE IN CONJUNCTION WITH LANDSAT DATA

* FUNDING PROPOSALS HAVE BEEN SUBMITTED TO EVALUATE LARGE FORMAT CAMERA (LFC) AND SIR-B (OSTA-3, 1984) IN AGRICULTURE CONTEXT (ITD BENEFITING)
  - ASSESS ROLE OF HIGH SPATIAL RESOLUTION DATA
  - FURTHER ASSESS RADAR ALL-WEATHER AND DAY-NIGHT BENEFITS
DATA AND DATA SYSTEMS

+ Conducted an analysis and developed requirements for sample segment and pixel size for the JSC extraction and registration of 1981 Landsat data from the GSFC MDP

+ Conducted study to verify test statistics associated with using 3 by 6 N. mile ground truth with 5 by 6 N. mile proportion estimates are acceptable for 1980 Central Corn Belt data analysis

+ Screened 1980 crop year imagery (U.S.) and prepared image quality data base

+ Digitized crop year 1981 ground truth (GT) data for 16 Argentina sites and transmitted to investigators at JSC and UCB (ERIM)

+ Received Australian GT (20 segments). Currently extracting Landsat data and digitizing GT

+ Obtained Australian Coop Met data set
  - 3 years (78-80)
  - Increased station density/coverage (500 Coop vs 25 synoptic)
  - Coverage of interior in addition to coastal regions
INVENTORY TECHNOLOGY DEVELOPMENT

AGRICULTURE INFORMATION SYSTEM CONCEPT

"SYSTEM LEVEL"

"SUBSYSTEM LEVEL"

"COMPONENT LEVEL"

SAMPLING -> DATA -> CROP CALENDAR

AREA ESTIMATION

CONFIDENCE ESTIMATES

AGGREGATION

CROP PRODUCTION ESTIMATION

YIELD ESTIMATES

CONFIDENCE ESTIMATES

SYSTEM EVALUATIONS AND AGGREGATION COMPONENT EVALUATIONS

PRODUCTION CONFIDENCE ESTIMATES

EXPERIMENT PERFORMANCE ASSESSMENT

- TIMELINESS
- AFFORDABILITY
- GENERAL APPLICABILITY
- ACCURACY
ITD "SYSTEM" CONCEPT

WHAT IT IS NOT:

- A HARDWARE/SOFTWARE SYSTEM FOR DELIVERY,
- THE DESIGN OF A USER OPERATIONAL SYSTEM.

WHAT IT IS:

- A WAY TO ORGANIZE THE "TECHNOLOGY" INTO FUNCTIONAL RELATIONS AND AN INTEGRATED CONTEXT THAT ENABLES RESEARCH AND EVALUATION TO ACCOMPLISH NECESSARY ACTIVITIES.

-- A MAJOR BENEFIT FROM THE RESEARCH QUALITY DATA BASE AND AND THE EFFICIENCY PROVIDED BY THE AUTOMATED PROCEDURES IS THE RAPID FEEDBACK OF PERFORMANCE RESULTS TO PROCEDURAL DEVELOPMENT.

-- NOW IT IS POSSIBLE TO VARY THE SUB-COMPONENT WITHIN THE ARCHITECTURE OF THE PROCEDURE AND DETERMINE THE EFFECTS OF THIS CHANGE ON SUB-SYSTEM OR COMPONENT PERFORMANCE ACCURACY, EFFICIENCY, OBJECTIVITY, ETC.
reported

TWO PAPERS PRESENTED AT ANNUAL MEETING OF AMERICAN SOCIETY OF AGRONOMY
INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING
EIGHTEENTH INTERNATIONAL SYMPOSIUM ON REMOTE SENSING OF ENVIRONMENT
- SENSED DATA
- AMERICAN STATISTICAL SOCIETY ANNUAL MEETING
- TWO PAPERS TO BE PRESENTED AT HOUSTON CHAPTER OF AIAA
- ITD QUARTERLY TECHNICAL INTERCHANGE MEETING HELD AT JSC MARCH 24, 25
- 23 PROJECT REPORTS PREPARED
NEW RESULTS IN THE DEVELOPMENT
OF SMALL GRAINS (SSG3) AND
CORN/SOYBEANS (CS1)
AREA ESTIMATION TECHNOLOGY

R. M. BIZZELL
4-19-82
SPRING SMALL GRAINS DEVELOPMENT/RESULTS

- RESULTS FROM FY81 PILOT EXPERIMENT WITH THE AUTOMATED TECHNOLOGIES SUFFICIENTLY ENCOURAGING TO WARRANT CONTINUATION OF THIS (SSG-3) AREA ESTIMATION TECHNOLOGY DEVELOPMENT

  + IDENTIFICATION AND QUANTIFICATION OF MAJOR SUBCOMPONENT ERROR SOURCES CONTINUING. PRELIMINARY FEEDBACK INDICATES:
    + ACQUISITION SELECTION/DESIGNATION MAJOR CONTRIBUTOR TO THE ERROR
    + INCORRECT IMPLEMENTATION OF A SUBCOMPONENT MODULE (SOFTWARE)
    + INFLUENCE OF BOUNDARY/MIXED PIXELS ON PROPORTION ESTIMATION VARIANCE
    + ACQUISITION SELECTION/DESIGNATION PROBLEM VERIFIED BY A SUBSEQUENT STUDY AND EVALUATION

- RESEARCH STUDIES TO DEFINE SOLUTIONS TO THE ACQUISITION SELECTION AND BOUNDARY/MIXED PIXELS HAVE BEEN INITIATED.
**SPRING SMALL GRAINS TECHNOLOGY DIFFERENCES**

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th><strong>SSG3B</strong></th>
<th><strong>SSG3C</strong></th>
<th><strong>SSG4</strong></th>
<th><strong>SSG2</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>SAMPLING</strong></td>
<td>+ Pixels</td>
<td>+ Pixels</td>
<td>+ Quasi-fields</td>
<td>+ Pixel</td>
</tr>
<tr>
<td>+ Target</td>
<td>+ Systematic sample</td>
<td>+ Systematic sample</td>
<td>+ All quasi-fields</td>
<td>+ Bayesian selection</td>
</tr>
<tr>
<td>+ Method of selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LABELER</strong></td>
<td>+ Analyst verification</td>
<td>+ Automated (biowindow midpoint model)</td>
<td>+ Automated (biowindow duration model)</td>
<td>+ Analyst verification</td>
</tr>
<tr>
<td>+ Acquisition selection</td>
<td>+ Hierarchical selection</td>
<td>+ Hierarchical selection</td>
<td>+ Table look-up (binary)</td>
<td>+ Hierarchical selection</td>
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<tr>
<td>- Vegetative index number</td>
<td>- Kauth-Thomas transformation</td>
<td>- Kauth-Thomas transformation</td>
<td>- Normalized channel rankings</td>
<td>- Kauth-Thomas transformation</td>
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<tr>
<td><strong>PROPORTION ESTIMATION</strong></td>
<td>+ 836 pixels</td>
<td>+ 836 pixels</td>
<td>+ All quasi-fields</td>
<td>+ 60 pixels</td>
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<tr>
<td>+ Sample size</td>
<td>+ Relative count</td>
<td>+ Relative count</td>
<td>+ Enumeration with adjustment</td>
<td>+ Bayesian proportion estimation</td>
</tr>
<tr>
<td>+ Method of estimation</td>
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</tr>
</tbody>
</table>
ERROR CHARACTERIZATION STUDIES

1. OUTLIER EXAMINATION STUDY SUMMARY

- Examine the segments with the largest errors for each procedure.
- Due to time constraints, only 20 segments were examined for each procedure.
- Not able to quantify the effects of the observed causes for all segments.
- Provides quick, efficient feedback on major sources of error.

<table>
<thead>
<tr>
<th>ERROR SOURCE</th>
<th>SSG4</th>
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<tr>
<td>Clerical/Software</td>
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<td>2</td>
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<tr>
<td>Biowindow Definition</td>
<td>4</td>
<td>17</td>
<td>19</td>
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<tr>
<td>Procedure Deficiency/Unknown</td>
<td>7</td>
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</table>

- Biowindow (Crop Spectral Appearance) designation model driven by temperature is the largest single source of error.

RESULTS SSG3B (CONTINUED)

4. BIOWINDOW DESIGNATION ERROR

INCORRECT ACQUISITION SELECTION

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<td>ND</td>
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<td>ND</td>
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<tr>
<td>3050</td>
<td>1979</td>
<td>SK</td>
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<td>ND</td>
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<td>ND</td>
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<td>MN</td>
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<td>1909</td>
<td>1978</td>
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<td>-15.9</td>
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"Extracted From Semi-Annual Project Management Report November 1981"
VALIDATION OF ACQUISITION SELECTION/DESIGNATION
FOR SSG-3 FROM FY '81 PILOT EXPERIMENT

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<td>SSG-3B</td>
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<tr>
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<td>SSG-3B</td>
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<tr>
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<tbody>
<tr>
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<td>n</td>
<td>35</td>
<td>45</td>
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</table>

*NOTE: SSG-3B1 = SSG-3B CORRECTED.
SSG-3B PROPORTION ESTIMATES VERSUS GROUND-TRUTH PROPORTIONS FROM FY '81 PILOT

1:1 Line

Regression line
\[ \hat{y} = 4.55 + 0.75 \text{ (SSG-3B)} \]
\[ r^2 = 0.68 \]
\[ n = 144 \]
CORRECTED SSG-3B PROPORTION ESTIMATES VERSUS GROUND-TRUTH PROPORTIONS

Regression line
\[ \hat{y} = 0.72 + 0.92 \text{ (SSG-3B corrected)} \]
\[ r^2 = 0.89 \]
\[ n = 138 \]

Mean error = 1.36
Standard deviation = 6.19

ORIGINAL PAGE OF POOR QUALITY
SPRING SMALL GRAINS DEVELOPMENT/RESULTS (CON'T.)

• ADVANCED SMALL GRAINS DEVELOPMENT SG-1

  + WHILE AWAITING RESULTS FROM THE SENSITIVITY STUDIES AND
    THE SUBCOMPONENT RESEARCH STUDIES, THE DEVELOPMENT OF A
    TOTAL SMALL GRAINS PROPORTION ESTIMATION TECHNOLOGY HAS
    BEEN INITIATED,

  ++ UTILIZE THE SSG-3B DESIGN AS A BASIS

  ++ DESIGN AND IMPLEMENT A WINTER GRAINS ESTIMATOR
     SUBCOMPONENT

  ++ INVESTIGATE THE UTILITY OF A BOUNDARY DOT
     RELOCATION TECHNIQUE DEVELOPED AND TESTED IN FY81

  + LONG RANGE PLAN

  ++ THIS GENERIC PROPORTION ESTIMATION TECHNOLOGY (SG-1) WILL
    BE INTEGRATED WITH USSR AND/OR AUSTRALIA FEATURES
    IDENTIFICATION STUDIES FOR THE NECESSARY ADAPTATIONS
    TO THE DESIGN AND IMPLEMENTATION OF FOREIGN SPECIFIC
    AREA ESTIMATION TECHNOLOGY DEVELOPMENT.
SUMMER CROPS, CORN/SOYBEANS RESULTS

- CS-1B, SEMIAUTOMATED SUMMER CROP, CORN/SOYBEANS PROPORTION ESTIMATION TECHNOLOGY EVALUATION

BACKGROUND:

+ CS-1 TECHNOLOGY DURING FY81 PILOT EXPERIMENT WAS INITIAL IMPLEMENTATION OF RESEARCH AND DEVELOPMENT IN CORN/SOYBEANS PROPORTION ESTIMATION TECHNOLOGY.

++ NEW SUBCOMPONENT MODULES
- NORMALIZATION
- ACQUISITION SELECTION
- TARGET IDENTIFICATION
- LABELING LOGIC
- PROPORTION ESTIMATION

+ THE PLANNED EVALUATIONS IN THE PILOT EXPERIMENT ALLOWED FOR THE IDENTIFICATION AND QUANTIFICATION OF SUBCOMPONENT CONTRIBUTION TO THE PROPORTION ESTIMATION ERROR.

+ THESE RESULTS GUIDED THE DESIGN AND IMPLEMENTATION OF ANIMPROVED TECHNOLOGY (CS-1A).
## COMPARISON OF C/S AREA ESTIMATION PROCEDURES

<table>
<thead>
<tr>
<th>PROCEDURE NAME</th>
<th>CS-1</th>
<th>CS-1A</th>
<th>MC-2</th>
<th>CS-4</th>
<th>CS-2A</th>
<th>CS-5</th>
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<tbody>
<tr>
<td>DEVELOPER</td>
<td>ERIM/UCB</td>
<td>ERIM/UCB/LEMSCO</td>
<td>LEMSCO</td>
<td>JSC/LEMSCO</td>
<td>JSC/LEMSCO/ERIM</td>
<td>ERIM/UCB</td>
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<td>HISTORIC</td>
<td>HISTORIC</td>
<td>MODEL</td>
<td>MODEL</td>
<td>HISTORIC</td>
<td>OPTIONAL</td>
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<td>PREPROCESSING</td>
<td>EXTERNAL EFFECTS</td>
<td>EXTERNAL EFFECTS</td>
<td>GREY LEVEL</td>
<td>SUN ANGLE</td>
<td>OPTIONAL</td>
<td>EXTERNAL EFFECTS</td>
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<tr>
<td>FEATURE EXTRACTION</td>
<td>TASSELED CAP, GRABS</td>
<td>TASSELED CAP, GRABS</td>
<td>SPATIAL COLOR SEQUENCE</td>
<td>PROFILE PARAMS $\alpha, \beta, \sigma$</td>
<td>TASSELED CAP GRABS</td>
<td>TASSELED CAP</td>
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<tr>
<td>LABELING TARGET</td>
<td>QUASI-FIELDS</td>
<td>QUASI-FIELDS</td>
<td>BIN</td>
<td>SUPER PURE DOT</td>
<td>RELOCATED DOT</td>
<td>OPTIONAL</td>
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<tr>
<td>LABELING METHOD</td>
<td>ANALYST DECISION TREE</td>
<td>ANALYST/MACHINE DECISION TREE</td>
<td>AUTOMATIC HISTORICAL COLOR SEQUENCE</td>
<td>ANALYST/MACHINE PROFILE FEATURE THRESHOLDS</td>
<td>AUTOMATIC DECISION TREE</td>
<td>SIGNATURE PROFILE MATCHING</td>
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<td>ESTIMATION METHOD</td>
<td>STRATIFIED AREA ESTIMATE (S.A.E.)</td>
<td>BIAS CORRECTED S.A.E.</td>
<td>BIAS CORRECTED AGGREGATION</td>
<td>LINEAR DECISION RULE</td>
<td>RELATIVE COUNT</td>
<td>IN DEVELOPMENT</td>
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<tr>
<td>EFFICIENCY</td>
<td>MANUAL</td>
<td>SEMI-AUTOMATIC</td>
<td>AUTOMATIC</td>
<td>SEMI-AUTOMATIC</td>
<td>SEMI-AUTOMATIC</td>
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<td>TIMELINESS</td>
<td>POST TASSELING</td>
<td>POST TASSELING</td>
<td>PRE-SEED</td>
<td>POST TASSELING</td>
<td>POST TASSELING</td>
<td>THROUGH SEASON</td>
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<td>AREA OF APPLICATION</td>
<td>U.S. CORN BELT</td>
<td>U.S. CORN BELT</td>
<td>U.S. CORN BELT</td>
<td>U.S. CORN BELT</td>
<td>ARGENTINA FSRs</td>
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<tr>
<td>CROPS</td>
<td>C,S</td>
<td>C,S</td>
<td>C,S</td>
<td>C,S</td>
<td>C,S</td>
<td>C,S</td>
</tr>
</tbody>
</table>

Giovanni F. Pappalardo

2-19
SPECIFIC OBJECTIVES OF THE FY81 CORN AND SOYBEANS EXPERIMENT *

● ADAPT A CORN AND SOYBEAN PRODUCTION ESTIMATION TECHNOLOGY TO A NEW CROP REGION USING EXISTING AREA ESTIMATION SUBCOMPONENTS - E.G., LABELING AND PROPORTION ESTIMATION - AND A CONSORTIUM OF RESEARCH AND DEVELOPMENT INSTITUTIONS. IMPLEMENT THIS TECHNOLOGY, ADDRESSING THE TECHNICAL NEEDS IDENTIFIED IN THE FY80 EXPLORATORY, AS A BASELINE FOR THE DEVELOPMENT OF A TECHNOLOGY FOR FOREIGN APPLICATION.

● DEVELOP AND IMPLEMENT AN EXPERIMENTAL METHODOLOGY WHICH WILL TEST THIS TECHNOLOGY AND PROVIDE EVALUATION RESULTS TO BE INCORPORATED INTO FURTHER DEVELOPMENT.

● EVALUATE THE PERFORMANCE OF THE BASELINE TECHNOLOGY IN A CONTROLLED EXPERIMENTAL ENVIRONMENT TO IDENTIFY AND QUANTIFY THE SUBCOMPONENTS THAT CONTRIBUTE THE SIGNIFICANT PROPORTION OF ERROR TO THE SEGMENT PROPORTION ESTIMATE SO AS TO FOCUS FURTHER DEVELOPMENT.

* FROM SEMI-ANNUAL PROJECT MANAGEMENT REPORT, NOV. 1981
IDENTIFIED SUBCOMPONENT ERROR SOURCES IN CS-1 TECHNOLOGY
AND PROPOSED MODIFICATIONS

WEAKNESS IN C/S-1

LABELING PERFORMANCE

1. INCONSISTENT LABELING OF PURE TARGETS

2. MISDETECTION OF CROPS WITH TWO VEGETATION PHASES.

3. FEW MIXED TARGETS DETECTED

4. POOR LABELING PERFORMANCE ON MIXED TARGETS

5. STRATIFICATION ASSIGNMENT TEDIOUS AND ERROR PRONE

6. C/S DISCRIMINANT

MACHINE PERFORMANCE

1. TARGET DEFINITION

2. BIASED TREATMENT OF UNSAMPLED STRATUM

MODIFICATION FOR C/S-1A

1. MACHINE LABELS "CLASSIC" TARGETS, PARTIALLY LABELS REMAINING TARGETS.

2. LABELING LOGIC REFINED, EXAMPLES GIVEN.

3. MACHINE IDENTIFIES POTENTIALLY MIXED TARGETS

4. LABEL SELECTED PIXELS FROM MIXED TARGET, NOT TARGET MEAN.

5. AUTOMATED STRATIFICATION

6. MULTIDATE SCATTERPLOT AND DEFAULT LINE

1. REDUCE NUMBER OF MIXED TARGETS
   A) IMPROVED ACQUISITION SELECTION
   B) MODIFIED TARGET ALGORITHM

2. ASSIGN LITTLE TARGETS TO CLUSTERS.

2-22
## Paired Segment Comparison of C/S-1 and C/S-1A Pooled Years

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th></th>
<th>Soybean</th>
<th></th>
<th>Summer</th>
<th></th>
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<tr>
<td></td>
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<td>C/S-1A</td>
<td>C/S-1</td>
<td>C/S-1A</td>
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<tr>
<td></td>
<td>6.83</td>
<td>1.38</td>
<td>-3.8</td>
<td>-2.69</td>
<td>3.02</td>
<td>-1.30</td>
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<tr>
<td></td>
<td>2.5</td>
<td>5.6</td>
<td>1.2</td>
<td>2.5</td>
<td>2.2</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>6.83</td>
<td>5.2</td>
<td>3.8</td>
<td>2.8</td>
<td>3.02</td>
<td>2.8</td>
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<td>53.8</td>
<td>53.8</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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### Segments Used - 1973 Iowa
- 144 - 2 processing in C/S-1
- 145
- 804
- 856

2-24
SUMMER CROPS, CORN/SOYBEANS CONCLUSIONS FROM CS1A TEST

+ TEST RESULTS FROM THE C/S-1A TECHNOLOGY WERE SUFFICIENT TO WARRANT SUBMISSION TO EXTENDED SUBCOMPONENT TESTING USING AN INDEPENDENT DATA SET (69 SEGMENTS IN IOWA, 1980 CROP YEAR).

+ THE DESIGN AND IMPLEMENTATION OF AUTOMATED SUBCOMPONENTS OF THE C/S-1A TECHNOLOGY PROCEEDED FASTER THAN ANTICIPATED. ALSO, DEVELOPMENTAL TEST RESULTS WERE VERY ENCOURAGING.

+ THE DECISION WAS MADE TO CONFIGURE AND INCORPORATE THE NEW AUTOMATED TECHNOLOGY C/S-1B INTO THE TEST. (MANUAL SUBCOMPONENTS OF C/S-1B UTILIZED PROCESSING RESULTS FROM THOSE IDENTICAL SUBCOMPONENTS OF THE C/S-1A).
C/S-1B TEST RESULTS
1978-79 C/S SEGMENT IN IOWA, INDIANA AND ILLINOIS

<table>
<thead>
<tr>
<th>DEVELOPMENT TESTING</th>
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<th>SOYBEAN</th>
<th>SUMMER</th>
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<tr>
<td>E</td>
<td>1.59</td>
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<td>S_E</td>
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<td>7.68</td>
<td>9.77</td>
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<td>M.A.E.</td>
<td>7.57</td>
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<td>7.32</td>
</tr>
<tr>
<td>P</td>
<td>37.91</td>
<td>25.35</td>
<td>36.75</td>
</tr>
<tr>
<td>N</td>
<td>14</td>
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<table>
<thead>
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<th>SHAKE-DOWN TEST</th>
<th>CORN</th>
<th>SOYBEAN</th>
<th>SUMMER</th>
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<td>3.36</td>
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<td>S_E</td>
<td>5.70</td>
<td>3.69</td>
<td>6.39</td>
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<td>-12.26</td>
<td>-0.01</td>
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<td>4.87</td>
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<td>27.48</td>
<td>60.50</td>
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C/S-1B 1980 TEST RESULTS

IOWA

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<th>Soybeans</th>
<th>Summer Crops</th>
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<tr>
<td>$\hat{e}$</td>
<td>4.41</td>
<td>1.82</td>
<td>6.32</td>
</tr>
<tr>
<td>$s_e$</td>
<td>5.96</td>
<td>3.32</td>
<td>8.74</td>
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<td>10.81</td>
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</tr>
<tr>
<td>$p$</td>
<td>40.18</td>
<td>18.24</td>
<td>58.42</td>
</tr>
<tr>
<td>$n$</td>
<td>18</td>
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PROCEDURES EFFICIENCY
PER SEGMENT

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<tbody>
<tr>
<td>MANUAL FUNCTIONS</td>
<td>Time Factors</td>
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<tr>
<td>DATA PREPARATION</td>
<td>1.25 (TECHNICIAN)</td>
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<tr>
<td>PROCEDURE EXECUTION</td>
<td>25.17 HRS</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>26.42 HRS</td>
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<tr>
<td>COMPUTER FUNCTIONS</td>
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<tr>
<td>CPU</td>
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</tr>
<tr>
<td>CONNECT</td>
<td>97 MIN</td>
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PROCESSABILITY
1980 IOWA

<table>
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<tr>
<th></th>
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<th>C/S-1B</th>
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<tbody>
<tr>
<td>SEGMENTS ALLOCATED</td>
<td>69</td>
<td>69</td>
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<tr>
<td>SEGMENTS PROCESSED TO CROP GROUP</td>
<td>49 (71%)</td>
<td>49 (71%)</td>
</tr>
<tr>
<td>SEGMENTS PROCESSED TO CROP TYPE</td>
<td>44 (64%)</td>
<td>44 (64%)</td>
</tr>
</tbody>
</table>

2-28
SUMMER CROPS, CORN/SOYBEANS CONCLUSIONS FROM CS1B TEST

- C/S-1B DEVELOPMENT HIGHLY SUCCESSFUL
  + MAJOR SOURCES OF ERROR IN C/S-1 TECHNOLOGY IDENTIFIED AND QUANTIFIED.
  + MODIFICATIONS OF THE PROBLEM SUBCOMPONENTS SUCCESSFUL AND TIMELY.
  + DUE TO OBJECTIVE NATURE OF THE TECHNOLOGY, THE DESIGN AND IMPLEMENTATION OF AUTOMATED COMPONENTS WAS STRAIGHTFORWARD.
  + THE PRELIMINARY ASSESSMENTS OF THE TEST RESULTS INDICATE THAT THE SUBSTANTIAL IMPROVEMENTS GAINED IN THE AUTOMATION OF THE CS1 TECHNOLOGY SHOULD LEAD TO TECHNOLOGY THAT SATISFIES ALL THE APPLICABLE PERFORMANCE CRITERIA.
C/S-1 DEVELOPMENT FUTURE ACTIVITIES

- NEXT PHASE OF DEVELOPMENT IN THE CS-1 FAMILY IS TO BEGIN AN ATTACK TO UNDERSTAND SIGNIFICANCE AND POSSIBLE SOLUTION TO BOUNDARY/MIXED TARGET. A VERSION (CS-1C) HAS BEEN DESIGNED WITH AN APPROACH TO THIS PROBLEM AREA.

- THE LONG RANGE PLAN HAD BEEN TO CONTINUE THE, THUS FAR, SUCCESSFUL RESEARCH, DESIGN, TEST, EVALUATE, RESEARCH, ... DEVELOPMENTAL CYCLE. RESEARCH HAS BEEN ONGOING IN GAINING UNDERSTANDING OF CORN/SOYBEANS SIGNATURES AND CHARACTERISTICS UNDER A VARIETY OF CONDITIONS. CURRENT FINDINGS GIVE INDICATIONS THAT SOME OF THE VARIATION CAN BE DETECTED BY LANDSAT DERIVED PARAMETERS.

- AS RESOURCES ALLOW, THE DEVELOPMENT OF AREA ESTIMATION TECHNOLOGY IN CORN/SOYBEANS FOR DIRECT FOREIGN UTILIZATION WILL TAKE ADVANTAGE OF THE RESULTS FROM THE TESTS AND DEVELOPMENT CAPABILITIES ESTABLISH OVER THE PAST TWO YEARS.

2-30
CROP SIGNATURE CHARACTERIZATION
FIELD REFLECTANCE DATA ANALYSES

Accomplishments

- Effects of Experimental Treatments on Green and Bright Reflectance Profiles Were Determined for Corn and Soybeans. Typical Variations in Factors Such as Nitrogen Availability, Planting Date, and Variety Can Cause Significant Changes in Corn and Soybean Spectral Development Patterns.

- Association of Green Reflectance Profile Features With Stages of Development Was Determined for Corn and Soybeans. Corn Peaks Well Before Tassel Emergence and Peak LAI, While the Soybean Profile Peak is Associated Not With Development Stage But With Canopy Closure.

- Separability of Corn and Soybeans in This Reflectance Data Set was Determined. Based on Peak Green Reflectance Value and Rate of Green Decline After Peak (Plateau in Corn), the Two Crops are Completely Separable. However, Variations in Field Conditions Tend to Act on These Same Profile Features, and Could Therefore Influence Separability.
ASSOCIATION OF SPECTRAL AND DEVELOPMENTAL EVENTS

(1) Fit Curve to Reflectance Data
(2) Fit Curve to Development Stage Data
(3) Associate Resulting Curves

Soybeans

- Peak Green Refl. at Stage 2.5 to 3.0
  - Two weeks prior to tassel emergence
  - Three weeks prior to expected peak LAI

- "Early" Peak Probably Related to
  - Vertical leaf distribution/shadowing by stem
  - Leaf angular orientation
  - Shadowing by tassels

- Peak Green Refl. Occurs at Wide Range of Vegetative and Reproductive Stages

- Strong Association Between Profile Peak and Maximum Canopy Closure

- Lack of Development Stage Association Probably Due to
  - Indeterminate nature of many soybean varieties
  - Density of soybean vegetative canopy
SUMMARY

- Significant progress has been made in automating the baseline summer crop/corn/soybeans proportion estimation technology.

- Early identification and quantification of major subcomponent error sources of the baseline automated spring small grains technology has guided the development of improvements and extensions for foreign adaptation.

- The exercise of the techniques development system concept has proven to be an efficient means for advancing the technology. This system approach should provide significant capability for future research and development activities.
NEW ESTIMATION APPROACHES
AND
FUTURE DATA ACQUISITION SYSTEMS
REQUIREMENTS DEFINITION

M. C. TRICHEL
APRIL 19, 1982
INTRODUCTION

- IN MID-1981
  - AVAILABILITY OF RESEARCH DATA BASES
  - EXPERIENCE WITH SIGNATURE STABILIZING TRANSFORMS
  - DISCUSSIONS WITH FCCAD

LED TO INITIATION OF HIGH-RISK AREA ESTIMATION APPROACHES ADDRESSING FOLLOWING:
  - EARLY SEASON ESTIMATION
  - REQUIREMENTS FOR REGISTERING, STORING LANDSAT DATA
  - TIMELINESS, FREQUENCY OF COVERAGE OF LANDSAT DATA
    + MOTIVATES FCCAD USE OF ENVIRONMENTAL SATELLITE DATA
  - ANALYSIS COST
  - FOREIGN ADAPTATION

- THREE OF THE FIVE SUCH ACTIVITIES ARE TO BE DISCUSSED HERE.
  - SMALL, HIGHLY SIGNIFICANT FRACTION OF ITD
    + EARLY SEASON APPROACH
    + PROFILE CHANGE ESTIMATOR
    + SEGMENT-BASED CHANGE ESTIMATION
  - ACTIVITIES PRESAGE FUTURE SYSTEMS DEFINITION ACTIVITY
DEVELOPMENT OF EARLY SEASON APPROACH
BACKGROUND FOR EARLY SEASON APPROACH

- IN 1978, ACCOMPLISHED GOOD EARLY SEASON ESTIMATES FOR WINTER SMALL GRAINS IN THE U.S., SOUTHERN GREAT PLAINS AND THE USSR.
  - NOT SUCCESSFUL IN NORTHERN GREAT PLAINS
  - ANALYST-INTENSIVE

- ATTEMPT TO PRODUCE GOOD EARLY SEASON SPRING SMALL GRAINS ESTIMATES IN 1978 COMPLETELY UNSUCCESSFUL
  - INADEQUATE LANDSAT DATA ACQUISITION A KEY PROBLEM

- ONLY RECENTLY (MID-1981) HAVE OBTAINED SOME SUCCESS IN EARLY SEASON SUMMER CROP ESTIMATES.

- THE PRESENT APPROACH IS BASED ON
  - TECHNICAL INPUTS FROM ERAD AND FCCAD
  - PROPORTION ESTIMATION RESEARCH FROM EARLY LACIE
    - HARTLEY, FEIVESON, ZIEGLER, OTHERS
    - PROMISING PRELIMINARY RESULTS NOT PREVIOUSLY PURSUED

- CURRENT RESULTS BETTER THAN STATE-OF-DEVELOPMENT WARRANTS
BASIS

- RELATIONSHIP BETWEEN VEGETATED AREA AT CERTAIN TIMES IN GROWING SEASON, AND

- AREAS OF SPECIFIC CROPS

EXPECTED ADVANTAGES

- REQUIRES FEWER LANDSAT DATA ACQUISITIONS

- DOES NOT REQUIRE PRECISE LANDSAT REGISTRATION

- ALLS USES OF ROBUST UNBIASED ESTIMATORS

- EXTENDABLE TO THROUGH-THE-SEASON ESTIMATION

- POTENTIALLY ALLOWS IMPROVED FREQUENCY OF INFORMATION VIA ENVIRONMENTAL SATELLITES

+ LANDSAT WOULD STILL BE REQUIRED
BASIS FOR EARLY SEASON APPROACH

TIME (NORMALIZED TO ACCOUNT FOR WEATHER)

FRACTION OF SCENE VEGETATED (PERCENT)

TIME (IDEALIZED COMPOSITE CURVE)

SUMMER CROPS

SSG

SUMMER CROPS

NATURAL VEGETATION

NATURAL VEGETATIONS

ORIGINAL PAGE 19
• LINEAR MODEL

The observed average spectral response of a scene may be estimated as a linear combination of the major elements in the scene,

\[ B_i = \sum A_{ij} x_j \]

subject to

\[ \sum x_j = 1 \]

\[ x_j \geq 0 \]

Where \( B_i \) -- the fractional emergence for the scene for acquisition date \( i \),

\( A_{ij} \) -- the expected fractional emergence for crop \( j \) on acquisition date \( i \),

\( x_j \) -- the proportion of crop \( j \)

• The \( x_j \) are found by a constrained least squares technique.
• CURRENT APPROACH
  • UNITEMPORAL SOLUTIONS OBTAINED AS INDICATED ON PREVIOUS PAGE
  • MULTITEMPORAL SOLUTIONS ARE AVERAGES OF UNITEMPORAL SOLUTIONS

• VARIATIONS UNDER CONSIDERATION
  • PERFORM MULTITEMPORAL SOLUTIONS AT STRATUM LEVEL
    + GROUPS OF SEGMENTS
  • DEVELOP MORE APPROPRIATE MULTITEMPORAL FORMULATION
    + MATRIX SOMETIMES ILL-CONDITIONED
  • USE ENVIRONMENTAL SATELLITES TO IMPROVE ESTIMATION OF TEMPORAL CURVE, FREQUENCY OF OBSERVATION
    + LANDSAT STILL NEEDED
STANDARD REPORTING STATISTICS

- **MEAN ERROR:**
  \[
  \bar{e} = \frac{1}{n} \sum_{i=1}^{n} (\hat{p}_i - p_i) / n = \frac{1}{n} \sum_{i=1}^{n} e_i
  \]

- **STANDARD DEVIATION OF ERRORS:**
  \[
  s_e = \left[ \frac{1}{n} \sum_{i=1}^{n} (e_i - \bar{e})^2 / n - 1 \right]^{1/2}
  \]

- **MEAN ABSOLUTE ERROR:**
  \[
  \text{MAE} = \frac{1}{n} \sum_{i=1}^{n} |e_i| / n
  \]

- **MEAN GROUND TRUTH:**
  \[
  \bar{p} = \frac{1}{n} \sum_{i=1}^{n} p_i / n
  \]

- **RELATIVE MEAN ERROR (%):**
  \[
  \text{RME} = \bar{e} / \bar{p} \times 100
  \]

- **STATISTICALLY SIGNIFICANT RESULTS:** THOSE WHICH WOULD OCCUR BY CHANCE LESS THAN 10 PERCENT OF THE TIME IF NO BIAS WERE PRODUCED BY THE PROCEDURE.

\( \hat{p}_i \) = PROPORTION ESTIMATE FOR \( i^{th} \) OBSERVATION (%)

\( p_i \) = GROUND TRUTH PROPORTION FOR \( i^{th} \) OBSERVATION (%)

\( e_i \) = PROPORTION ERROR FOR \( i^{th} \) OBSERVATION = \( \hat{p}_i - p_i \)

\( n \) = NUMBER OF OBSERVATIONS
SSG5
EARLY SEASON SPRING SMALL GRAINS

TEST RESULTS

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1978*</th>
<th>1979</th>
<th>OVERALL</th>
</tr>
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<tbody>
<tr>
<td>NUMBER SEGMENTS</td>
<td>15</td>
<td>23</td>
<td>7</td>
<td>45</td>
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<tr>
<td>MEAN ERROR</td>
<td>-0.57</td>
<td>1.93</td>
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<td>9.814</td>
<td>9.050</td>
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<td>27.78</td>
<td>42.17</td>
<td>31.57</td>
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<td>7.38</td>
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<td>RELATIVE MEAN ERROR</td>
<td>-1.75</td>
<td>6.94</td>
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* TRAINING DATA
PERCENT PROCESSABLE* TO ESTIMATE BY SS65 FOR U.S. SPRING SMALL GRAINS REGION

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PERCENT</th>
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<tbody>
<tr>
<td>1976</td>
<td>73.1</td>
</tr>
<tr>
<td>1977</td>
<td>64.8</td>
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<td>1973</td>
<td>63.3</td>
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<tr>
<td>1973</td>
<td>34.1**</td>
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<tr>
<td>OVERALL</td>
<td>63.5</td>
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</tbody>
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*BASED ON CONTENTS OF IMAGE QA DATA BASE ON 3/12/82 FOR EARLY SEASON WINDOW 250 ≤ ACCUMULATED DEGREE DAYS ≤ 600.

**1979 LANDSAT DATA ACQUISITION SUBSTANTIALLY REDUCED BY NEED TO RETRO ORDER DATA.
## COMPARISON OF EARLY SEASON (SSG5) AND AT HARVEST (SSG4) SPRING SMALL GRAINS ESTIMATES OVER COMMON SEGMENTS

<table>
<thead>
<tr>
<th></th>
<th>1976 ssg4</th>
<th>ssg5</th>
<th>1978 ssg4</th>
<th>ssg5*</th>
<th>1979 ssg4</th>
<th>ssg5</th>
<th>OVERALL ssg4</th>
<th>ssg5</th>
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</thead>
<tbody>
<tr>
<td>NUMBER SEGMENTS</td>
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<td>13</td>
<td>19</td>
<td>19</td>
<td>6</td>
<td>6</td>
<td>38</td>
<td>38</td>
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<tr>
<td>MEAN ERROR</td>
<td>-4.99</td>
<td>-0.43</td>
<td>-2.35</td>
<td>3.93</td>
<td>-0.69</td>
<td>3.47</td>
<td>-2.99</td>
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<tr>
<td>MEAN GROUND TRUTH</td>
<td>32.84</td>
<td>32.84</td>
<td>29.42</td>
<td>29.42</td>
<td>42.61</td>
<td>42.61</td>
<td>32.67</td>
<td>32.67</td>
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<tr>
<td>MEAN ABSOLUTE ERROR</td>
<td>7.80</td>
<td>7.68</td>
<td>8.03</td>
<td>7.38</td>
<td>8.93</td>
<td>8.84</td>
<td>8.08</td>
<td>7.71</td>
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</tbody>
</table>

* TRAINING DATA
SIGNIFICANCE OF EARLY SEASON APPROACH RESULTS

- ACHIEVED PRETILLERING ACCURACY AND PROCESSABILITY COMPARABLE TO BEST PREVIOUS END-OF-SEASON ESTIMATORS
- METHOD DOES NOT REQUIRE REGISTERED LANDSAT DATA
- METHOD REQUIRES LITTLE OR NO ANALYST INTERVENTION
- METHOD PLACES MINIMAL DEMANDS ON DATA PROCESSING AND STORAGE
  - AMENABLE TO ON-BOARD COMPUTATION
- METHOD SUITABLE FOR DIVERSE SEGMENT SIZES
- ENVIRONMENTAL SATELLITE DATA CONCEPTUALLY USABLE TO AUGMENT LANDSAT FREQUENCY, TIMELINESS
AREAS OF EARLY SEASON APPROACH REQUIRING FURTHER RESEARCH

- Best approach for using multitemporal data
- Simultaneous estimation at multiple segment (stratum) level
- More robust estimators
  - Bin method
  - Method of moment
- Other crops, regions
- Augmentation of Landsat with environmental satellites
- Best transforms
  - Spectral
  - Temporal
MOTIVATION

- PREVIOUS SEGMENT AND COUNTRY LEVEL ESTIMATORS AIMED AT ABSOLUTE ESTIMATES
- OUTPUTS ARE ESTIMATED CROP PROPORTION AT SEGMENT LEVEL, CROP ACREAGE AT COUNTRY AND SUBCOUNTRY LEVEL
- USDA HAS LONG ADVOCATED DEVELOPMENT OF RELATIVE ESTIMATORS
  - WOULD ESTIMATE PROPORTION CHANGES AT SEGMENT LEVEL, CROP ACREAGE CHANGE AT HIGHER LEVELS
- INSENSITIVE TO LANDSAT ESTIMATOR BIAS
- PRESUMED MORE EFFICIENT DUE TO STRONG CORRELATIONS
- ALLOWS USER TO SELECT OWN BASE YEAR FIGURES
DIRECT LANDSAT CHANGE ESTIMATION

USING A

CROP TEMPORAL PROFILE CHANGE ESTIMATOR (SSG-6)
PROFILE CHANGE ESTIMATOR (SSG-6)

- BASIS
  - RELATIONSHIP BETWEEN
    + YEAR-TO-YEAR CHANGE IN VEGETATED AREA AT CERTAIN TIMES IN GROWING SEASON, AND
    + YEAR-TO-YEAR CHANGES IN AREAS OF CERTAIN CROPS.
  - RELATIONSHIP EXPLOITED VIA LINEAR MODEL

- EXPECTED ADVANTAGES
  - RETAINS ADVANTAGES OF FOREGOING EARLY SEASON APPROACH
  - ELIMINATES NEED TO DEVELOP EMERGENCE VERSUS GDD CURVES
GENERAL APPROACH TO PROFILE CHANGE ESTIMATION (SSG-6)

- Determine fraction of pixels spectrally emerged in scene for each acquisition in current year and historic base year.
- Compute growing degree days (GDD) for each acquisition.
- Plot per cent spectrally emerged vs. GDD for both years.
- Smooth plots using polynomial regression.
  - Data from both years used to determine curve shape.
- Difference in height of plots is basis of change estimation.
- Model form
  - Per cent spectrally emerged =
    \[ \hat{p}_0 + \hat{p}_1 \times \text{year} + \hat{p}_2 \times \text{GDD} \times (\text{GDD} - 2000) + \hat{p}_3 \times \text{GDD}^2 \times (\text{GDD} - 3 \times 10^6) \]
  - Constrained to have zero derivative at 1000 GDD.
  + Appropriate for spring small grains.
  - Estimated change is \( \hat{p}_1 \).
SMOOTHED % VEGETATED PIXELS AS A F'N OF GROWING-DEGREE-DAYS
SEGMENT 1924 (SSG) VEGETATIVE INDEX-CATE REDNESS

GROWING-DEGREE-DAYS

LEGEND: YR  ---- 78  ------- 79
EARLY- AND THROUGH-THE-SEASON PERFORMANCE EXAMPLE

SSG-6

+ = BIAS
• = STANDARD DEVIATION OF ERRORS

ERROR (ABSOLUTE)

-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7

GROWING DEGREE DAYS

0 500 1000 1500 2000 2500 3000 3500

ORIGINAL PAGE 64
OF POOR QUALITY
END-OF-SEASON* CHANGE RESULTS AND COMPARISON WITH 1981 PILOT RESULTS OVER COMMON SEGMENTS

<table>
<thead>
<tr>
<th>STANDARD STATISTICS</th>
<th>SSG-6</th>
<th>SSG-6</th>
<th>Δ (SSG-4)</th>
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</thead>
<tbody>
<tr>
<td>MEAN ERROR</td>
<td>-1.43%</td>
<td>-1.15%</td>
<td>6.15%</td>
</tr>
<tr>
<td>STANDARD DEVIATION OF ERRORS</td>
<td>3.51</td>
<td>3.59</td>
<td>16.12</td>
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<tr>
<td>MEAN ABSOLUTE ERROR</td>
<td>3.01</td>
<td>2.90</td>
<td>15.18</td>
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<tr>
<td>MEAN GROUND TRUTH</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1978</td>
<td>26.23</td>
<td>27.44</td>
<td>27.44</td>
</tr>
<tr>
<td>1979</td>
<td>24.50</td>
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<td>1979-1973</td>
<td>-1.73</td>
<td>-1.76</td>
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<tr>
<td>MEAN RELATIVE ERROR</td>
<td>-5.28</td>
<td>-4.48</td>
<td>23.95</td>
</tr>
<tr>
<td>(\frac{(\text{AVG GT 78 + EST. CHANGE - GT 79})}{\text{AVG (GT 79)}})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>3.79</td>
<td>3.77</td>
<td>17.25</td>
</tr>
<tr>
<td>N (SEGMENTS)</td>
<td>10</td>
<td>9</td>
<td>9</td>
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</table>

* LAST ACQUISITION USED = 3039 GDD
## SEGMENT-LEVEL AND OVERALL RESULTS AT END-OF-SEASON

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>1978 GROUND TRUTH</th>
<th>ESTIMATED CHANGE</th>
<th>78 GT + ESTIMATED CHANGE</th>
<th>1979 GROUND TRUTH</th>
<th>ERROR</th>
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<tbody>
<tr>
<td>1924</td>
<td>39.90</td>
<td>-5.32</td>
<td>34.58</td>
<td>35.37</td>
<td>-0.79</td>
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<tr>
<td>1920</td>
<td>22.16</td>
<td>-2.44</td>
<td>19.72</td>
<td>21.12</td>
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<td>1918</td>
<td>14.90</td>
<td>-5.82</td>
<td>9.08</td>
<td>13.88</td>
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<tr>
<td>1755*</td>
<td>11.97</td>
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<td>7.42</td>
<td>12.19</td>
<td>-4.77</td>
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<td>6.93</td>
<td>-2.88</td>
<td>4.08</td>
<td>7.67</td>
<td>-3.59</td>
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<td>1658</td>
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<td>1485**</td>
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<td>+3.60</td>
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<td>-0.14</td>
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<tr>
<td>1457</td>
<td>42.66</td>
<td>+0.14</td>
<td>42.80</td>
<td>40.32</td>
<td>+2.48</td>
</tr>
</tbody>
</table>

**AVERAGE**

|                  | 26.23             | -3.19            | 23.04                    | 24.50             | -1.43 |

**STANDARD DEVIATION OF ERRORS**

3.51

**MEAN ABSOLUTE ERROR**

3.01


** SEGMENT ∼ 25% NON-INVENTORIZED.
<table>
<thead>
<tr>
<th>LATEST ACQUISITION GDD</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1250</th>
<th>1500</th>
<th>1750</th>
<th>2000</th>
<th>2100</th>
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<tr>
<td>SEGMENT</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1920</td>
<td>-4.5</td>
<td>-4.0</td>
<td>-2.02</td>
<td>-2.02</td>
<td>+2.22</td>
<td>+2.22</td>
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<td>-2.02</td>
<td>-2.02</td>
<td>-2.00</td>
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<td>+6.9</td>
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<td>-1.22</td>
<td>-1.22</td>
<td>-1.22</td>
<td>-1.22</td>
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</tbody>
</table>

** SEGMENT ~ 25% NON-INVENTORYED.
SIGNIFICANCE OF PROFILE CHANGE ESTIMATOR RESULTS

- RESULTS INDICATE GREATLY REDUCED ERRORS IN ESTIMATION OF SEGMENT LEVEL CHANGE THAN BEST PREVIOUS METHODS
- METHOD DOES NOT REQUIRE REGISTERED LANDSAT DATA
- INDICATIONS THAT METHOD USABLE IN EARLY SEASON AS WELL
- METHOD REQUIRES LITTLE OR NO ANALYST INTERVENTION
- METHOD MAKES MINIMAL DEMANDS FOR COMPUTATION AND DATA STORAGE
  - AMENABLE TO ON-BOARD COMPUTATION
- SUITABLE FOR DIVERSE SEGMENT SIZES
- ENVIRONMENTAL SATELLITE DATA CONCEPTUALLY USABLE TO AUGMENT LANDSAT FREQUENCY, TIMELINESS
PROFILE CHANGE ESTIMATOR AREAS REQUIRING FURTHER RESEARCH

- Extension of formulation to multiple crops
- Large area and multiple segment formulations
- Multiyear model
- Augmentation of Landsat with environmental satellites
- Stability of estimator when crop growth poorly constrained by weather
  - Subtropical regions
- EST transforms
  - Spectral
  - Temporal
TECHNICAL BASIS FOR SEGMENT BASED CHANGE ESTIMATOR

• MOTIVATION
  • YEAR-TO-YEAR ESTIMATES OF REGIONAL CROP AREA USUALLY POSITIVELY CORRELATED
    + PLANTED ACREAGE USUALLY CHANGES SLOWLY
    + ESTIMATES IN SUCCEEDING YEARS BASED MOSTLY ON SAME SEGMENTS

• SUPPOSE
  \[ \pi_B = \text{TRUE PROPORTION FOR BASE YEAR} \]
  \[ \pi_T = \text{TRUE PROPORTION FOR TARGET YEAR} \]
  \[ \Delta_{TB} = \pi_T - \pi_B \]
  \[ \hat{\pi}_B = \pi_B + \text{BIAS} \pm (\text{STD DEV}) \]
  \[ \hat{\pi}_T = \pi_T + \text{BIAS} \pm (\text{STD DEV}) \]
  \[ \hat{\Delta}_{TB} = \hat{\pi}_T - \hat{\pi}_B = \pi_T - \pi_B \pm 2(1-\rho)(\text{STD DEV}) \]
  \[ \rho = \text{CORRELATION COEFFICIENT OF ERRORS} \]

• ADVANTAGES
  • BIAS CANCELS OUT
  • IF \( \rho > 0.5 \), RANDOM ERRORS ALSO REDUCED
    + OR CAN USE FEWER SEGMENTS FOR SAME ACCURACY
ACCOMPLISHMENTS AND STATUS

- HAVE COMPLETED INITIAL STUDY OF USSR DATA TO ESTABLISH LOWER BOUND ON
  POTENTIAL EFFICIENCY GAIN
  - SIMPLEST CHANGE ESTIMATOR

- STUDY
  - SHOWED LACIE SAMPLE ALLOCATION ADEQUATE AS BASIS FOR CHANGE ESTIMATION
  - FOUND EXPECTED VARIANCE IN LARGE AREA ESTIMATE VS. NUMBER OF SEGMENTS
    + APPROXIMATELY 25%-30% REDUCTION IN SEGMENTS NECESSARY
  - BASED ON USE OF LACIE USSR RESULTS WITH SEGMENT CHANGE APPROACH

- R&D CURRENTLY ON HOLD AWAITING
  - RESULTS OF STUDY OF FOUR AGGREGATION PROCEDURES
    + ESPECIALLY MULTIYEAR APPROACH
  - FURTHER DEVELOPMENT OF CROP PROPORTION ESTIMATORS
SAMPLE SIZES VS. STANDARD ERROR FOR USSR SWIR

LEGEND: ESTIMATE  ---- CHANGE  *** DIRECT

**Based on the USSR stratification developed for use in 1977..
BACKGROUND

- Previous research on sensor specifications concentrated on optical spectral band definition
  + Some work on spatial resolution, microwave
- More work needed in these areas

- Very little work to date on
  - Interaction between information extraction approach, sensors/satellites, and ground preprocessing
  - Frequency of coverage, number of satellites, orbit selection
  - Multistage system offering mixed resolution and frequency of coverage
    (e.g., Landsat/environmental satellite)
  - Effect of cloud cover
  - Ground preprocessing requirements, on-board preprocessing
  - Cost-effectiveness of features

- Development of a cost-effective agricultural remote sensing system requires total system approach
  - Information to support such an approach urgently needed

- ITD effort in sensor system specifications aims to provide such information
ELEMENTS OF THE EFFORT

- ANALYSIS OF DATA TO DETERMINE AGRICULTURAL INFORMATION VALUE OF INDIVIDUAL SENSOR FEATURES
  + E. G., SPATIAL RESOLUTION
- DATA FROM TM, MSS, METSAT, LARGE FORMAT CAMERA, SEASAT, SIR-A, B
  + TM DATA REQUESTED VIA ITD LIDQA AN
  + LFC, SIR-B DATA FOR COORDINATED EFFORT REQUESTED UNDER UPN 666
- RESEARCH ON INNOVATIVE PROCESSING METHODS AND STRATEGIES TO REDUCE DATA ACQUISITION, PREPROCESSING REQUIREMENTS
  + E. G., EARLY SEASON APPROACH
- PERFORMANCE ESTIMATION OF SYSTEM CONFIGURATIONS VIA SIMULATION
  + INCLUDING REALISTIC CLOUD COVER EFFECTS
INVENTORY TECHNOLOGY DEVELOPMENT
THEMATIC MAPPER PLANS

BACKGROUND

- TM DATA ANALYSIS ALWAYS MAJOR ELEMENT IN ITD FY82-87 PLANS
- SCOPE OF ANALYSIS REDUCED ALONG WITH BUDGET
- FOCUS CONCURRENTLY REDIRECTED
  - EVALUATION OF AGRICULTURAL APPLICATIONS VALUE OF INDIVIDUAL LANDSAT-D SYSTEM FEATURES
- THIS PREVIOUSLY PLANNED WORK PROPOSED IN RESPONSE TO GSFC LIDQA AN
  - NO COST (EXCEPT DATA)
  - FITS NATURALLY WITHIN SCOPE OF AN
INVENTORY TECHNOLOGY DEVELOPMENT
THEMATIC MAPPER PLANS

FOCUS

- ASSESS TM DATA QUALITY, ESPECIALLY
  - SIGNAL-TO-NOISE RATIO (SNR)
  - SPATIAL RESOLUTION
    + INCLUDING REGISTRATION EFFECTS

- DEVELOP A PHYSICAL INTERPRETATION OF NEW SPECTRAL INFORMATION CONTENT
  - RELATES SNR, BAND SELECTION TO GROUND OBSERVABLES
  - PROVIDES BASIS FOR RATIONAL DEVELOPMENT OF ANALYSIS METHODS

- RESEARCH ON INFORMATION EXTRACTION TAKING ADVANTAGE OF TM FEATURES

- ASSESS IMPACT OF DATA QUALITY ON ANALYSIS ESPECIALLY WITH REGARD TO
  - ANALYSIS COST
  - ANALYSIS TIMELINESS
  - ANALYSIS APPLICABILITY
  - ANALYSIS ACCURACY
INVENTORY TECHNOLOGY DEVELOPMENT (ITD)*

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*As of January 19, 1982, the project name and objectives were changed.

This listing includes only those documents published between October 1, 1981, and March 30, 1982.
### PROJECT: INVENTORY TECHNOLOGY DEVELOPMENT

#### TASK DESCRIPTIONS - 00300

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