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Quarterly Report July 7, 1981

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# Scene Radiation Applied Research Issues in Crop Identification

ISSUE: WHAT ARE THE KEY CULTURAL AND BIOPHYSICAL CHARACTERISTICS OF CROPS (WHICH ARE POTENTIALLY OBSERVABLE FOR REMOTELY SENSED DATA) THAT PERMIT SEPARABILITY BETWEEN CROPS AND IDENTIFIABILITY OF CROP TYPES AT HARVEST AND EARLIER IN THE SEASON?

SPECIFIC OBJECTIVES:

1. WHAT ARE THE KEY DIFFERENCES BETWEEN CROPS OF INTEREST AND THEIR CONFUSION CROPS IN THE TIMING AND DURATION OF KEY PHYSIOLOGICAL AND CULTURAL EVENTS? HOW DO THESE DIFFERENCES DEPEND ON ENVIRONMENTAL, CULTURAL, AND REGIONAL EFFECTS?

2. WHAT ARE THE KEY DIFFERENCES IN MANAGEMENT PRACTICES AMONG CROP TYPES? HOW DO THESE DIFFERENCES DEPEND ON ENVIRONMENTAL, CULTURAL, AND REGIONAL EFFECTS?

3. WHAT ARE THE KEY DIFFERENCES IN CANOPY GEOMETRY AND COMPOSITION AMONG CROP TYPES? HOW DO THESE DIFFERENCES DEPEND ON ENVIRONMENTAL, CULTURAL, AND REGIONAL EFFECTS?

4. WHAT ARE REASONABLY REPRESENTATIVE FUNCTIONAL FORMS FOR THE DISTRIBUTION FUNCTIONS OF THE KEY CROP CHARACTERISTICS?

## APPROACH:

OBJECTIVES 1, 2, AND 4:

- AGRONOMIC RESEARCH INTO THE LITERATURE CAN HELP ADDRESS THESE OBJECTIVES.

  REGIONS OF INTEREST: U.S., BRAZIL, ARGENTINA

  CROPS OF INTEREST: ALL (CONFUSION CROPS MUST BE INCLUDED IN THIS STUDY)

  LOOK AT ESTIMATED PLANTING DATES, REGIONAL CROP CALENDARS, ETC.

- FIELD TRIPS AND SEGMENT DATA HELP DETAIL MANAGEMENT PRACTICES

- SEGMENT DATA CAN HELP PROVIDE SOME MORE LOCALIZED INFORMATION IN EXAMINATION OF THE PERIODIC OBSERVATIONS.

- THIS INFORMATION SHOULD BE SUMMARIZED AND RELATED TO GEOGRAPHIC REGION AND CROP MIX PRESENT.

- OUTPUT FROM ADDRESSING THESE TWO OBJECTIVES WOULD BE A DESCRIPTIVE REPORT ON WHICH FURTHER SPECTRAL RESEARCH COULD BE BASED.

APPROACH:

OBJECTIVE 3:

- LITERATURE REVIEW
- FIELD STUDIES - R & D MAY BE NEEDED TO DEVELOP METHODS OF MEASURING CANOPY GEOMETRY.
- RELATE TO GEOGRAPHIC LOCATION (E.G., DIFFERENT VARIETIES GROWN)

ISSUE: WITH REGARD TO EXISTING AND PLANNED SENSORS SUCH AS MSS, TM, SPOT, AND OTHER ADVANCED SENSORS, HOW CAN THE KEY CROP CHARACTERISTICS BE OBSERVED?

## SPECIFIC OBJECTIVES:

1. WHAT ARE THE FUNCTIONAL RELATIONSHIPS AMONG KEY CROP CHARACTERISTICS, REMOTE SENSING OBSERVABLES (WITH CURRENT AND PLANNED SENSOR SYSTEMS), AND BACKGROUND EFFECTS (E.G., SOIL BACKGROUND, ATMOSPHERIC HAZE, VIEW ANGLE, AND SUN ANGLE?

2. WHAT FUNCTIONS OF REMOTE SENSING OBSERVABLES (BAND MEANS, TRANSFORMATIONS, LINEAR COMBINATIONS, ETC.) HAVE THE FOLLOWING PROPERTIES?

    - THE OBSERVABLES ARE PREDOMINANTLY A FUNCTION OF THE CROP CHARACTERISTIC OF INTEREST.

    - THE OBSERVABLES ARE INSENSITIVE TO BACKGROUND EFFECTS.

## APPROACH:

### OBJECTIVE 1:

- A SET OF REMOTE SENSING OBSERVABLES WILL BE EXAMINED
  - FOR MSS, KAUTH GREENNESS AND BRIGHTNESS
    - FOUR CHANNELS
    - RATIOS
    - OTHERS
  - FOR OTHER SATELLITES, INDIVIDUAL CHANNELS AND RATIOS WILL BE EXAMINED.
  - FOR ALL SENSORS, RESEARCH INTO APPROPRIATE BANDS OR TRANSFORMATIONS FOR ESTIMATION OF PARTICULAR CANOPY CHARACTERISTICS WILL BE CONDUCTED.

- Relationship of these remote sensing observables with the following will be examined:

Background

- Temporal behavior of vegetative canopies
- Soil Background
- Canopy Row Structure
- Solar elevation and Azimuth Orientation
- Optical Depth of Intervening Haze

Crop Characteristics

- Green Leaf Area Index
- Percent Soil Cover
- Green Biomass
- Development Stage
- Leaf Slope Distribution (e.g., the vertical and horizontal components of LAI)
- Canopy Condition
- Canopy Composition (e.g., canopy moisture content, leaf chlorophyll content, etc.)

- VALUES WHICH ARE DIFFERENTIABLE AND NOT DIFFERENTIABLE WILL BE IDENTIFIED AS WELL AS ANY SATURATING VALUES (I.E., WHEN THE REMOTELY SENSED MEASUREMENT DOES NOT CHANGE WITH INCREASING VALUES OF THE CANOPY PARAMETER.)

- FUNCTIONAL RELATIONSHIPS BETWEEN REMOTELY SENSED VARIABLES (BANDS, TRANSFORMS) AND THE KEY CROP CHARACTERISTICS WILL BE DETERMINED.

- WHAT ARE THE PREDOMINANT CHARACTERISTICS RESPONSIBLE FOR THE "DIP" IN BRIGHTNESS OBSERVED PRIOR TO CROP SENESCENCE?

APPROACH:

OBJECTIVE 2:

- GIVEN THESE FUNCTIONAL RELATIONSHIPS, WHICH TRANSFORMATIONS (OR BANDS) MAXIMIZE SENSITIVITY TO VARIOUS INDIVIDUAL CROP CHARACTERISTICS AND MINIMIZE SENSITIVITY TO UNDESIRED BACKGROUND EFFECTS?

ISSUE: WHAT NEW KINDS OF OBSERVATIONS ARE NEEDED TO IMPROVE THE ESTIMATES OF KEY CROP CHARACTERISTICS SHOWN TO PERMIT SEPARABILITY BETWEEN CROPS AND IDENTIFIABILITY OF CROP TYPES?

## APPROACH:

- Spectral measurements must be acquired in the field and at sites with sensors other than the current and planned sensors
  - Exotech 20C or helicopter/aircraft to cover other visible and near-to-middle IR regions
  - Thermal measurements
  - Microwave measurements
  - Illumination/View Angle measurements
  - Other?
- Then analysis of data will compare the power of the data types for discrimination purposes.

ISSUE: WHAT KEY DEVELOPMENT STAGES OF CROPS CAN BE DETERMINED FROM SPECTRAL, METEOROLOGICAL, AND CROP CALENDAR INFORMATION?

SPECIFIC OBJECTIVES:

1. TO DETERMINE WITH WHAT PROBABILITY CAN WE DISCRIMINATE DEVELOPMENT STAGES USING SPECTRAL, METEOROLOGICAL, AND CROP CALENDAR DATA.

2. TO DETERMINE WHAT CHARACTERISTICS OF DATA IN SPECTRAL/AGRONOMIC SPACE PROVIDE INFORMATION RELATED TO CROP DEVELOPMENT STAGE.

3. TO DEVELOP A MODEL USING SPECTRAL, METEOROLOGICAL, AND CROP CALENDAR DATA TO ESTIMATE DEVELOPMENT STAGE.

## APPROACH:

### OBJECTIVE 1:

- APPLY KNOWLEDGE AND TECHNIQUES DEVELOPED DURING THIS QUARTER TO LANDSAT DATA FROM SEGMENTS.

### OBJECTIVE 2:

- CONTINUE TO INVESTIGATE SPECTRAL/AGRONOMIC SPACE USING STEREO PAIRS OF PLOTS AND TRAJECTORY PLOTS OF THE DATA.

### OBJECTIVE 3:

- DEFINE APPROACH BASED ON THE RESULTS FROM OBJECTIVES 1 AND 2.

## DATA REQUIREMENTS:

- SPECTRAL DATA AND TIMELY AGRONOMIC DATA OF CORN AND SOYBEANS
  - FIELD RESEARCH DATA ON CORN AND SOYBEANS (EXISTING)
  - LANDSAT SEGMENT PERIODIC OBSERVATIONS

# Determination of the Optimal Level for Combining Acreage and Yield Estimates

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July 8, 1981

# OBJECTIVE

DETERMINE THE OPTIMAL LEVEL FOR COMBINING AREA AND YIELD TO ESTIMATE PRODUCTION.

# OVERVIEW OF APPROACH

- OPTIMIZATION FOR MULTIPLE CROPS CONSIDERED
  - IOWA FOR CORN AND SOYBEANS
  - WHEAT IN NORTH DAKOTA POSTPONED DUE TO LACK OF AVAILABLE METEOROLOGICAL DATA
- OPTIMAL LEVEL TO BE ASSESSED UTILIZING CURRENT TECHNOLOGY
  - ANALYSIS OF LANDSAT MSS DATA OVER SAMPLE SEGMENTS FOR AREA ESTIMATION
  - CCEA-TYPE REGRESSION MODELS FOR YIELD
- SEVERAL LEVELS OF ESTIMATION CONSIDERED FOR BOTH ACREAGE AND YIELD
  - STATE
  - CROP REPORTING DISTRICT
  - COUNTY
  - REFINED STRATA
  - REFINED/SPLIT STRATA

## YIELD ESTIMATION



- CCEA MODEL VARIABLES USED AT THE STATE LEVEL WILL BE USED FOR ALL LEVELS:

| IOWA CORN | IOWA SOYBEANS |
|---|---|
| LINEAR TREND 1941-60 | LINEAR TREND 1932-74 |
| LINEAR TREND 1961-72 | CUMULATIVE PRECIP OCT-APR DFN |
| MAY TEMP * PRECIP | MAY TEMP * PRECIP |
| JUNE TEMP * PRECIP | JUNE TEMP DFN |
| JUNE TEMP $(DFN)^2$ | JULY PRECIP DFN |
| JULY PRECIP DFN | JULY TEMP DFT |
| JULY TEMP DFT | AUG. PRECIP DFN |
| JULY TEMP $(DFT)^2$ | AUG. PRECIP $(DFN)^2$ |
| AUG. TEMP DFT | AUG. TEMP DFT |

NOTE: DFN = DEPARTURE FROM NORMAL

DFT = DEPARTURE FROM TREND

# YIELD ESTIMATION

- TO ENABLE ESTIMATION OF YIELD AT ALL LEVELS OF INTEREST, METEOROLOGICAL ESTIMATES ARE NEEDED AT EACH LEVEL (E.G., COUNTY, REFINED STRATUM).

- METEOROLOGICAL DATA AVAILABLE WERE DAILY REPORTS OF MINIMUM TEMPERATURE, MAXIMUM TEMPERATURE, AND PRECIPITATION FROM ALL COOPERATIVE METEOROLOGICAL STATIONS IN IOWA (POINT ESTIMATES).

- METEOROLOGICAL DATA WERE SMOOTHED BY THE WAGNER VARIATIONAL ANALYSIS TECHNIQUE TO OBTAIN ESTIMATES FOR POLYGONS OF INTEREST.

- USING THESE VARIABLES AND SMOOTHED MET DATA, REGRESSION COEFFICIENTS WERE DEVELOPED FOR EACH SET OF STRATA UTILIZING

  1931 - 1977 METEOROLOGICAL DATA

  1932 - 1977 YIELD DATA (USDA STATISTICS)

- 1970 WAS NOT USED IN CORN YIELD MODEL DUE TO BLIGHT YEAR.

# VARIANCE OF YIELD ESTIMATES

- VARIANCE OF YIELD ESTIMATES WAS COMPUTED FROM THE REGRESSIONS BY

$$V(\hat{y}) = \sigma^2_{y|x} \left(1 + x'(X'X)^{-1}x\right)$$

- TABULAR VALUES ARE AGGREGATED WEIGHTING BY CROP AREA IN EACH STRATUM.

| STRATIFICATION SYSTEM | NO. OF STRATA | CORN | | SOYBEANS | |
|---|---|---|---|---|---|
| | | VARIANCE | STANDARD DEVIATION | VARIANCE | STANDARD DEVIATION |
| STATE | 1 | 109.6 | 10.5 | 14.2 | 3.8 |
| CRD | 9 | 17.0 | 4.1 | 2.4 | 1.5 |
| COUNTY | 99 | 2.1 | 1.4 | 0.3 | 0.5 |
| REFINED | 3 | 44.9 | 6.7 | 6.7 | 2.6 |
| REF/SPLIT | 8 | 20.8 | 4.6 | 3.1 | 1.8 |

# VARIANCE OF AREA ESTIMATES

* COMPUTED USING METHODS DESCRIBED BY CHHIKARA AND PERRY.

* NUMBER AND DISTRIBUTION OF PC'S AND GPC'S OBTAINED FROM NASA. FOR REGIONS WITHOUT IMAGERY, POTENTIAL SEGMENTS WERE ASSIGNED THE SAME DISTRIBUTION AS OBSERVED SEGMENTS IN THAT COUNTY.

* FIELD SIZE ESTIMATES OBTAINED FROM D. PITTS DATA BASE. COUNTIES WITHOUT SEGMENTS WERE ASSIGNED A FIELD SIZE OF A COUNTY WITH SIMILAR FARM SIZE IN GEOGRAPHIC PROXIMITY.

# VARIANCE OF AREA ESTIMATES

TWO METHODS WERE UTILIZED $\hat{\sigma}^2_x = AX^B$

FIELD SIZE:

$$\sigma^2_{x_o} = \frac{4}{9}\tilde{p}(1-\tilde{p})$$

PIXEL SIZE:

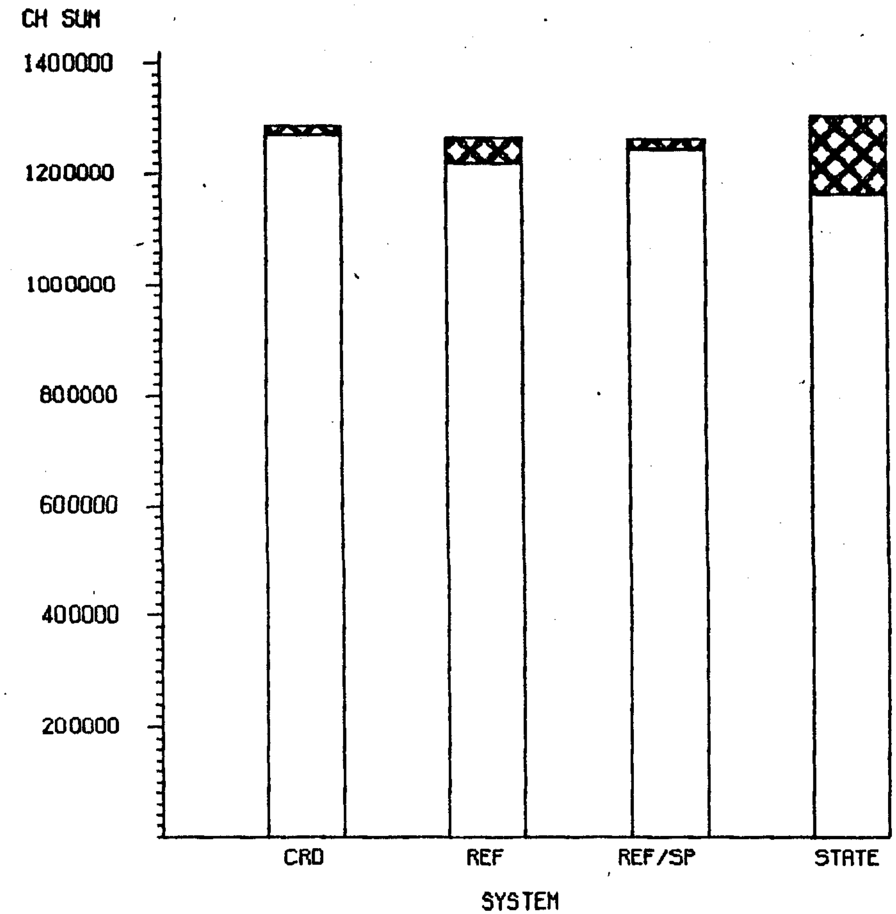
$$\sigma^2_{x_o} = \alpha_1(1-\tilde{p}) + \alpha_2\tilde{p}^2 + \alpha_3(0.3682 - \tilde{p} + \tilde{p}^2)$$

# VARIANCE OF PRODUCTION ESTIMATES

$$V(\hat{P}) = V(\hat{A}\cdot\hat{y})$$

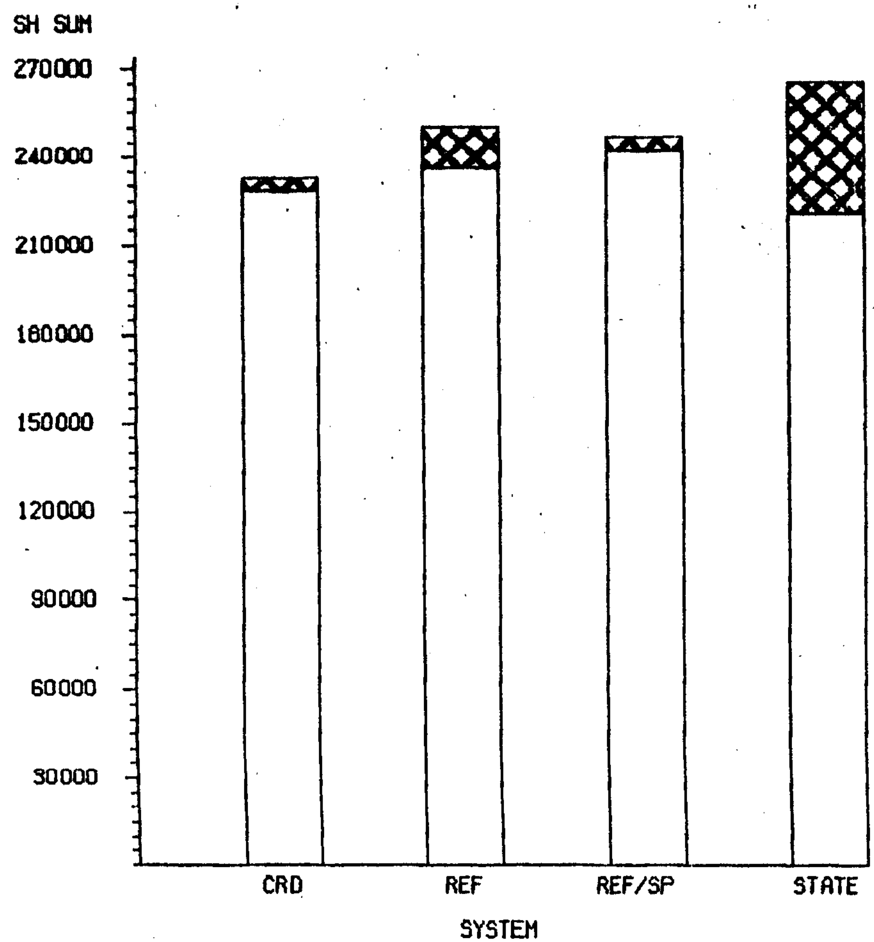
$$= V(\hat{A})\mu^2_{\hat{y}} + V(\hat{y})\mu^2_{\hat{A}} + V(\hat{A})V(\hat{y})$$

# ESTIMATED 1978 CORN PRODUCTION FOR IOWA
## PIXEL SIZE VARIANCE ESTIMATION METHOD




SHADED AREA IS ESTIMATED PRODUCTION PLUS OR MINUS STD ERROR

# ESTIMATED 1978 SOYBEAN PRODUCTION FOR IOWA
# PIXEL SIZE VARIANCE ESTIMATION METHOD




SHADED AREA IS ESTIMATED PRODUCTION PLUS OR MINUS STD ERROR

## Accomplishments for this Quarter

1. Majority of hardware specified and ordered
2. Plans made for modification of pick-up trucks
3. Purdue data logger streamlined from prototype
4. Plans for helicopter system begun

## Plans for next Quarter

1. Install booms on pick-up trucks
2. Install polycorder data loggers and other instrumentation - using Model 100 sensors

# EQUIPMENT ACQUISITION

| | |
|---|---|
| 15 | Barnes Model 12-1000 modular multiband radiometers |
| 12 | Omnidata polycorder data loggers (truck operations) |
| 4 | Purdue data loggers (helicopter operation & back-up) |
| 5 | Nikon/Purdue 250 frame 35mm motor drive cameras |
| 4 | Nikon 36 frame 35mm motor drive cameras |
| 2 | Long boom with pick-up truck modifications |
| 1 | Short boom with pick-up truck modifications |
| 2 | Short booms |
| 10 | Calibration panels |

# FIELD RADIOMETER ACQUISITION

SPECIFIC OBJECTIVE:

TO ACQUIRE FIELD RADIOMETERS, DATA LOGGERS, AND INSTRUMENTATION BOOMS NECESSARY TO AUGMENT THE SUPPORTING FIELD RESEARCH GROUND DATA ACQUISITION.

ACCOMPLISHMENTS FOR THIS QUARTER

1. MAJORITY OF HARDWARE SPECIFIED AND ORDERED
2. PICK-UP TRUCK MODIFICATIONS AND INITIAL INSTRUMENTATION COMPLETED
   VISITS TO KANSAS STATE UNIVERSITY AND UNIVERSITY OF NEBRASKA FOR INSTALLATION OF INSTRUMENTS
3. CONSTRUCTION OF FOUR HIGH SPEED DATA LOGGERS - 50% COMPLETE
4. FOUR OMNI DATA UNITS RECEIVED, TESTED, DISTRIBUTED TO
   - KANSAS STATE UNIVERSITY (2)
   - UNIVERSITY OF NEBRASKA (1)
   - PURDUE/LARS (1)

PLANS FOR NEXT QUARTER

1. RECEIVE AND TEST PRODUCTION MODELS OF THE BARNES MODEL 12-1000 MULTIBAND RADIOMETER
2. DISTRIBUTE TESTED RADIOMETERS FOR USE WITH OMNI DATA LOGGERS

# 1981 DEPLOYMENT

| SITE | SENSOR | BOOM | MODIFY TRUCK | LOGGER | CAMERA | CAL PANEL | COMPLETE |
|---|---|---|---|---|---|---|---|
| PURDUE | MMR | LONG | YES | POLY PURDUE | 250MD | 2 | *YES |
| KANSAS STATE | MMR | LONG | YES | POLY | 36MD | 3 | *YES |
| S. DAKOTA STATE | MMR | SHORT | YES | POLY | 250MD | 2 | *YES |
| NEBRASKA | MMR | LONG | YES | POLY | 250MD | 2 | *YES |

*EXCEPT MMR. DELIVERY EXPECTED IN AUGUST.

# TRAINING AND COORDINATION OF RADIOMETER USERS

## OVERALL OBJECTIVE:

TRAIN AND COORDINATE NEW INVESTIGATORS IN THE USE OF FIELD RADIOMETER SYSTEMS

## SPECIFIC OBJECTIVES:

- IDENTIFY AND SELECT USERS
- PREPARE AND DISTRIBUTE MANUALS DESCRIBING SYSTEM OPERATION, DATA HANDLING, MAINTENANCE, AND CALIBRATION
- CONDUCT ON SITE TRAINING SESSIONS

# ACCOMPLISHMENTS FOR THIS QUARTER

INVESTIGATORS VISIT PURDUE/LARS (ONE WEEK) FOR DISCUSSIONS OF FIELD SYSTEMS

- KANSAS STATE
- S.D. STATE
- NEBRASKA

PURDUE/LARS INVESTIGATORS VISITS (TWO DAYS) TO

- KANSAS STATE
- NEBRASKA