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SIX MONTH SUMMARY PROGRESS REPORT

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DEVELOPMENT OF TECHNIQUES FOR PRODUCING STATIC STRATA MAPS AND DEVELOPMENT OF PHOTOINTERPRETATION METHODS BASED ON MULTITEMPORAL LANDSAT DATA

Principal Investigator:	*Robert N. Colwell*
Project Scientists:	*Claire M. Hay* *Randall W. Thomas* *Andrew S. Benson*

15 December, 1976
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16. Abstract

The Report documents the progress of research conducted in support of the Large Area Crop Inventory Experiment (LACIE). Research was conducted for two tasks. These tasks include 1) evaluation of the UCB "static" stratification procedure and modification of that procedure if warranted, and 2) the development of alternative photo-interpretative techniques to the present LACIE procedures for the identification and selection of training fields (areas).

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Six Month Summary Progress Report

for

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Principal Investigator

Professor R.N. Colwell

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*See Hay and Thomas, 1976a, Section 2.0.

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SECTION 1:

INTRODUCTION

SECTION 2:

TASK I - DEVELOPMENT OF TECHNIQUES FOR PRODUCING STATIC STRATA MAPS

1.0 INTRODUCTION

This report summarizes the progress of research conducted by personnel of the Remote Sensing Research Program (RSRP), University of California Berkeley (UCB), from 15 May 1976 to 14 November 1976 for Contract NAS 9-14565 which is entitled "Development of Techniques for Producing Static Strata Maps and Development of Photointerpretive Methods Based on Multitemporal Landsat Data".

The research for the contract consists of two specific tasks which are follow-on efforts to research started earlier in support of the Large Area Crop Inventory Experiment (LACIE), and reported upon in May 1976. (See Hay and Thomas, 1976a). The two tasks included in the present contract and covered in this report are:

Task I: Development of Techniques for Producing Static Strata Maps, and

Task II: Development of Photointerpretive Methods Based on Multitemporal Landsat Data.

During the past six months the major effort has been directed to Task I for completion of the North Dakota stratification and evaluation of the previously completed stratification for the western two-thirds of Kansas. Work performed upon Task II has focused on basic task design considerations, namely, specific approach definition, selection of initial alternative procedures to be refined and tested, and selection and definition of evaluation criteria to be used for the tests. This design work serves as preparation for the major effort to be expended on Task II in the next contract period.

2.0 TASK I: DEVELOPMENT OF TECHNIQUES FOR PRODUCING STATIC STRATA MAPS

2.1 INTRODUCTION

The purpose of this task is to improve the signature extension stratification maps developed by the University of California (UCB) in previous LACIE work. Specifically, variables used to produce the strata maps are being analyzed with regard to their influence on the spectral signature of wheat fields, and, if needed, new variables will be introduced to refine or otherwise alter the stratification process.

During the six months covered by this Summary Progress Report, Task I has consisted of two subtasks. These subtasks were Subtask A - Completion of the North Dakota Stratification and Subtask B - Evaluation and Refinement of Static Strata Maps.

2.2 SUBTASK A: NORTH DAKOTA STRATIFICATION

2.2.1 OBJECTIVE

The objective of this subtask was to complete a static stratification for the state of North Dakota utilizing procedures developed by UCB in previous LACIE tasks. The statification procedures had been developed in the winter wheat area of Kansas. Thus to insure that the procedures were applicable in a broad spectrum of environments, the spring wheat region of North Dakota was selected as the test area for further development of the stratification procedures.

2.2.2 APPROACH

Work on the North Dakota Stratification that was begun during a previous performance period (15 February 1976 to 14 May 1976) was completed during the six months performance period covered by this summary progress report. The procedures utilized in the production of the North Dakota stratification were essentially the same ones used in the UCB Kansas stratification except for slight modifications as noted. The basic stratification procedures employed are fully described in a previous report (Hay and Thomas, 1976a).

2.2.2.1 Specific North Dakota Stratification Procedures

2.2.2.2 Climatic Strata Generation

Long-term average growing season (spring wheat season - June through August) precipitation and degree-day sum isolines were generated for the state of North Dakota in similar fashion to the Kansas stratification. Precipitation and temperature data** for climatological recording stations*

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* *The degree-day (also termed day-degree) value for a given month is defined (based on Nuttonson, 1956) as the number of days in a given month times the difference between the average temperature in that given month and a growth threshold temperature (commonly 40°F, below which wheat has been found not to accumulate significant biomass). Thus the growing season day-degree sum can be expressed as*

$$S = \sum_j n_j \cdot (\bar{T} - 40° F)$$

where j is the month index. Based on the work of Pascale and Damario (1962) the average most important portion of the growing season for summation of day-degrees may be the three month period following the vernal equinox; i.e., for Kansas, April, May, and June.

** *NOAA, Climatological Data, North Dakota, Environmental Data Service, Asheville, N.C. 28801.*

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throughout North Dakota was fed into an automatic interpolator for the production of the precipitation and temperature isolines. (For a more complete discussion of the automatic interpolator see Hay and Thomas, 1976a, Appendix B.) The initial climatic strata have been defined as the areas bounded by adjacent precipitation isolines with a contour interval of 0.2 inches, and adjacent temperature isolines with a contour interval of 40 degree-days. Precipitation and degree-day sum isolines for North Dakota are shown in figures 2.1 and 2.2 respectively. The resultant climatic strata are shown in figure 2.3.

2.2.2.3 Land Use/Soil Association Strata Delineation Base Date Selection

Three years (July 1973 through September 1975) of full frame Landsat color composite imagery were available for the North Dakota stratification work. Two base date periods, as compared to one for Kansas, were selected for the land use/soil association stratification of North Dakota. Two base date periods were needed for North Dakota due to a higher frequency of cloud coverage than in Kansas. The base date periods selected were mid-June and late-August.

The late-August period in North Dakota corresponded to the early-July base date period used in Kansas. During late August in North Dakota (as in early-July in Kansas) the small grain crop has turned golden and wheat fields appear as yellowish-white fields on the Landsat imagery. Small grain fields are in clear contrast with all other crop types and vegetation conditions at this time. Consequently, the distribution of the small grains can be easily determined.

As imagery was not available for the entire state during the late August period, mid-June was chosen as a back up base date period. In June cropland sharply contrasted with areas of range and forest vegetation. Thus the percentage and distribution of cropland throughout an area could be determined. Cropland distribution patterns are important characteristics utilized in the delineation of soil association groupings.

In addition to the base dates, supplemental Landsat dates were used in order to check the consistency of soil and land use patterns throughout the year. It is important that the land use/soil association delineations be made after a multitemporal analysis of the data. If only single date analysis is employed, there is the possibility that ephemeral patterns may not be recognized as such and that as a consequence their significance will be weighted too heavily in the stratification process.

Soil Association Delineation

Soil association delineations for North Dakota were made using procedures as described for the Kansas stratification. (See Hay and Thomas, 1976a, Section 3.3.3.3a). County boundaries used for registration of ancillary soils data were taken from 1:1,000,000 U.S.G.S. base maps. Ancillary soils data consisted of various general soil maps for the state as well as a limited

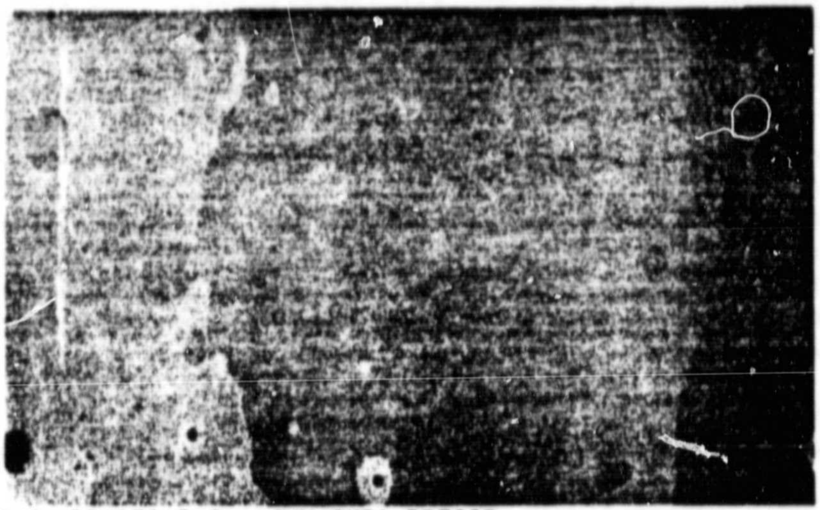

Figure 2.1. Long-Term Average Growing Season (June through August) Precipitation Isolines for the Entire State of North Dakota. The top, left, and bottom boundaries correspond to the North, West, and South boundaries of the state, respectively. The Eastern boundary is not linear and angles off to the west from the bottom right corner.

Red	*7.6" - 7.8"*	*Blue*	*8.6" - 8.8"*
Yellow	*7.8" - 8.0"*	*Gray-pink*	*8.8" - 9.0"*
Yellow-green	*8.0" - 8.2"*	*Violet*	*9.0" - 9.2"*
Green	*8.2" - 8.4"*	*Dark Violet*	*9.2" - 9.4"*
Blue-green	*8.4" - 8.6*		

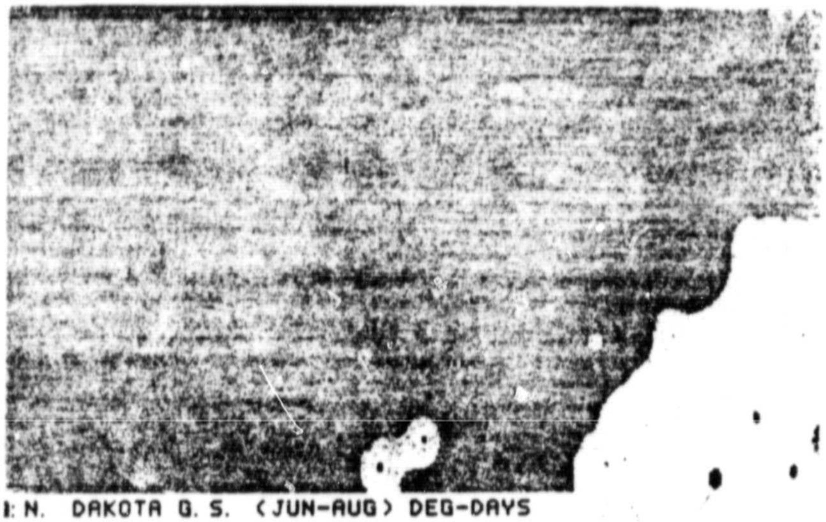

Figure 2.2. Long-Term Average Growing Season (June through August) Temperature Isolines for the Entire State of North Dakota. The top, left and bottom boundaries correspond to the North, West and South borders, respectively, of the state. The Eastern border is not a linear, but angles off to the west from the bottom right corner.

Blue-violet	2320 - 2360	degree - days
Dark green	2360 - 2400	degree - days
Turquoise	2400 - 2440	degree - days
Green	2440 - 2480	degree - days
Yellow-green	2480 - 2520	degree - days
Yellow	2520+	degree - days

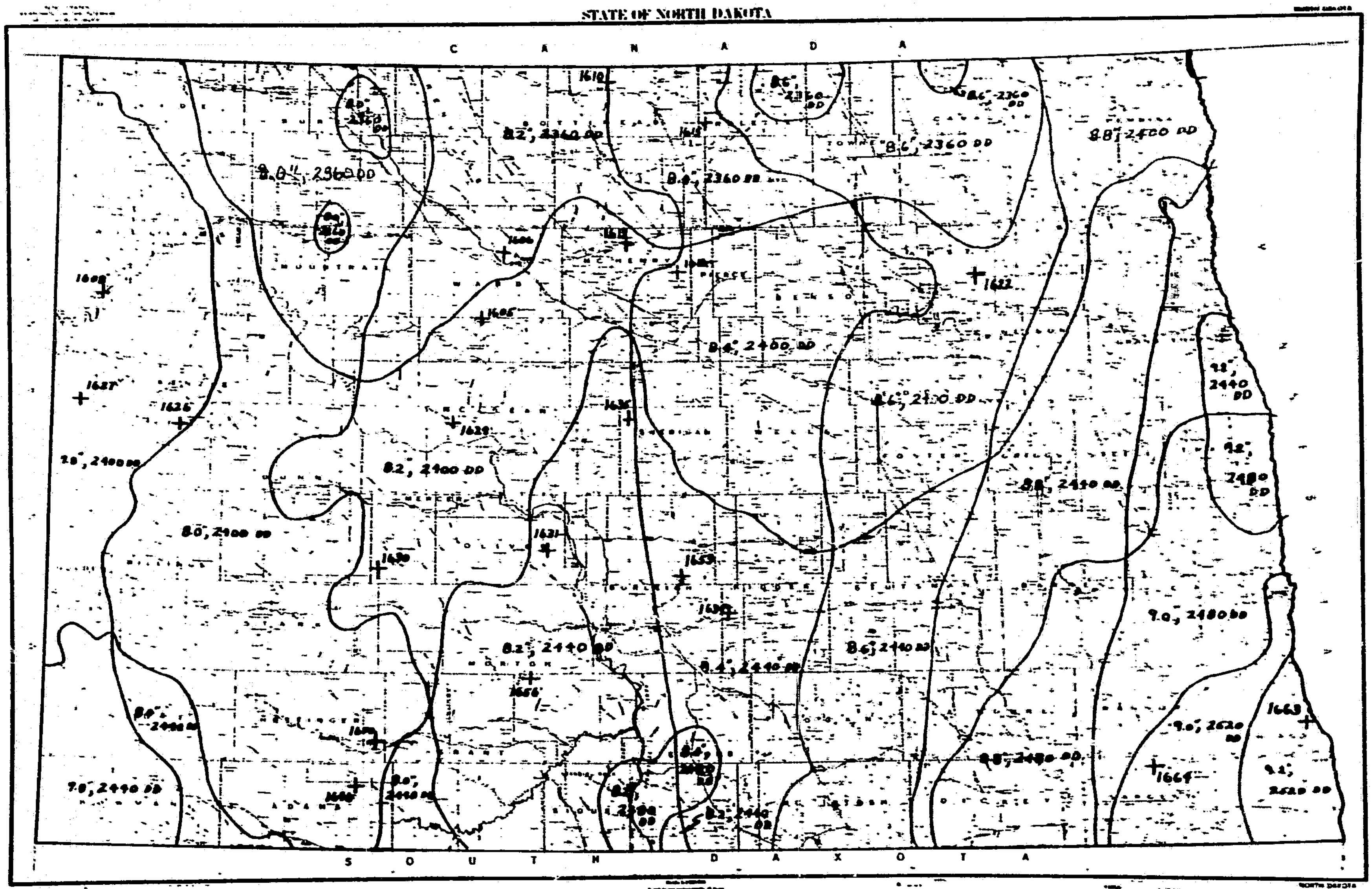

Figure 2.3. Initial Climatic Strata for the State of North Dakota Based on the Climatic Data Displayed in Figures 2.1 and 2.2.

number of detailed county soil surveys.*

The ancillary soils data was transferred to overlays on the Landsat imagery and adjusted accordingly after interpretation of the imagery. As was the case in the Kansas stratification, the detailed county soil surveys were used as local familiarization information from which extension was made through image interpretation into areas for which no detailed soil information existed.

Correlation of soil associations and groupings across the state was difficult due to incomplete state-wide coverage for either of the base date periods, or any other period. In order to help alleviate this problem a mosaic of Landsat prints was put together from the available imagery (Figure 2.4). The late-August base date period was used whenever available. When a late-August image was not available, a mid-June image was used for the mosaic. Some areas of the state were not covered by either of the base date periods, and it was necessary to use less than optimum imagery for the mosaic.

The mosaic was produced in order to facilitate the interpretation progression from one Landsat frame to another. A mosaic was not necessary for the Kansas stratification since the entire area was covered by the base date period and, as a consequence, interpretation of the imagery could easily proceed from one frame to another.

If more optimum imagery becomes available for the areas lacking base date coverage, the stratification will be rechecked in those areas.

Land Use Delineation

The land use stratification and coding was performed after the soil association delineations were completed. In as much as changes in land use patterns are utilized significantly as indicator characteristics of soil association boundaries, most of the land use delineations were completed as by-products of the soil association delineations. All that was required for the land use stratification was to re-evaluate the soil association strata with respect to any possible subdivision based on the land use classification system and to code the resultant strata according to their land use class.

The land use classification system utilized for the North Dakota stratification was the same system as employed for the Kansas stratification and is reproduced in Appendix A. Landsat imagery was not available for approximately 7% of the state so that land use interpretations could not be made for these areas.

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* Aandahl, A. (1972), Patterson, D.D., et al (1968), Omodt, H.W., et al (1968), USDA Soil Conservation Service and the North Dakota Agricultural Experiment Station.

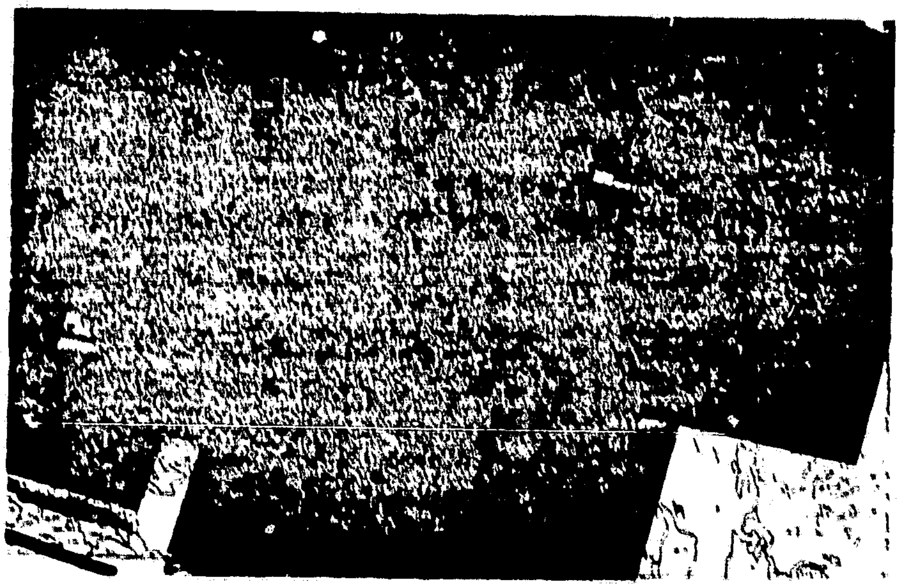

Figure 2.4. Landsat Mosaic of North Dakota Showing the Land Use/Soil Association Stratification Overlayed onto the Mosaic. Landsat CIR frames from the two base date periods (late August and mid-June) were predominantly used to produce this mosaic. Dates of imagery other than the base dates were used for areas not covered by cloud free imagery during the base date periods. Imagery was unavailable for approximately 7% of the state so that land use interpretations could not be made for these areas.

2.2.2.4 Segment Grouping and Descriptions

Twenty-one blind sites were provided as part of the test and evaluation data for signature extension. These blind sites were plotted onto the U.S.G.S. 1:1,000,000 base map with the completed stratification and grouped according to their climatic strata (See Table 2.1). Descriptions of each segment in terms of its associated land use/soil association strata appear in Table 2.2. These descriptions will be used to determine potential segment matches within the climatic strata segment groups. Since the current evaluation work of the Kansas stratification will result in information that will allow better formulation of potential segment matching procedures, a list of potential segment matches for the North Dakota blind sites has not been generated as of this date.

2.2.3 RESULTS AND DISCUSSION

2.2.3.1 Deliverable Products

The results from the North Dakota stratification effort consist of the following:

- the long-term average growing season (June through August) precipitation isolines - Figure 2.1
- the long-term average growing season (June through August) degree-day sum isolines - Figure 2.2
- the resultant initial climatic strata - Figure 2.3
- the land use/soils "static" stratification for the entire state of North Dakota (except for 7% of the area not covered by available imagery) - Figure 2.5
- twenty-one blind sites grouped according to their climatic strata - Table 2.1
- segment strata descriptions for the twenty-one blind sites - Table 2.2

A summary of the signature extension stratification proceduere is provided below.

A. Stratification Variables

- average (long-term) growing season (June through August in North Dakota) precipitation.
- average (long-term) growing season (June through August in North Dakota) degree-day sums
- general soil type (soil association)
- land use

Table 2.1

North Dakota Blind Sites - Listed According to Climatic Areas

Temperature Strata Day-Degree Sums (DD)	-2360 DD		2360 DD				2400 DD							2440 DD								2480 DD					2520 DD	
Precipitation Strata inches	8.0	8.6	8.0	8.2	8.4	8.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.2	8.2	8.4	8.8	9.0	9.2	9.0	9.2
Blind Site Segment #				1606 1610	1610 1615		1608 1626 1627	1646 1650	1605 1613 1629 1630	1612	1622					1631 1635 1656	1634 1653										1664	1663

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NO

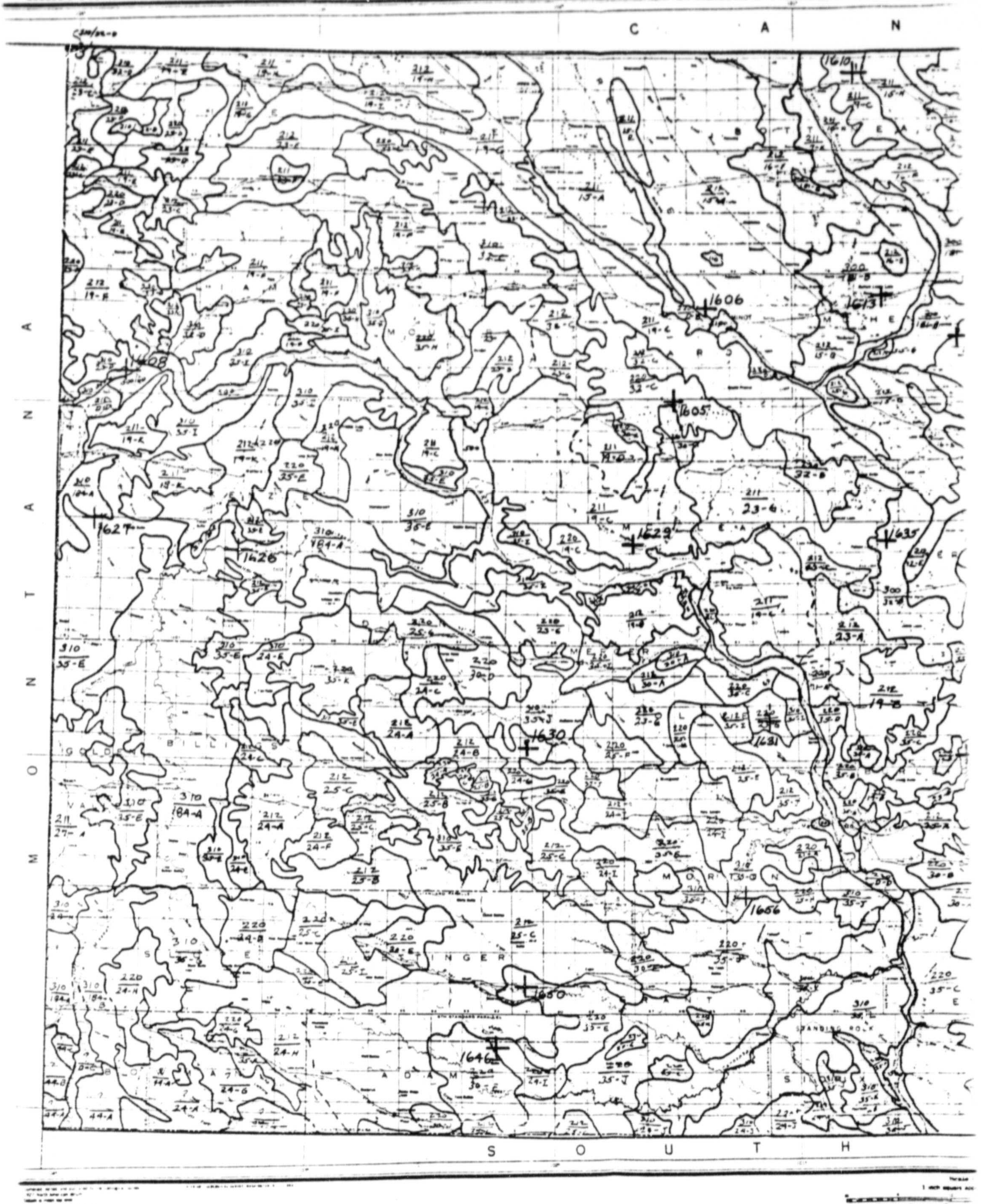

FIG 2.5

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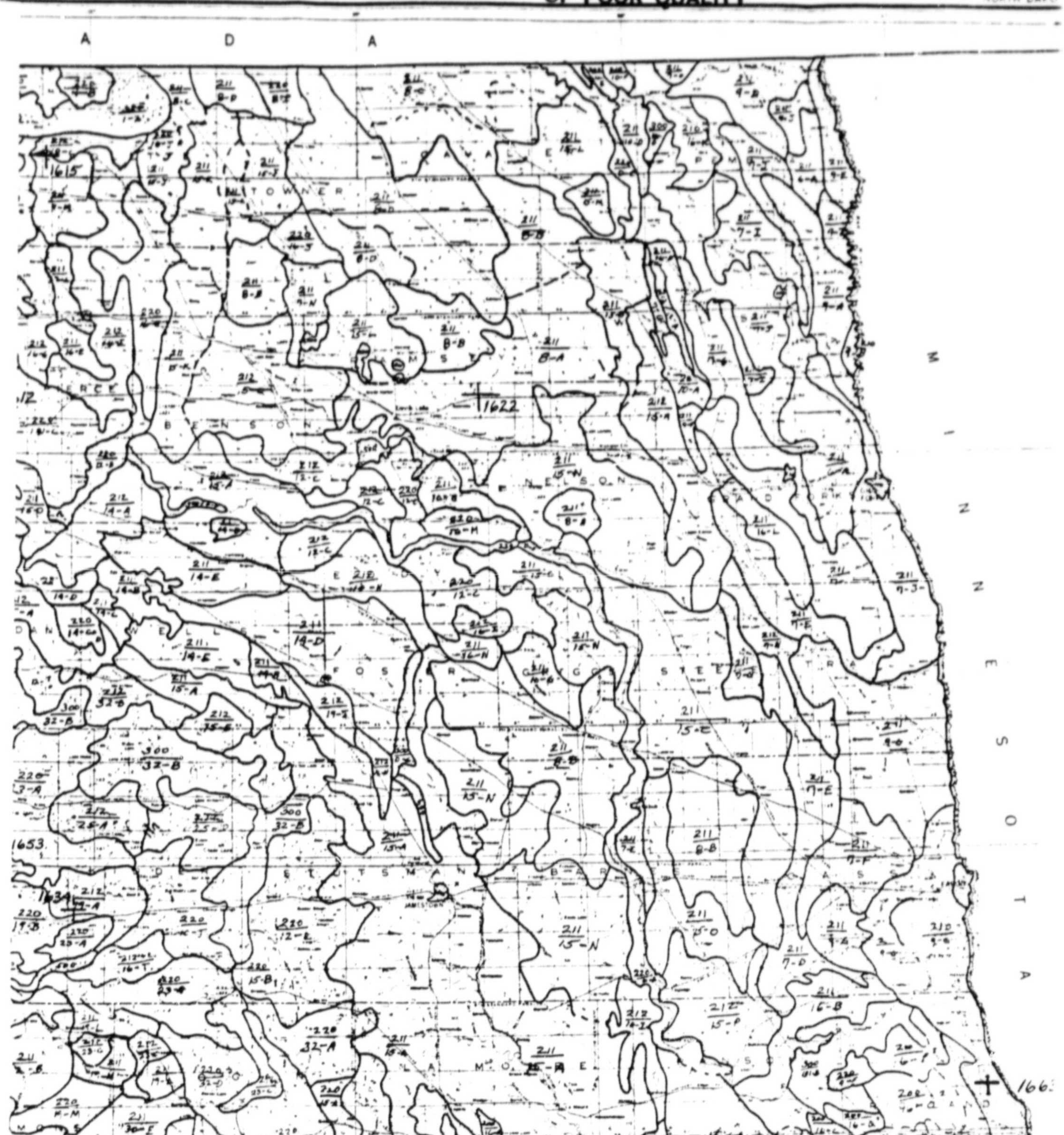

Table 2.2

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NORTH DAKOTA BLIND SITE STRATA DESCRIPTIONS

Seg. #	County Name	Blind Site Strata Decriptions
1605	Ward Co.	$\frac{212^{5*}}{\text{32-C}}$, $\frac{220^{85}}{\text{32-C}}$, $\frac{220^{10}}{\text{30-C}}$
1606	Ward Co.	$\frac{211^{55}}{\text{15-A}}$, $\frac{220^{35}}{\text{D-B}}$, $\underline{110}^{10}$
1608	Williams Co.	$\frac{310^{38}}{\text{23-D}}$, $\frac{500^{35}}{\text{D}}$, $\frac{310^{10}}{\text{35-I}}$, $\underline{500}^{5}$, $\frac{212^{12}}{\text{19-F}}$
1610	Bottineau Co.	$\frac{211^{65}}{\text{9-C}}$, $\frac{211^{35}}{\text{15-H}}$
1612	Mc Henry Co.	$\frac{300^{40}}{\text{181-B}}$, $\frac{212^{5}}{\text{16-G}}$, $\frac{220^{55}}{\text{181-C}}$
1613	Mc Henry Co.	$\frac{300^{100}}{\text{181-B}}$
1615	Rolette Co.	$\frac{212^{38}}{\text{10-C}}$, $\frac{320^{5}}{\text{1-A}}$, $\frac{211^{15}}{\text{7-L}}$, $\frac{211^{40}}{\text{7-M}}$, $\frac{211^{2}}{\text{15-I}}$
1622	Ramsey Co.	$\frac{211^{98}}{\text{8-A}}$, $\frac{211^{2}}{\text{8-B}}$
1626	Mc Kenzie Co.	$\frac{310^{75}}{\text{184-A}}$, $\frac{310^{15}}{\text{35-E}}$, $\frac{212^{10}}{\text{35-E}}$
1627	Mc Kenzie Co.	$\frac{310^{45}}{\text{184-A}}$, $\frac{310^{52}}{\text{35-E}}$, $\frac{211^{3}}{\text{19-K}}$
1629	Mc Lean Co.	$\frac{211^{95}}{\text{19-C}}$, $\underline{500}^{5}$
1630	Mercer Co.	$\frac{310^{15}}{\text{35-J}}$, $\frac{220^{78}}{\text{24-G}}$, $\frac{220^{2}}{\text{35-J}}$, $\frac{220^{5}}{\text{35-E}}$
1631	Oliver Co.	$\frac{220^{75}}{\text{23-G}}$, $\frac{310^{15}}{\text{35-I}}$, $\frac{212^{5}}{\text{35-I}}$, $\frac{310^{5}}{\text{35-J}}$
1634	Kidder Co.	$\frac{212^{80}}{\text{19-A}}$, $\frac{220^{10}}{\text{19-B}}$, $\frac{220^{10}}{\text{23-A}}$
1635	Sheridan Co.	$\frac{211^{38}}{\text{23-G}}$, $\frac{300^{62}}{\text{32-B}}$

* percentage of segment within the given stratum.

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Seg. #	County Name	Blind Site Strata Desriptions
1646	Adams Co.	$\frac{220}{24\text{-I}}^{45}$, $\frac{212}{25\text{-C}}^{25}$, $\frac{220}{30\text{-E}}^{30}$
1650	Hettinger Co.	$\frac{220}{30\text{-E}}^{75}$, $\frac{212}{25\text{-C}}^{25}$
1653	Burleigh Co.	$\frac{220}{23\text{-A}}^{40}$, $\frac{220}{19\text{-B}}^{20}$, $\frac{212}{23\text{-B}}^{40}$
1656	Morton Co.	$\frac{310}{35\text{-J}}^{73}$, $\frac{220}{35\text{-J}}^{20}$, $\frac{220}{25\text{-H}}^{2}$, $\frac{220}{35\text{-E}}^{5}$
1663	Richland Co.	$\frac{211}{9\text{-G}}^{100}$
1664	Sargent Co.	$\frac{211}{3\text{-A}}^{95}$, $\frac{200}{16\text{-A}}^{5}$

B. Stratification Procedural Steps:

Step 1. A base date/dates of Landsat imagery is selected from a time period when soils/land use-cropping practices are most contrasted and most easily delineable.

Step 2. Soil associations are delineated on the base date/dates color infrared transparency using available published soils data and interpretation of the Landsat imagery. The associations are then correlated across the crop reporting district and ultimately across the entire area of interest.

Step 3. Land use-cropping practices are delineated on the base date/dates color infrared transparency referencing the soil association delineations previously completed.

Step 4. The delineations from steps 2 and 3 are combined to produce one land use/general soil type delineation.

Step 5. All remaining CRD's are processed in a similar manner. The resulting land use/general soil type strata from each CRD are transferred to a 1:1,000,000 U.S.G.S. base map and any boundary inconsistencies between CRD's are eliminated.

Step 6. Growing season day-degree sums are calculated and plotted on the base coordinate system by reporting meteorological station. Isolines are then determined by either manual or automatic/manual interpolation of the data.

Step 7. Growing season precipitation is calculated and plotted on the base coordinate system by reporting meteorological station. Isolines are then determined by either manual or automatic-manual interpolation of the data.

Step 8. Climatic strata are defined.

Step 9. Land use/soil association strata within boundary climate isolines are grouped into analogue areas based on similarity of stratification variable values and ultimately also on the sensitivity of the specific signature extension algorithm used to given stratification variables.

A complete documentation of the UCB signature extension static stratification procedure can be found in Hay and Thomas (1976a , Section 3.0.)

2.3 SUBTASK B : EVALUATION AND REFINEMENT OF STATIC STRATA MAPS

2.3.1 OBJECTIVE

The objective of this subtask is to evaluate and if necessary improve the signature extension stratification maps developed by UCB in previous LACIE tasks. Specifically, the ability of the strata to group spectrally similar wheat subclasses is being evaluated. In addition, variables used to produce the strata maps are being analyzed with regard to their influence on spectral signature of wheat fields, and, if needed, new variables will be introduced to refine or otherwise alter the stratification process.

Analysis to date has centered on the "static" stratification produced for the western two thirds of Kansas. A similar strata map for North Dakota completed in this contract period (see section 2.1) will be similarly evaluated in future work.

2.3.2 APPROACH

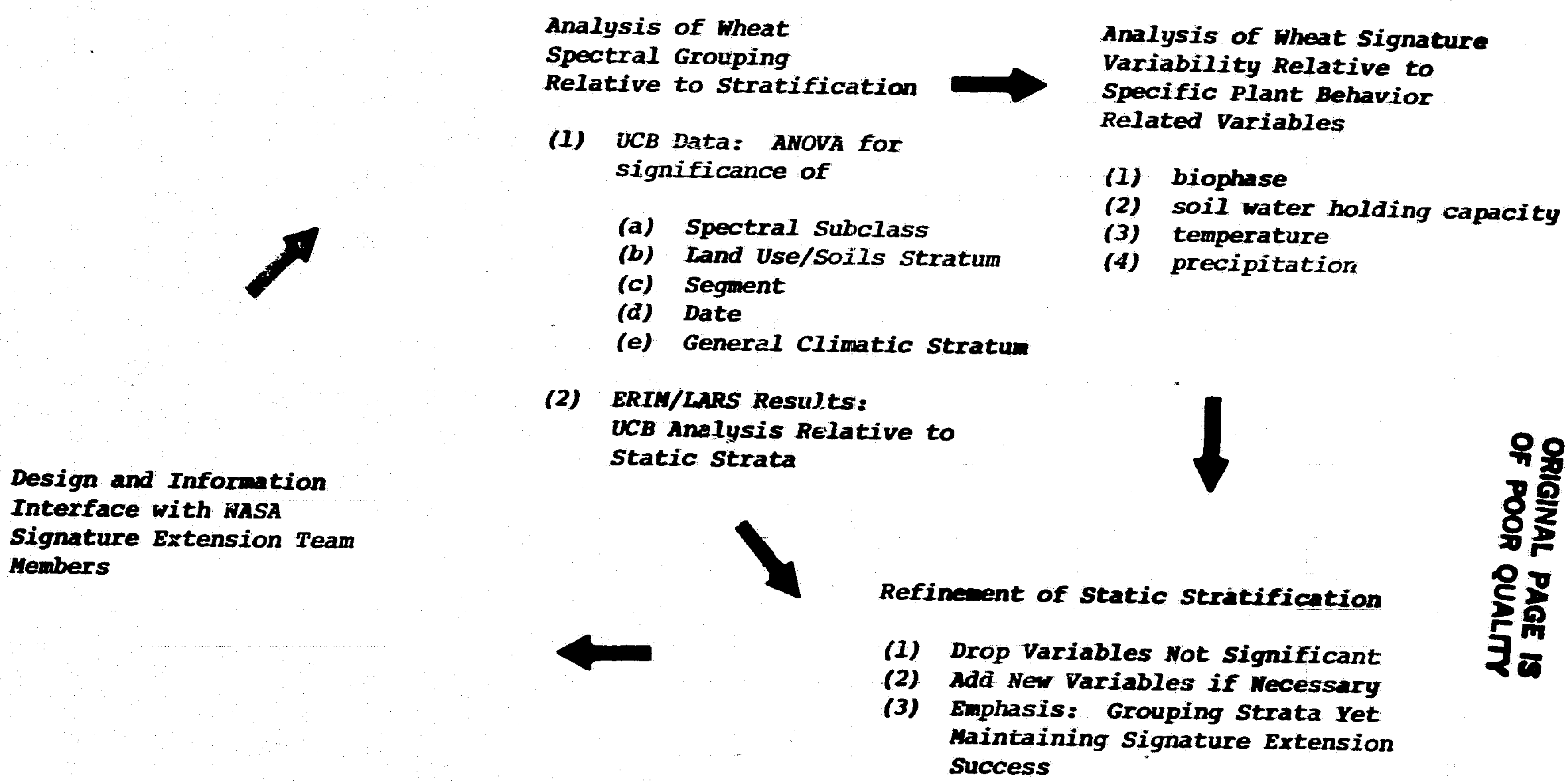
The subtask designed to evaluate the statistical significance of the static stratification and to provide information for its refinement has been divided into two subtasks (Figure 2.6). These are (1) to evaluate through analysis of variance (ANOVA) the static stratification's ability to group spectrally similar areas in order to maximize signature extension success and (2) to determine the statistically significant signature controlling variables for use in refining the stratification procedure.

2.3.2.1 The Analysis of Variance Subtask

The procedure being employed for the first subtask consists of obtaining the spectral mean vector (i.e., the means for each LANDSAT band for each distinct wheat spectral subclsss in each land use/soil association type significantly represented in the 1973-74 Kansas T&E segments. These spectral mean vectors are tests. The result of this analysis is a statistical grouping of spectrally similar and dissimilar wheat subclasses within and between land use/soil association types. Comparison of these groupings with those indicated by the static strata provides a measure of success for the stratification.

The analysis of variance is being utilized to determine the influence of five major factors on wheat signature grouping behavior. These factors are (1) wheat subclass, (2) land use/soil stratum from the "static" strata map, (3) segment, (4) date, and (5) general climatic stratum from the "static" strata map. Wheat subclasses have initially been determined by a resource analyst's judgement of wheat field appearance (e.g. solid bright red, solid dark red, solid light red to pink, or a mix of the above) as

Figure 2.6: *UCB Approach to Evaluation and Refinement of Static Stratification for Signature Extension*



Design and Information Interface with NASA Signature Extension Team Members

Analysis of Wheat Spectral Grouping Relative to Stratification

(1) UCB Data: ANOVA for significance of

  - *(a) Spectral Subclass*
  - *(b) Land Use/Soils Stratum*
  - *(c) Segment*
  - *(d) Date*
  - *(e) General Climatic Stratum*

(2) ERIM/LARS Results: UCB Analysis Relative to Static Strata

Analysis of Wheat Signature Variability Relative to Specific Plant Behavior Related Variables

(1) biophase
(2) soil water holding capacity
(3) temperature
(4) precipitation

Refinement of Static Stratification

(1) Drop Variables Not Significant
(2) Add New Variables if Necessary
(3) Emphasis: Grouping Strata Yet Maintaining Signature Extension Success

viewed on the RSRP television display system*.

A series of one-way ANOVA's is employed to determine the effect of each of these five factors on actual wheat signature grouping relative to the groupings suggested by the "static" strata map. The comparison of interest for each layout is given in Table 2.3. If feasible, results from ERIM and LARS will also be evaluated relative to the five grouping factors.

A separate ANOVA is run for each Landsat band. When a statistically significant between group difference occurs (as .10), Scheffé multiple comparison tests can be used to isolate which groups in the set of groups (e.g. land use/soils strata compared for a given wheat subclass) caused rejection of the null hypothesis of no significant difference among groups.

Separate ANOVA's are being performed by image biophase.** The current date priority for analysis is (1) late April 1974 through early May 1974, (2) late May 1974 through the first half of June 1974, (3) July 1974, and (4) October 1973. Work to date has focused on T&E segments for the late April, early May period. This biophase is the most homogeneous spectrally on the average, and, as such, should provide the most stringent test of the "static" strata for isolating wheat spectral subclasses.

Landsat spectral statistics used in the analysis of variance are obtained in the following manner. First, groups of segments are selected which (1) contain combinations of similar land use strata, (2) fall in the same general climatic stratum, and (3) have useable dates available for the image biophase in question. Field identification data for sample segments in each group are gained from (1) SRS data, (2) JSC field by field A.I. data for 1973-74, and (3) field by field interpretation by RSRP resource analysts.

A systematic sample of wheat fields is then selected using the RSRP interactive display system. Within the central 196 point by 117

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* This computer driven display system is known as the Refresh Memory Display System (REMEDYS). A Nova 840 serves as the host computer, with a Hazeltine 2000 employed for counsel interactive menus; a high speed printer serves for large volume listing.

** image biophase: field color/texture pattern relatable to specific crop life cycle stages; see section 2.0 of Hay and Thomas (1976).

TABLE 2.3: Factors Controlling Wheat Signature Grouping and Their Corresponding Analysis of Variance Comparisons

Grouping Factor	Corresponding One-Way ANOVA Comparison
I. Wheat Spectral Subclass	Between Different Wheat Subclasses Within A Given Land Use/Soils Stratum in A Given Segment on A Given Date
II. Land Use/Soils Stratum	Between Different Land Use/Soils Strata for A Given Wheat Subclass in A Given Segment on A Given Date
III. Segment	Between Different Segments for the Same Wheat Subclass in A Given Land Use/Soils Stratum on A Given Date
IV. Date (Compounded w/ Segment Effect)	Between Different Dates in Different (or Same) Segments for A Given Wheat Subclass for A Given Land Use/Soils Stratum
V. General Climatic Stratum (Compounded w/ Segment and Land Use/Soils Stratum Effect)	Between Different General Climatic Strata in Different Segments in Generally Different Land Use/Soils Strata in A Similar Wheat Subclass on A Similar Date

line segment area, 60 sample points are located with a curser every 20th point and line. The first sample point is located by convention at point 8, line 42.** Six rows of ten sample points are then established. The wheat field falling closest to each sample point is noted as the curser is moved along a given line. The field's ID (JSC A.I. identifier used if available), sample point with which it is associated, and its wheat spectral subclass is recorded in a list under the land use/soils stratum in which it falls. Only wheat fields falling entirely in a stratum are used. On occasion fields must be divided into separate portions when their spectral subclass makeup is significantly different in each subarea. If no wheat fields occur within a 10 to 15 pixel radius of a sample point, then no data is recorded for that point. When the initial systematic sample obtains only a small number of fields (e.g. less than 7), then all wheat fields in a given land use/soils statum are included in the sample.*

*Once the sample of fields is obtained, the curser is used to locate individual wheat field boundaries (generally inset by 1 pixel from the field edge) as displayed on the screen at a scale of two TV lines depth per pixel.*** After the boundaries for a given wheat field included in the sample are defined, the computer is requested to give an immediate listing of the mean vector (bands 4, 5, 6, and 7), covariance matrix, correlation matrix, together with skew and kurtosis distribution statistics. An example of such a listing for a given field is shown in Figure 2.7. The means in each Landsat band for each wheat field in the sample are then employed directly in the analysis of variance.*

2.3.2.2 Signature Controlling Factor Sensitivity Analysis Subtask

This subtask differs from the first in that the physical cause for signature variability is explored. Measurable covariants of direct spectral signature controlling factors are identified and related to signature variability in given Landsat bands. This relationship is

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* *A sample size of 60 fields was selected based on analyst time requirements and on a sample size of 50 pixels required per wheat subclass per land use/soils stratum to give an estimate of a Landsat band mean for that subclass within 5 percent of its true population value 99 percent of the time assuming an average coefficient of variation equal to 10 percent.*

** *Equivalent to point 10, line 50 in 200 x 200 pixel matrix for the T&E segments.*

*** *This scale corresponds to an 8 by 10 inch enlargement of PFC film or RSRP hardcopy film.*

established formally with least squares analysis. The average wheat signature in a given Landsat band, broken out by wheat subclass if necessary, is treated as the dependent variable and the signature controlling factor covariates (refered to as signature controlling factors and/or variables hereafter) are defined to be the independent or predictor variables. Statistical significance of the signature controlling effect or partial regression coefficient for each signature predictor variable is determined after development of the least squares relationship.

Candidate signature controlling variable (Table 2.4) receiving first priority in this analysis are (1) image biophase (manual assessment from full frame segment enlargements), (2) average band 7 to band 5 ratio (crop type/calendar related), (3) atmospheric attenuation (manual assessment of presence of haze, thin cloud cover, and cloud shadow), (4) average bare soil background reflectance by land use/soils stratum, (5) available water holding capacity/soil drainage, (6) planting season precipitation and degree-days (nearest meteorological station), (7) accumulated growing season precipitation and degree-days (nearest meteorological station), and (8) precipitation in the four days preceding the Landsat pass (soil moisture/color related) as recorded at the nearest meteorological station. All factors except climate and soils are field specific. The average bare soil background reflectance is defined to be land use/soil stratum, segment, and date specific, and is obtained from the sum of reflectances in all Landsat bands from a representative sample of bare soil fields selected from analysis of Landsat full frame CIR transparencies. Values for each predictor variable, along with associated average Landsat band responses, are recorded for each wheat field examined in the first subtask.

Candidate signature controlling variables receiving second priority include (1) average January 1974 temperature and average January 1974 minimum temperature (crop development related), (2) 30 year average growing season precipitation and degree-days, and (3) cover type mix/land use descriptors. The sensitivity of wheat spectral signature to these additional variables is to be evaluated if time permits.

Based on the results of the sensitivity analysis just described, stratification variables (e.g. degree-days, soil association) related to signature controlling factors determined to be statistically significant will be retained in the stratification. Those correlated with variables not found significant will be dropped and strata regrouped accordingly. If new variables easily measurable and identifiable for stratification purposes are found to be significant then further stratification on these variables will be considered. Emphasis is placed on determining the degree to which strata can be grouped together to simplify stratification and maintain adequate signature extension success.

Table 2.4: Signature Controlling Variables Employed in the Sensitivity Analysis

	Variable	*Measurement Technique*
(1)	*Wheat Image Biophase*	*Manual Assessment of Field-Specific Full Frame Landsat Data*
(2)	*Band 7 to Band 5 Ratio*	*From Field-Specific Band 7 and Band 5 Landsat Digital Data*
(3)	*Atmospheric Attenuation*	*Manual Assessment of Field-Specific Presence of Haze, Thin Cloud Cover, or Cloud Shadow on Full Frame Data*
(4)	*Average Bare Soil Background Reflectance*	*From Average Sum of Landsat Band 4, 5, 6, and 7 Digital Reflectance Values for a Sample of Bare Soil Fields in Each Land Use/Soils Stratum*
(5)	*Available Water Holding Capacity/Drainage*	*From Land Use/Soils Strata Descriptions, Field-Specific Soil Texture Determination (County Soil Surveys and Landsat CIR Full Frame Interpretation), and Slope Class from 1:250,000 Topographic Maps*
(6)	*Planting Season Precipitation and Degree-Days Accumulated to Pass Date*	*Calculated from Data Supplied from Nearest Meteorological Station Having a Physical/Climatic Setting Most Closely Approximating the Segment*
(7)	*Growing Season Precipitation and Degree-Days Accumulated to Pass Date*	*Same as (6)*
(8)	*Precipitation in the Four Days Preceding Pass Date*	*Same as (6)*

2.3.3 RESULTS AND DISCUSSION

2.3.3.1 The Analysis of Variance Subtask

Initial results were obtained in Kansas for each of the five wheat signature grouping factors given in Table 2.1. Five JSC Test and Evaluation (T&E) segments (crop year 1973-74) were used in this anlysis. These were Scott (1029), Grant (1036), Kearny (1040), Haskell (1065), and Marion (1109). The Marion segment represented an east-central Kansas environment (average growing season degree-days greater than 2250 and rainfall greater than 11 inches for the same period), while the other four segments all belonged to a west-southwestern Kansas environment characterized by a growing season degree-day range of 2000 to 2250 and rainfall less than 8 inches for the same period. Table 2.5 gives a listing of each segment's land use/soils strata that were sampled for wheat spectral data on the specified dates. Land use/soils strata defined to be identical for purposes of this analysis are given on the same line of the table. Data in parenthesis indicates the number of wheat fields sampled in each spectral subclass type. A more complete description of the land use/soils makeup and location of these segments is given in (Hay and Thomas 1976a).

Results from the series of one-way analyses of variance to determine the impact of each wheat signature grouping factor relative to the static signature extension stratification are given in Tables 2.6a - 2.6o. The first six tables illustrate the varying importance of wheat spectral subclass in defining statistically different groupings. Generally, different wheat spectral subclasses within a given land use/soils stratum were found to be highly significantly different. Only in segment 1036 were some bands found to have non-significant difference between subclasses in a stratum. The importance of these wheat subclass differences will have to be evaluated in future work relative to non-wheat confusion subclasses. In particular, within land use/soils strata wheat spectral differences can be ignored for wheat proportion estimating purposes when no significant confusion exists between wheat and non-wheat classes.

Examination of Tables 2.6g through 2.6j shows that little difference was obtained between land use/soils strata in a given segment for a given wheat spectral subclass. This result should be expected at this point in the development of the crop. Full plant canopy cover and minimal canopy structural variation will tend to obscure differences in soil background reflectance or in soil-limited growth response in a given climatic stratum.

Spectral differences (within a wheat subclass) between strata should be evident only in the cases of extreme contrast between soil type or land use characteristics. Table 2.6i demonstrates such spectral differences in bands 4 and 5 among a continuum of strata. Land use strata codes in this example are relatively similar but significant differences exist

Table 2.5: Signature Extension Field Sample, Kansas 1973-74 T&E Data

1029 (20 Apr 74')	1036 (9 May 74')	1040 (9 May 74')	1065 (9 May 74')
211-3/88A (8A,35B,7C)	211-3/88A(1A,5B,3C,4D)	211-3/88A(3B)	
211-3/104A(1A,2B,1C)			
	211-2/88A(1A,6B,8C, 2D,1BC 2BD,1DB)		211-2/88B(17A,15B.7C,1D,6AB, 1BD,1CD)
	211-2/102A(3A,3B,2C)		
	212-3/104A(1A,4B,3C, 1BC		
		210-2/D-A(5A,6B,3C,1BC)	
		220-3/102A(3A,1B,2C)	

Wheat Subclass Key:

A: *Solid Bright Red*

B: *Mixed Bright & Dark Red*

C: *Approximately Solid Dark Red*

D: *Light Red (Pink)*

Other: *Combinations of Above*

Table 2.5 Continued

<u>1109 (6 May)</u>

212-3/55A (3A,7B,4C,1D,2E,7F,1G,
2AC,2AD,1BD,2CA,1FC,3FD)

212-3/55B (1A,2B,3AD,1GF)

Wheat Subclass Key Continued:

E: Light Reddish Brown

F: Dark Green/Blue

G: Light Green

Other: Combinations of Above

Table 2.6a: Spectral Subclass ANOVA

Segment: 1029, Stratum: 211-3/88A

Comparison (i=): 1=Subclass A, 2=Subclass B, 3=Subclass C

Band 4

$i = 1$	2	3
$n_i = 8$	35	7
$\bar{x}_i = 28.32$	29.38	30.07
$s_i = 1.14$	1.27	1.62

$TSS = 91.69$	$df_1 = 2$	$TrMS = 6.06$	
$TrSS = 12.12$	$df_2 = 47$	$MS_e = 1.69$	
$SS_e = 79.56$	$df_3 = 49$	$F = 3.58$	$p = 0.0357$

Band 5

$\bar{x}_i = 21.66$	24.06	25.89
$s_i = 1.26$	1.89	2.31

$TSS = 232.64$	$df_1 = 2$	$TrMS = 34.37$	
$TrSS = 68.74$	$df_2 = 47$	$MS_e = 3.49$	
$SS_e = 163.90$	$df_3 = 49$	$F = 9.86$	$p = 0.0003$

Band 7

$\bar{x}_i = 36.08$	31.69	27.89
$s_i = 1.23$	1.96	1.60

$TSS = 411.05$	$df_1 = 2$	$TrMS = 127.01$	
$TrSS = 254.02$	$df_2 = 47$	$MS_e = 3.34$	
$SS_e = 157.03$	$df_3 = 49$	$F = 38.01$	$p = 1.5 \times 10^{-10}$

Symbol Key:

i = = comparison group index
n_i = number of fields for group i
$\bar{x}_i$ = average spectral response for group i
s_i = spectral standard deviation for group i
TSS = total sum of squares
$TrSS$ = treatment sum of squares
SS_e = sum of squares for error

df_1 = treatment degrees of freedom
df_2 = degrees of freedom for error
df_3 = total degrees of freedom
$TrMS$ = treatment mean square
MS_e = mean square for error
F = F - statistic
p = level of statistical significance; values $\leq$ 0.10 indicate significant group difference

Table 2.6b: Spectral Subclass ANOVA

Segment: 1036, Stratum: 211-3/88A

Comparison (i=): 1 = Subclass B, 2 = Subclass C, 3 = Subclass D

Band 4

$i = 1$	2	3	
$n_i = 5$	3	4	
$\overline{x}_i = 33.07$	29.34	45.79	
$s_i = 3.96$	3.55	6.13	
$TSS = 758.18$	$df_1 = 2$	$TrMS = 278.63$	
$TrSS = 557.26$	$df_2 = 9$	$MS_e = 22.32$	
$SS_e = 200.91$	$df_3 = 11$	$F = 12.48$	$p = .0025$

Band 5

$\overline{x}_i = 30.77$	25.67	46.82	
$s_i = 6.36$	5.92	3.44	
$TSS = 1176.27$	$df_1 = 2$	$TrMS = 454.49$	
$TrSS = 908.99$	$df_2 = 9$	$MS_e = 29.70$	
$SS_e = 267.28$	$df_3 = 11$	$F = 15.30$	$p = .0013$

Band 7

$\overline{x}_i = 28.15$	26.05	29.17	
$s_i = 1.02$	0.87	1.16	
$TSS = 26.67$	$df_1 = 2$	$TrMS = 8.47$	
$TrSS = 16.94$	$df_2 = 9$	$MS_e = 1.08$	
$SS_e = 9.73$	$df_3 = 11$	$F = 7.83$	$p = .0107$

Table 2.6c: Spectral Subclass ANOVA

Segment: 1036; Stratum: 211-2/102A

Comparison (i=): 1 = Subclass A, 2 = Subclass B, 3 = Subclass C

Band 4

$i = 1$	2	3	
$n_i = 3$	3	2	
$\bar{x}_i = 30.42$	29.22	33.60	
$s_i = 4.54$	3.08	0.03	
$TSS = 83.87$	$df_1 = 2$	$TrMS = 11.80$	
$TrSS = 23.59$	$df_2 = 5$	$MS_e = 12.06$	
$SS_e = 60.28$	$df_3 = 7$	$F = 0.98$	$p = 0.4374$

Band 5

$\bar{x}_i = 25.33$	24.61	32.73	
$s_i = 5.59$	5.42	1.21	
$TSS = 213.53$	$df_1 = 2$	$TrMS = 45.48$	
$TrSS = 90.96$	$df_2 = 5$	$MS_e = 24.51$	
$SS_e = 122.57$	$df_3 = 7$	$F = 1.86$	$p = 0.2490$

Band 7

$\bar{x}_i = 32.42$	28.38	25.80	
$s_i = 3.06$	1.60	0.88	
$TSS = 81.02$	$df_1 = 2$	$TrMS = 28.18$	
$TrSS = 56.35$	$df_2 = 5$	$MS_e = 4.93$	
$SS_e = 24.67$	$df_3 = 7$	$F = 5.71$	$p = 0.0512$

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Table 2.6d: Spectral Subclass ANOVA

Segment: 1036; Stratum 212-3/104A

Comparison (i =): 1 = Subclass B, 2 = Subclass C

Band 4

i = 1	2		
n_i = 4	3		
$\bar{x}_i$ = 28.97	34.28		
s_i = 1.62	0.73		
TSS = 57.28	df_1 = 1	$TrMS$ = 48.35	
$TrSS$ = 48.35	df_2 = 5	MS_e = 1.79	
SS_e = 8.93	df_3 = 6	F = 27.06	p = 0.0096

Band 5

$\bar{x}_i$ = 24.52	33.12		
s_i = 2.51	1.13		
TSS = 148.24	df_1 = 1	$TrMS$ = 126.84	
$TrSS$ = 126.84	df_2 = 5	MS_e = 4.28	
SS_e = 21.40	df_3 = 6	F = 29.63	p = 0.0082

Band 7

$\bar{x}_i$ = 28.40	26.67		
s_i = 1.55	0.55		
TSS = 12.97	df_1 = 1	$TrMS$ = 5.12	
$TrSS$ = 5.12	df_2 = 5	MS_e = 1.57	
SS_e = 7.84	df_3 = 6	F = 3.26	p = 0.1316

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Table 2.6e: Spectral Subclass ANOVA

Segment: 1065; Stratum: 211-2/88B

Comparison ($i =$): 1 = Subclass A, 2 = Subclass B, 3 = Sublcass C,
4 = Subclass AB

Band 4

$i = 1$	2	3	4
$n_i = 17$	15	7	3
$\bar{x}_i = 27.51$	28.52	31.00	27.12
$s_i = 2.08$	2.70	2.42	2.78

TSS = 287.68	df_1 3	TrMS = 21.99	
TrSS = 65.97	$df_2 = 38$	$MS_e = 5.83$	
$SS_e = 221.71$	$df_3 = 41$	$F = 3.77$	$p = 0.0183$

Band 5

$\bar{x}_i = 21.72$	24.70	29.02	21.20
$s_i = 3.38$	4.56	3.62	4.59

TSS = 890.67	$df_1 = 3$	TrMS = 98.55	
TrSS = 295.65	$df_2 = 38$	$MS_e = 15.66$	
$SS_e = 595.03$	$df_3 = 41$	$F = 6.29$	$p = 0.0014$

Band 7

$\bar{x}_i = 29.52$	24.46	22.61	28.56
$s_i = 2.59$	1.38	1.66	2.80

TSS = 502.29	$df_1 = 3$	TrMS = 111.99	
TrSS = 335.98	$df_2 = 38$	$MS_e = 4.38$	
$SS_e = 166.31$	$df_3 = 41$	$F = 25.59$	$p = 2.7\text{X}10^{-9}$

Table 2.6f: Spectral Subclass ANOVA

Segment: 1109; Stratum: 212-3/55A

Comparison (i =): 1 = Subclass A, 2 = Subclass B, 3 = Subclass C, 4 = Subclass F, 5 = Subclass FD

Band 4

i = 1	2	3	4	5
n_i = 3	7	4	7	3
$\bar{x}_i$ = 27.44	28.19	28.15	29.51	29.66
s_i = 0.91	1.43	0.43	0.64	0.53

TSS = 32.58	df_1 = 4	TrMS = 3.77	
TrSS = 15.08	df_2 = 19	ME_e = 0.92	
SS_e = 17.50	df_3 = 23	F = 4.09	p = 0.0148

Band 5

$\bar{x}_i$ = 19.36	21.52	21.59	24.26	24.05
s_i = 2.06	1.97	0.82	1.01	0.62

TSS = 108.76	df_1 = 4	TrMS = 17.01	
TrSS = 68.02	df_2 = 19	MS_e = 2.14	
SS_e = 40.74	df_3 = 23	F = 7.93	p = 0.0006

Band 7

$\bar{x}_i$ = 32.69	25.74	23.86	22.46	23.62
s_i = 6.22	1.19	2.70	0.87	0.74

TSS = 350.33	df_1 = 4	TrMS = 59.25	
TrSS = 237.00	df_2 = 19	MS_e = 5.96	
SS_e = 113.33	df_3 = 23	F = 9.93	p = 0.0002

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Table 2.6g: Land Use/Soils Strata ANOVA

Segment 1029; Spectral Subclass: B

Comparison (i =): 1 = 211-3/88A; 2 = 211-3/104A

Band 4

i = 1	2		
n_i = 35	2		
$\bar{x}_i$ = 29.38	29.48		
s_i = 1.27	0.23		
TSS = 54.65	df_1 = 1	TrMS = 0.02	
TrSS = 0.02	df_2 = 35	MS_e = 1.56	
SS_e = 54.63	df_3 = 36	F = 0.01	p = 0.9221

Band 5

$\bar{x}_i$ = 24.06	24.71		
s_i = 1.89	1.91		
TSS = 125.28	df_1 = 1	TrMS = 0.81	
TrSS = 0.81	df_2 = 35	MS_e = 3.56	
SS_e = 124.47	df_3 = 36	F = 0.23	p = 0.6395

Band 7

$\bar{x}_i$ = 31.69	30.66		
s_i = 1.96	2.72		
TSS = 140.47	df_1 = 1	TrMS = 2.01	
TrSS = 2.01	df_2 = 35	MS_e = 3.96	
SS_e = 138.46	df_3 = 36	F = 0.51	p = 0.4863

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Table 2.6h: Land Use/Soils Strata ANOVA

Segment: 1036; Spectral Subclass: B

Comparison (i =): 1 = 211-3/88A, 2 = 211-2/102A, 3 = 212-3/104A

Band 4

$i =$ 1	2	3	4
$n_i =$ 5	6	3	4
$\bar{x}_i =$ 33.07	30.10	29.22	28.97
$s_i =$ 3.96	3.92	3.08	1.62

$TSS = 214.79$ $df_1 = 3$ $TrMS = 16.10$
$TrSS = 48.30$ $df_2 = 14$ $MS_e = 11.89$
$SS_e = 166.49$ $df_3 = 17$ $F = 1.35$ $p = .2984$

Band 5

$\bar{x}_i =$ 30.77	26.51	24.61	24.52
$s_i =$ 6.36	6.20	5.42	2.51

$TSS = 545.62$ $df_1 = 3$ $TrMS = 38.08$
$TrSS = 114.25$ $df_2 = 14$ $MS_e = 30.81$
$SS_e = 431.37$ $df_3 = 17$ $F = 1.24$ $p = .3325$

Band 7

$\bar{x}_i =$ 28.15	27.48	28.38	28.40
$s_i =$ 1.02	1.55	1.60	1.55

$TSS = 31.40$ $df_1 = 3$ $TrMS = 0.94$
$TrSS = 2.81$ $df_2 = 14$ $MS_e = 2.04$
$SS_e = 28.59$ $df_3 = 17$ $F = 0.46$ $p = .7146$

Table 2.6i: Land Use/Soils Strata ANOVA

Segment: 1036; Spectral Subclass: C

Comparison ($i =$): 1 = 211-3/88A, 2 = 211-2/88A, 3 = 211-2/102A,
4 = 212-3/104A

Band 4

$i =$	1	2	3	4
$n_i =$	3	8	2	3
$\bar{x}_i =$	29.34	31.47	33.60	34.28
$s_i =$	3.55	2.10	0.03	0.73

$TSS = 101.11$ $df_1 = 3$ $TrMS = 14.64$
$TrSS = 43.92$ $df_2 = 12$ $MS_e = 4.77$
$SS_e = 57.19$ $df_3 = 15$ $F = 3.07$ $p = .0689$

Band 5

$\bar{x}_i =$	25.67	28.65	32.73	33.12
$s_i =$	5.92	3.47	1.21	1.13

$TSS = 268.01$ $df_1 = 3$ $TrMS = 36.58$
$TrSS = 109.74$ $df_2 = 12$ $MS_e = 13.19$
$SS_e = 158.27$ $df_3 = 15$ $F = 2.77$ $p = .0874$

Band 7

$\bar{x}_i =$	26.05	26.00	25.80	26.67
$s_i =$	0.87	0.92	0.88	0.55

$TSS = 10.05$ $df_1 = 3$ $TrMS = 0.41$
$TrSS = 1.24$ $df_2 = 12$ $MS_e = 0.73$
$SS_e = 8.81$ $df_3 = 15$ $F = 0.56$ $p = .6515$

Table 2.6j: Land Use/Soils Strata ANOVA

Segment: 1040; Spectral Subclass: A

Comparison (i =): 210-2/D-A, 2 = 220-3/102A

Band 4

i = 1	2		
n_i = 5	3		
$\bar{x}_i$ = 29.37	30.70		
s_i = 3.56	1.94		
TSS = 61.60	df_1 = 1	TrMS = 3.32	
TrSS = 3.32	df_2 = 6	MS_e = 9.71	
SS_e = 58.28	df_3 = 7	F = 0.34	p = 0.5811

Band 5

$\bar{x}_i$ = 22.74	25.10		
s_i = 4.90	3.48		
TSS = 130.51	df_1 = 1	TrMS = 10.41	
TrSS = 10.41	df_2 = 6	MS_e = 20.02	
SS_e = 120.10	df_3 = 7	F = 0.52	p = 0.4980

Band 7

$\bar{x}_i$ = 34.79	33.23		
s_i = 3.55	5.83		
TSS = 122.93	df_1 = 1	TrMS = 4.57	
TrSS = 4.57	df_2 = 6	MS_e =19.73	
SS_e = 118.36]	df_3 = 7	F = 0.23	p = 0.6485

Table 2.6k: Segment ANOVA

Stratum: 211-2/88A or B; Spectral Subclass B

Comparison (i =): 1 = 1036 (88A soil), 2 = 1065 (88B Soil)

Band 4

$i = 1$	2		
$n_i = 6$	15		
$\bar{x}_i = 30.10$	28.52		
$s_i = 3.92$	2.70		
$TSS = 189.53$	$df_1 = 1$	$TrMS = 10.69$	
$TrSS = 10.69$	$df_2 = 19$	$MS_e = 9.41$	
$SS_e = 178.83$	$df_3 = 20$	$F = 1.14$	$p = 0.3125$

Band 5

$\bar{x}_i = 26.51$	24.70		
$s_i = 6.20$	4.56		
$TSS = 497.80$	$df_1 = 1$	$TrMS = 14.09$	
$TrSS = 14.09$	$df_2 = 19$	$MS_e = 25.46$	
$SS_e = 483.71$	$df_3 = 20$	$F = 0.55$	$p = 0.4797$

Band 7

$\bar{x}_i = 27.48$	24.46		
$s_i = 1.55$	1.38		
$TSS = 77.59$	$df_1 = 1$	$TrMS = 39.05$	
$TrSS = 39.05$	$df_2 = 19$	$MS_e = 2.03$	
$SS_e = 38.54$	$df_3 = 20$	$F = 19.26$	$p = 0.0005$

Table 2.61: Segment ANOVA

Stratum: 211-2/88A or B; Spectral Subclass: C

Comparison (i =): 1 = 1036 (88A Soil), 2 = 1065 (88B Soil)

Band 4

$i = 1$	2
$n_i = 8$	7
$\bar{x}_i = 31.47$	31.00
$s_i = 2.10$	2.42

$TSS = 66.81$	$df_1 = 1$	$TrMS = 0.80$	
$TrSS = 0.80$	$df_2 = 13$	$MS_e = 5.08$	
$SS_e = 66.01$	$df_3 = 14$	$F = 0.16$	$p = 0.7075$

Band 5

$\bar{x}_i = 28.65$	29.02
$s_i = 3.47$	3.62

$TSS = 163.06$	$df_1 = 1$	$TrMS = 0.51$	
$TrSS = 0.51$	$df_2 = 13$	$MS_e = 12.50$	
$SS_e = 162.55$	$df_3 = 14$	$F = 0.04$	$p = 0.8508$

Band 7

$\bar{x}_i = 26.00$	22.61
$s_i = 0.92$	1.66

$TSS = 65.41$	$df_1 = 1$	$TrMS = 42.88$	
$TrSS = 42.88$	$df_2 = 13$	$MS_e = 1.73$	
$SS_e = 22.54$	$df_3 = 14$	$F = 24.73$	$p = 0.0005$

Table 2.6m: Segment ANOVA

Stratum: 211-3/88A; Spectral Subclass: B

Comparison ($i =$): 1 = 1036, 2 = 1040

Band 4

$i = 1$ 2
$n_i = 5$ 3

$\bar{x}_i = 33.07$ 25.23
$s_i = 3.96$ 1.30

$TSS = 181.51$ $df_1 = 1$ $TrMS = 115.31$
$TrSS = 115.31$ $df_2 = 6$ $MS_e = 11.03$
$SS_e = 66.21$ $df_3 = 7$ $F = 10.45$ $p = 0.0179$

Band 5

$\bar{x}_i = 30.77$ 19.01
$s_i = 6.36$ 2.30

$TSS = 431.46$ $df_1 = 1$ $TrMS = 259.16$
$TrSS = 259.16$ $df_2 = 6$ $MS_e = 28.72$
$SS_e = 172.29$ $df_3 = 7$ $F = 9.03$ $p = 0.0239$

Band 7

$\bar{x}_i = 28.14$ 28.30
$s_i = 1.02$ 1.31

$TSS = 7.68$ $df_1 = 1$ $TrMS = 0.04$
$TrSS = 0.04$ $df_2 = 6$ $MS_e = 1.27$
$SS_e = 7.64$ $df_3 = 7$ $F = 0.03$ $p = 0.8682$

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Table 2.6n: Date ANOVA

Stratum: 211-3/88A; Spectral Subclass B

Comparison (i =): 1 = 1029 (20 Apr. '74), 2 = 1036 (9 May '74)
3 = 1040 (9 May '74)

Band 4

$i = 1$	2	3
$n_i = 35$	5	3
$\overline{x}_i = 29.38$	33.07	25.23
$s_i = 1.27$	3.96	1.30

TSS = 239.73	$df_1 = 2$	TrMS = 59.47	
TrSS = 118.95	$df_2 = 40$	$MS_e = 3.02$	
$SS_e = 120.78$	$df_3 = 42$	$F = 19.70$	$p = 1.1 \times 10^{-6}$

Band 5

$\overline{x}_i = 24.06$	30.77	19.01
$s_i = 1.89$	6.36	2.30

TSS = 586.88	$df_1 = 2$	TrMS = 146.88	
TrSS = 293.76	$df_2 = 40$	MS = 7.33	
$SS_e = 293.12$	$df_3 = 42$	$F = 20.04$	$p = 9.3 \times 10^{-7}$

Band 7

$\overline{x}_i = 31.69$	28.15	28.30
$s_i = 1.96$	1.02	1.31

TSS = 217.52	$df_1 = 2$	TrMS = 39.42	
TrSS = 78.83	$df_2 = 40$	MS = 3.47	
$SS_e = 138.69$	$df_3 = 42$	$F = 11.37$	$p = 1.2 \times 10^{-4}$

Table 2.6o: Major Climatic Stratum ANOVA

Segments: 1036 & 1065 (211-3/88A), 1109 (212-3/55A)

Subclass: C

Comparison (i -): 1 & 2 = 2000-2250 Degree-Days, <8 Inches Precipitation (1036 & 1065)
3 = >2250 Degree-Days, >11 Inches Precipitation (1109)

Band 4

i =	1	2	3
n_i =	3	7	4
$\bar{x}_i$ =	29.34	31.00	28.15
s_i =	3.55	2.42	0.43

$TSS = 82.61$	$df_1 = 2$	$TrMS = 10.84$	
$TrSS = 21.67$	$df_2 = 11$	$MS_e = 5.54$	
$SS_e = 60.94$	$df_3 = 13$	$F = 1.96$	$p = 0.1870$

Band 5

$\bar{x}_i$ =	25.67	29.02	21.59
s_i =	5.92	3.62	0.82

$TSS = 291.97$	$df_1 = 2$	$TrMS = 70.67$	
$TrSS = 141.33$	$df_2 = 11$	$MS_e = 13.69$	
$SS_e = 150.64$	$df_3 = 13$	$F = 5.16$	$p = 0.0263$

Band 7

$\bar{x}_i$ =	26.05	22.61	23.86
s_i =	0.87	1.66	2.70

$TSS = 64.97$	$df_1 = 2$	$TrMS = 12.50$	
$TrSS = 25.01$	$df_2 = 11$	$MS_e = 3.63$	
$SS_e = 39.96$	$df_3 = 13$	$F = 3.44$	$p = 0.0691$

among the soil types. The 88A series consists of clay and silt loam soils of the High Plains, 102A shallower loamy soils on sloping surfaces, and 104A sandier loams transitional between Sandhill soils and High Plains Tablelands Soils. Effectively, this set of soils can be considered a gradient from relatively high water holding capacity (88A) to lower (104A) with 102A intermediate. While the specific soil-related cause for the monotonically increasing spectral response in bands 4 and 5 moving from 88A to 104A has not been determined at this time, at least two hypotheses may be offered. The first would attribute the rise in spectral response to increasingly less dense canopy cover owing to increasing lower availibility of water. This would progressively allow more soil of increasing lighter color (soil texture-related) to add to spectral response.

Another explanation for the differences encountered in segment 1036 is that the drier 104A soils tend to cause a faster maturation of the wheat crop, thus tending to reduce chlorophyl absorption (i.e. increase reflectance), particularly in band 5. The existence of an average wheat crop maturity difference in this segment on this date between strata is supported by band 7 to band 5 ratio values. These values decrease from 2.03 in the 211-3/88A stratum to 1.61 in the 212-3/104A stratum. Ongoing work at RSRP has indicated that the band 7/5 ratio may be a good indicator of crop development stage (see Appendix B). The data in Table 2.6i suggest that the wheat on the 88A soil is more actively metabolizing (higher ratio) while that on the 104A soil may have already peaked in terms of active biomass and may be, as indicated by the lower ratio, in the headed stage. Consequently, lower chlorophyll absorption and higher reflectance in band 5 can be expected.

Unexplained, however, by the crop maturity difference theory is the higher green channel (band 4) reflectance in the relatively drier 104A soil type or the lack of significant difference in the corresponding band 7 reflectance from that in other strata. All other factors being equal, lower metabolic activity in the 104A wheat fields should have given a lower band 7 response. The answer may be that a combination of canopy density reflectance difference and crop development difference, both related to soil available water holding capacity, has given rise to the reflectance data in Table 2.6i. Increased soil background reflectance resulting from a lower density canopy would tend to increase band 4 reflectance, while at the same time increasing the band 7 response over what it would have been on dark soils with greater available waterhold capacity. Crop maturity differences could account for differences in band 5 reflectance, as explained previously, in combination with reflectance increases due to lower canopy density. The sensitivity analysis task will be required to determine the actual causal mechanism(s) giving rise to the spectral relationships evident in Table 2.6i.

A comparison of wheat signature differences between different segments for the same land use/soils stratum and the same spectral subclass is given in Tables 2.6k - 2.6m. The first two of these tables compare *wheat spectral response between segment 1036 and 1065 for the 211-2/88 soil type. In both cases, no significant difference was found between band 4 and 5 values while band 7 differences were highly significant. Exactly the reverse was true in Table 2.6m where spectral response was compared for the 211-3/88A land use/soils type in segments 1036 and 1040.*

Interpretations regarding the cause of these differences are weakened by the manner in which the spectral subclasses were defined. In particular, the histogram equalization monitor display procedure did not consistently portray wheat subclasses as they would appear on the same Landsat full frame CIR transparency. For example, subclass C as depicted in standardized manner across all segments on a given full frame could be enhanced, and thus subclass coded, somewhat differently between segments on the color monitor. Limited reference to hardcopy was made to control for this error source. However, subsequent analysis of the resulting spectral statistics by subclass suggests that non-standardization of wheat subclass designations may have occurred between segments. Between segment subclass standardization and results of the signature controlling factor analysis will be required before the differences in Tables 2.6k - 2.6m can be explained.

Table 2.6n compares segment data from two dates 18 days apart while land use/soil stratum and wheat subclass are kept constant. Significant differences were found in all bands. Scheffé multiple comparison tests (Table 2.7) were then applied to isolate which pairwise combinations were causing rejection of the null hypothesis of no difference among means. Review of Table 2.7 indicates that the difference between the Scott (1029, 20 Apr 74) and Kearny (1040, 9 Apr 74) segments was highly significant for all bands. Highly significant differences were also obtained between the Grant (1036, 9 May 74) and Kearny segments in bands 4 and 5, but not in band 7. Scott versus Grant gave mixed results.

These results (Tables 2.6n and 2.7) suggest that significant differences can occur between dates in the same land use/soils stratum and between segments on the same date. The authors suspect that date specific biophase differences are largely responsible for the differences observed in this case. Due to variation in average climate (primarily greater growing season degree-day sums) across a given climatic stratum, the Grant segment should be developmentally ahead of both the Scott and Kearny segments, and Kearny ahead of Scott in the case of the 18 day difference. However, a thorough evaluation of signature controlling factors and the spectral subclass definition problem discussed earlier will have to be performed before definitive statements can be made regarding the cause of the differences in Table 2.6n.

A comparison of wheat spectral data from two different climatic strata is given in Table 2.6o. Examination of the Scheffé multiple comparison test results (Table 2.8) for this data shows that in one case (Haskell vs. Marion) there was a significant difference (Bands 4 and 5) between segments in the two different climatic strata while in the other case (Grant vs. Marion) no significant difference was found. Indeed, in band 7 a greater separation was detected between the segments in the same climatic stratum

Table 2.7: Scheffé Multiple Comparisons Among Wheat Subclass B Spectral Means from Data of Table 2.6n

Segment Comparison (i = ,)	F - Statistic	Significance Level	
Band 4			
1,2	2.14	>10%	Not Significant
1,3	14.12	<.5%	Highly Significant
2,3	8.31	<.5%	Highly Significant
Band 5			
1,2	2.75	<10%	Moderately Significant
1,3	6.84	<.5%	Highly Significant
2,3	7.02	<.5%	Highly Significant
Band 7			
1,2	19.71	<.5%	Highly Significant
1,3	8.43	<.5%	Highly Significant
2,3	0.01	>10%	Not Significant

Table 2.8: Scheffé Multiple Comparisons Among Wheat Subclass C Spectral Means from Data of Table 2.6o

Band 4

Segment Comparison (i = ,)	F - Statistic	Significance Level	
1,2	0.28	>10%	Not Significant
1,3	0.17	>10%	Not Significant
2,3	4.60	< 5%	Moderately Significant

Band 5

Segment Comparison (i = ,)	F - Statistic	Significance Level	
1,2	0.42	>10%	Not Significant
1,3	0.70	>10%	Not Significant
2,3	13.53	<.5%	Highly Significant

Band 7

Segment Comparison (i = ,)	F - Statistic	Significance Level	
1,2	9.16	<.5%	Highly Significant
1,3	0.53	>10%	Not Significant
2,3	0.36	>10%	Not Significant

than between climatic strata. Several factors including spectral biophase difference are being used to evaluate these differences relative to improvement in the static stratification procedure.

2.3.3.2 Signature Controlling Factor Sensitivity Analysis Subtask

Work to date on this subtask has focused on signature controlling variable definition and data preparation for the Kansas T&E segment set. All 1973-74 planting and growing season degree-day precipitation information has been obtained for each segment from a designated ground meteorological station in the National Weather Service network. Most stations fell within 20 miles of the segment center and were selected to represent physiographic settings as potentially mesoclimatically similar as possible to the average physiographic setting for the segment in question. Precipitation for the four days previous to given segment pass dates is also being determined from the same stations.

Manual assessment of wheat image biophase is proceeding for late April and early May 1974 Kansas T&E segment pass dates. Image biophase is being determined* for fields selected in the spectral grouping analysis sample described in the last section (2.3.3.1). Analyst judgement is based on interpretation of Landsat CIR full frame transparencies of the corresponding pass date.

A more rigorous definition of field-specific wheat biophase is being obtained from digital band 7 to band 5 ratio data for fields previously analyzed manually for image biophase. This ratio data is being obtained by use of the RSRP interactive color display system. The relative biophase for given wheat spectral subclasses is being determined according to the position that subclass occupies on the 7/5 ratio time sequence curve explained in Appendix B.

Average bare soil background reflectance data is being obtained for all Kansas T&E segment passes in the late April, early May 1974 time frame. The procedure consists of locating a small sample of fields in the given land use/soils stratum in the given segment that appear on full frame data to have average bare soil reflectance. Spectral data from each field is obtained via statistics summary procedure on the color display system and then pooled together to give average bare soil band means and variances. Originally a manual bare soil reflectance class assessment was required. However, this approach proved to be inconsistent due to differences in film processing between transparencies.

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* According to image biophase definitions given in Section 2.3.3.1a of Hay and Thomas (1976).

Available water holding capacity data is primarily land use/soils stratum specific, but in some cases field specific data is available from county soil survey maps. This data is being obtained for all Kansas T&E segments.

To date, field specific atmospheric attenuation has been limited to "clear" versus "haze" as judged from analysis of full frame Landsat imagery for the late April and early May 1974 pass dates. Thin cloud, cloud, or cloud shadow field spectral data has not been significantly present.

2.4 SUMMARY AND CONCLUSIONS

The static stratification evaluation task has been divided into two subtasks. First, a grouping analysis is being performed via ANOVA to determine how wheat is spectrally grouping relative to its supposed grouping pattern under the assumptions of the static signature extension stratification. The second subtask involves a sensitivity analysis to explain the wheat spectral grouping behavior observed in the first subtask according to specific signature controlling factors. Results from both subtasks will then be used, in conjunction with work and results available from ERIM, LARS, and JSC, to refine the static stratification if necessary.

Initial results are available only for the wheat spectral grouping subtask. These results suggest that:

(1) Differences among wheat spectral subclasses are statistically significant in the same land use/soils stratum;

(2) Land use/soil association strata within a segment appear to have a wheat spectral grouping capability; see discussion of Table 2.6i;

(3) Spectral differences between segments, even within the same land use/soils stratum type, can be significant; a problem of inconsistent spectral subclass definition between segments was identified that complicates the analysis of results presented; and

(4) The sensitivity analysis will be required to explain most of the spectral differences observed in Tables 2.6a-o.

2.5 FUTURE WORK

The initial procedure used for the wheat spectral grouping analysis subtask will be reviewed and revised. Specific changes will include

(1) a more consistent wheat spectral subclass definition method,

(2) the use of pairwise crop subclass comparison tests (e.g. Scheffé) simultaneously employing several bands of Landsat-derived data as opposed to single band comparisons reported here, and

(3) comparison of wheat spectral subclasses with non-wheat classes in order to allow grouping of wheat subclasses when confusion with non-wheat is not significant.

Other changes in the analysis procedure will be considered if appropriate. The Kansas segment set analyzed will be expanded in the next reporting period to include additional 1974 and possibly 1975 dates.

The sensitivity analysis relating wheat signature controlling factor values to corresponding Landsat wheat spectral response will continue to focus on the Kansas 1974 data set in the next reporting period.

SECTION 3:

TASK II - DEVELOPMENT OF PHOTOINTERPRETATION METHODS BASED ON MULTITEMPORAL LANDSAT DATA

3.0 TASK II: DEVELOPMENT OF PHOTOINTERPRETATION METHODS BASED ON MULTITEMPORAL LANDSAT DATA

3.1 INTRODUCTION

The purpose of this task is to develop photointerpretive methods for using multitemporal Landsat data which are improvements to the current LACIE methods. This task will be approached through three subtasks. The subtasks are: (1) Subtask A - familiarization with JSC/LACIE photointerpretation procedures, (2) Subtask B - the Development of Multitemporal Interpretation - Training Field Selection Procedures whereby individual temporal images and temporal spectral data are analyzed by means of some decision making logic sequence for the identification and selection of training areas (fields), and (3) Subtask C - the development and evaluation of methods for reducing multitemporal data to a single image or set of multitemporally combined/enhanced images.

3.2 SUBTASK A: FAMILIARIZATION WITH JSC/LACIE PHOTOINTERPRETATION PROCEDURES

3.2.1 OBJECTIVE

The objective of this subtask is to familiarize UCB with JSC/LACIE photointerpretion procedures. Besides an initial familiarization effort with current LACIE procedures, a continuing effort to remain current on all implemented and proposed photointerpretation procedure modifications will be maintained. This subtask is vital to efficient and effective performance upon the other two subtasks within Task II.

3.2.2 APPROACH

An initial familiarization visit to JSC was made in August 1976. During this visit CAMS Operations personnel provided tutorial sessions and over-the-shoulder-look interpretation sessions for the RSRP personnel. CAMS procedure documents were reviewed by UCB prior to the JSC visit. This review was used to identify ambiguities in the documents and problems relative to the AI expanded data** that could be addressed and discussed with*

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* *NASA/LEC (1976a)*

** *A number of signature extension T&E segments were 100% interpreted by JSC AI's to provide an expanded data set for the signature extension effort. This data set is referred to as AI expanded data.*

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the CAMS Operations personnel at the time of the visit.

UCB will maintain contact with CAMS Operations personnel and will request additional interactive sessions as needed to remain current on any modifications to the JSC/LACIE photointerpretation procedures.

3.2.3 DISCUSSION

Some observations and comments of the UCB personnel with respect to LACIE photointerpretation procedures stemming from the initial JSC AI procedures familiarization visit were recorded in the previous quarterly progress report (Hay et al 1976b). The comments have been reviewed and reported upon by LACIE Operations personnel (NASA 1976b).

3.3 SUBTASK B: DEVELOPMENT OF MULTITEMPORAL INTERPRETATION - TRAINING FIELD SELECTION PROCEDURES

3.3.1 OBJECTIVE

The purpose of this subtask is to develop improved multitemporal interpretation - training field selection procedures relative to those currently employed in LACIE. Specifically,procedures which allow the analyst to utilize both normal multitemporal image presentations and preprocessed spectral data presentations for the selection of machine classifier training will be developed and evaluated.

This subtask will build on manual interpretation procedures developed in a previous UCB-LACIE task (see Hay and Thomas, 1976a) and incorporate the usage of digital spectral information along with the analysis of the standard band CIR image product.

The standard image product does not adequately represent the full spectral variability contained within the data and consequently may not provide all information required for optimum training area selection. The analyst must be able to "see" the data as the machine "sees" the data. The analyst must, however, still be able to interpret the scene within his own sensor reference frame in order to adequately analyse that data. Thus a combination of individual multitemporal standard CIR images and preprocessed spectral data may be a more optimum data set for the analyst to use in both identification and training area selection tasks.

3.3.2 APPROACH

Several alternative class identification and training-field selection procedures using multitemporal sequences of single date Landsat standard band CIR images and special spectral data presentations will be defined and evaluated. Candidate procedures currently in development include a variety of image types and preprocessed spectral data. The candidate data formats currently being considered are summarized in Table 3.1.

Image types to be utilized will include the standard JSC PFC transparency product, enlargements from Landsat full frame CIR transparencies, IGOR image production products, and an interactive color monitor display**. JSC PFC product will be utilized most significantly in as much as it is*

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* *IGOR - Imaging Ganged Optics Reproducer, a UCB in-house filing harcopy system.*

** *The color display system to be used is REMEDYS, a UCB in-house system.*

Table 3.1

Subtask B: Development of Multitemporal Interpretation Training Field Selection Procedures

Data Formats

Image Types

- *JSC PFC Film*
- *Enlargements from Landsat Full Frame CIR Transparencies*
- *UCB Hardcopy (IGOR) Image Production Film*
- *Interactive Monitor Display*

Digital Data

- *Spectral Means, Standard Deviations and Covariance Matrices of Candidate Training Fields*
- *7/5 Field/Pixel-Specific Ratios*
- *Cluster Maps (Output from Clustering Algorithm)*

Ancillary Data

- *Signature Extension Static Stratifications*
- *Other*

currently the standard image type most available to JSC analyst interpreters (AI). The other image types will be utilized to a lesser extent to fill in holes in the data base to gain insight into possible improvements that can be made in the PFC product and to examine optimum utilization procedures for an interactive color monitor display system.

Digital data presentations currently under consideration include spectral means, standard deviations and covariance matricies of candidate training fields, band 7 to band 5 field, cluster and/or pixel-specific ratios presented in tabular and/or color coded display formats, and clustering algorithm output maps in a color coded display format (see figure 3.1).

All standard ancillary data products will be utilized as described in Hay and Thomas, 1976a, Section 2.3.0. In addition, additional ancillary data such as stratification maps from the signature extension task will be considered for utilization within the alternative procedures.

The candidate alternative measurement procedures currently being considered are summarized in Table 3.2. They include procedures which are aimed at (1) improving the training statistics provided to the classifier, and (2) improving the AI's ability to identify the training areas correctly. Candidate procedure modifications aimed at improving training statistics include a systematic sample of the segment, changes in subclass pixel sample sizes based on subclass variances, and provision digital spectral feedback information for the refinement of subclass/class training area locations. Candidate procedure modifications designed to aid the analyst in obtaining more correct identification of fields and/or subclasses include field boundary definition around a sample point or throughout the segment, and the use of spectral data in tabular and/or color coded display formats.

All procedure modifications will be evaluated against current JSC/LACIE interpretation procedures (the control treatment). Evaluation criteria for the procedure modifications will include (1) ability to improve classification performance, (2) ability to decrease effort expended and increase throughput rate, (3) the repeatability of the results, and (4) the degree to which total spectral variability within a segment is represented. These evaluation criteria are summarized in Table 3.3.

3.3.3 PROGRESS TO DATE

The initial candidate procedure modifications have been selected for testing as well as a set of seven Kansas T & E test segments. The seven test segments selected were chosen because they provided a variety of (1) average field size conditions, (2) soil environments, (3) climate environments, and (4) land use types represented. The seven Kansas T & E segments selected for testing of the procedure modifications are:

1.	Graham	1018
2.	Stevens North	1045N
3.	Haskell	1065
4.	Dickenson	1105
5.	Ellsworth	1107
6.	Marion	1109
7.	McPherson	1110

Figure 3.1. Color Coded ISOCLAS* Output for Haskell-1065 Kansas T & E Segment for 9 May 1974. The clusters were ordered by 7/5 ratio of the cluster means and displayed in a rainbow ordered color sequence.

7/5 ratio	Color	Crop
4.75	blue violet	alfalfa/pasture
4.24	red	alfalfa
3.27	dark red	wheat
3.20	red-violet	alfalfa
2.36	red-violet	alfalfa
2.24	red-orange	wheat
2.05	orange	wheat
1.61	yellow	wheat
1.39	brown	wheat
1.15	yellow-green	pasture/wheat
.94 through .88	green	bare soil
.85 - .53	dark gray	soil blow outs

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*ISOCLAS is UCB's adaptation of JSC's unsupervised clustering algorithm ISOCLS.

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Table 3.2

Subtask B: Development of Multitemporal Interpretation Training Field Selection Procedures

Comparative Measurement Procedures for Selecting Classifer Training

Control

JSC Procedure

Candidate Procedure Improvements:

Systematic Sample of the Segment

Field/Pixel Sample Size

Field Boundary Definition

Sample Selection Relative to Signature Extension Strata

Systematic Check of All Class Combinations

Digital "Spectral Feedback" for Refinement of Subclass/Class Training Areas

Clustering Output Algorithm for Subclass Definition

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Table 3.3

Subtask B: Development of Multitemporal Interpretation Training Field Selection Procedures

Evaluation Criteria

- *Classification Performance*
  - *Several Measurement Procedures*
- *Effort Expended/Throughput Rate*
- *Repeatability of Results*
- *Degree to which Total Spectral Variability Represented*

These seven test segments will be processed according to the current JSC/LACIE interpretation procedures and then processed by the candidate modified procedures.

The Kansas ITS' are not included in the testing for this subtask at this time due to possible analyst bias arising from intensive utilization of the Kansas ITS's in a previous LACIE task (see Hay and Thomas, 1976a, Section 2.0).

3.3.3.1 Initial Procedure Description

In order to operationally familiarize UCB analysts with the JSC/LACIE interpretation procedures to be used as the control method, and to preliminarily evaluate some initial modifications, the Ellis SRS (1106) segment was processed using (1) JSC/LACIE "control" procedures, (2) an iterative, supervised training statistics definition procedure, and (3) a machine subclass labeling method. Training statistics produced from each of the three procedures were then input to a supervised classifer to generate classification performance matrices.

JSC/LACIE interpretation procedures are documented in NASA/LEC (1976a) and are summarized below.

On the PFC transparencies:

1. *Define spectral subclasses by analysis of the full segment.*
2. *Select training fields from within spectrally homogeneous areas to represent all subclasses defined in Step 1.*
3. *Identify all spectral subclasses as wheat or non-wheat using multi-temporal interpretation procedures.*
4. *Select five test fields which have not been selected as training areas.*
5. *Digitize and verify training and test field coordinates using a coordinatograph and the LARS terminal.*
6. *Submit segment for batch classification processing.*
7. *Evaluate the classification results using class map and performance matrix for training and test areas.*
8. *If necessary, modify training and submit for reclassification.*

To simulate the JSC/LACIE control procedures, UCB analysts employed the following procedure.

UCB - simulation of JSC/LACIE control procedures:

1. *On the PFC transparencies, define subclasses according to JSC procedures.*
2. *Select training fields according to JSC procedures.*
3. *Identify as wheat or non-wheat all subclasses using JSC procedures.*
4. *Select five test fields according to JSC procedures.*
   - 4a. *Systematically select additional test areas throughout the segment. (It is UCB's view that five test areas are insufficient for an adequate evaluation of the classification results.)*

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5. Extract training and test field coordinates using the UCB-Remedys color monitor display system. A coordinatograph as used at JSC is not available at UCB.
6. Submit the training deck to the supervised classifier (CALSCAN)* for processing.
7. Evaluate the classification results using the class map and performance matrix for training and test areas.

The first procedure modification tested in the initial run-through required the analyst to process the segment normally through step 5 of the UCB-JSC control procedure simulation. Prior to step 6, the analyst departed from the control method by reviewing the training area statistics, i.e. hand means, standard deviations, and histograms. If the standard deviation in one or more bands was significantly above 3.00, or if any histogram was significantly multimodal, then the training areas for the subclass involved were reevaluated for homogeneity and adjusted if indicated. After this check for "clean" training statistics, the segment was processed normally according to the remaining UCB-JSC control simulation procedures.

The second procedure modification tested required the analyst to process the segment normally through step 5 of the UCB-JSC control procedure simulation. Again, prior to submitting the training areas to the supervised classifier in step 6, the analyst performed the statistics clean-up procedure from the first procedure modification and then submitted the coordinates of the edited training areas to the clustering algorithm ISOCLAS.** Coordinates of training areas were grouped by training class, not subclass, viz: wheat, non-wheat no. 1, non-wheat no. 2, ..., non-wheat no. n.

The ISOCLAS algorithm determined subclass statistics within each of the classes. Resulting subclass training statistics were submitted to CALSCAN for processing according to the UCB-JSC control procedure simulation sequence.

ISOCLAS control parameters used in the second modified procedure just described are presented in Table 3.4.

Table 3.4 ISOCLAS CONTROL PARAMETERS

Keyword	Parameter Value	Function
ISTOP	5	Perform 5 iterations in the clustering procedure and stop.
NMIN	5	Delete any cluster with fewer than 5 members.

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* CALSCAN is UCB's adaptation of the LARSYS maximum likelihood software package.

** ISOCLAS is the UCB adaptation of JSC's clustering algorithm ISOCLS.

Table 3.4 ISOCLAS CONTROL PARAMETERS (continued)

Keyword	*Parameter Value*	*Function*
DLMIN	*3.2*	*Combine any two clusters whose means are closer than 3.2.*
STMAX	*2.5*	*Split any cluster whose maximum standard deviation is greater than 2.5.*
MAXCLS	*5*	*Maximum number of classes is 5.*

3.3.3.1a Results and Discussion of Initial Procedure

The training statistics produced from the three training selection procedures described above, viz.: (1) JSC/LACIE control procedures, (2) iterative, supervised training statistics definition procedure, and (3) machine subclass labeling procedure, are given in Tables 3.5, 3.6, and 3.7, respectively. The classification performance matrices associated with the CALSCAN runs for each procedure are presented in Tables 3.8, 3.9, and 3.10, respectively. Five performance matrices were generated for each of the classification runs. The criteria used to generate the five matrices were:

1. *classification performance in the training fields,*
2. *classification performance in the five test fields selected according to JSC procedures,*
3. *classification performance in additional test fields (35 to 45 in number) added by a systematic sample to obtain a more complete performance evaluation,*
4. *classification agreement between a systematic point sample of AI "expanded" field-by-field identification data for the segment and corresponding point CALSCAN classification, and*
5. *agreement between wheat proportion estimates from a systematic sample of the AI expanded segment data and corresponding wheat proportion estimates based on CALSCAN classification of the entire segment.*

Coefficient of variation (CV) percentages (band standard deviation times 100 divided by corresponding band mean) derived from the JSC control and the iterative training statistics definition procedures are presented in Tables 3.5 and 3.6, respectively. CV percentages show a decrease for some classes in the iterative procedure (procedure 2) versus the JSC control (procedure 1). These lower CV's indicate that the training field editing in procedure 2 produced a more compact spectral model for the wheat no. 3, wheat no. 4, riparian, bare soil no. 1, bare soil no. 3, and unknown classes. In contrast CV's increased in procedure 2 relative to 1 for the wheat no. 1, wheat no. 2,

Table 3.5. Summary of Unedited Training Statistics. Segment 1106, 1 July 74.

Training Classes	No. of Train. Fields	No. of Pixels		Spectral Bands			
				500-600	600-700	700-800	800-1100
Wheat 1	5	157	Mean	47.09	54.92	57.82	26.57
			St. Dev.	2.64	4.13	2.94	1.34
			C.V.	5.61	7.52	5.08	5.04
Wheat 2	7	194	Mean	46.37	52.84	56.76	26.32
			St. Dev.	1.92	2.59	2.61	1.29
			C.V.	4.14	4.90	4.60	4.90
Wheat 3	2	69	Mean	41.48	46.70	53.59	25.68
			St. Dev.	1.74	2.61	2.26	1.02
			C.V.	4.19	5.59	4.22	3.97
Wheat 4	3	151	Mean	42.71	46.25	47.25	21.34
			St. Dev.	2.15	3.02	2.93	1.69
			C.V.	5.03	6.53	6.20	7.92
Riparian	4	67	Mean	34.49	30.04	52.09	27.66
			St. Dev.	2.71	5.17	3.10	2.04
			C.V.	7.86	17.21	5.95	7.38
Pasture 1	4	156	Mean	35.01	31.27	48.42	24.63
			St. Dev.	1.12	1.77	2.31	1.70
			C.V.	3.20	5.66	4.76	6.90
Pasture 2	2	100	Mean	37.03	35.26	47.71	23.49
			St. Dev.	1.53	2.11	2.29	1.65
			C.V.	4.13	5.98	4.80	7.02
Bare Soil 1	2	130	Mean	40.13	42.36	42.89	19.21
			St. Dev.	2.55	3.97	4.13	2.35
			C.V.	6.35	9.37	9.63	12.23
Bare Soil 2	3	56	Mean	46.05	46.68	52.46	23.20
			St. Dev.	4.25	6.24	6.39	2.75
			C.V.	9.23	13.37	12.18	11.85
Bare Soil 3	3	45	Mean	36.58	36.02	37.78	16.96
			St. Dev.	1.34	1.29	2.46	.95
			C.V.	3.66	3.58	6.51	5.60
Water	5	26	Mean	32.46	25.23	31.04	12.81
			St. Dev.	2.63	4.03	9.14	5.03
			C.V.	8.10	15.97	29.45	39.27
"Unknown"*	1	42	Mean	34.45	31.50	41.67	20.10
			St. Dev.	1.06	1.35	1.65	.88
			C.V.	3.08	4.29	3.96	4.38
TOTAL	41	1193					

* The "Unknown" category is probably corn or sorghum, but because no imagery later in the growing season was available, a more positive identification could not be made.

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Table 3.6. *Summary of Edited Training Statistics. Segment 1106, 1 July 74.*

Training Classes	No. of Train. Fields	No. of Pixels		Spectral Bands 500-600	600-700	700-800	800-1100
Wheat 1	5	86	Mean	47.62	55.86	58.58	26.48
			St. Dev.	2.88	3.72	2.94	1.21
			C.V.	6.05	6.66	5.02	4.57
Wheat 2	6	153	Mean	46.29	52.66	56.42	26.29
			St. Dev.	1.98	2.61	2.58	1.33
			C.V.	4.28	4.96	4.57	5.06
Wheat 3	2	58	Mean	42.07	47.48	53.60	25.55
			St. Dev.	1.40	1.62	2.10	.98
			C.V.	3.33	3.41	3.92	3.84
Wheat 4	2	64	Mean	43.04	42.72	47.33	21.25
			St. Dev.	1.62	2.25	2.68	1.53
			C.V.	3.76	5.27	5.66	7.20
Riparian	4	52	Mean	33.73	28.60	52.10	27.81
			St. Dev.	2.19	3.40	2.80	2.23
			C.V.	6.49	11.89	5.37	8.02
Pasture 1	4	149	Mean	34.99	31.26	48.36	24.62
			St. Dev.	1.13	1.79	2.33	1.72
			C.V.	3.23	5.73	4.82	6.99
Pasture 2	2	70	Mean	37.01	35.33	47.10	22.91
			St. Dev.	1.56	2.00	2.30	1.56
			C.V.	4.22	5.66	4.88	6.81
Bare Soil 1	2	75	Mean	39.11	40.39	40.96	18.40
			St. Dev.	2.30	3.40	3.90	2.22
			C.V.	5.88	8.42	9.52	12.07
Bare Soil 2	2	23	Mean	43.96	45.61	47.91	20.87
			St. Dev.	4.95	6.88	6.66	2.53
			C.V.	11.26	15.08	13.90	12.12
Bare Soil 3	3	42	Mean	36.50	35.90	37.55	16.83
			St. Dev.	1.33	1.23	2.35	.85
			C.V.	3.64	3.43	6.26	5.05
Water	5	20	Mean	32.50	25.40	32.55	13.90
			St. Dev.	2.70	4.26	10.45	6.15
			C.V.	8.31	16.77	32.10	44.24
"Unknown"	1	13	Mean	34.23	31.62	42.15	20.08
			St. Dev.	1.01	.96	1.52	.49
			C.V.	2.95	3.04	3.01	2.44
TOTAL	38	805					

Table 3.7. Summary of Mixed Training Statistics. Segment 1106, 1 July 74.

Training Clusters	No. of Train. Fields	No. of Pixels		Spectral Bands			
				500-600	600-700	700-800	800-1100
Wheat 1	15	64	Mean	49.42	57.95	60.50	27.31
			St. Dev.	1.82	2.16	1.93	.91
			C.V.	3.68	3.73	3.19	3.33
Wheat 2		93	Mean	42.78	48.17	53.42	25.12
			St. Dev.	1.63	1.90	1.78	.93
			C.V.	3.81	3.94	3.33	3.70
Wheat 3		146	Mean	46.24	52.99	56.60	26.29
			St. Dev.	1.55	1.90	1.74	1.41
			C.V.	3.35	3.59	3.07	5.36
Wheat 4		58	Mean	42.74	46.74	46.66	21.03
			St. Dev.	1.50	1.52	1.81	1.40
			C.V	3.51	3.25	3.88	6.66
Riparian 1	4	15	Mean	36.27	32.47	53.00	27.67
			St. Dev.	1.53	2.22	1.67	1.14
			C.V.	4.22	6.84	3.15	4.12
Riparian 2		20	Mean	32.20	25.60	54.05	29.65
			St. Dev.	1.25	1.69	1.80	1.88
			C.V.	3.88	6.60	3.33	6.34
Riparian 3		17	Mean	33.29	28.71	49.00	25.76
			St. Dev.	1.36	1.77	1.57	1.21
			C.V.	4.09	6.17	3.20	4.70
Pasture 1	6	75	Mean	37.21	35.47	47.03	22.93
			St. Dev.	1.19	1.55	1.61	1.09
			C.V.	3.20	4.87	3.42	4.75
Pasture 2		66	Mean	35.12	30.67	50.55	26.03
			St. Dev.	1.05	1.70	1.49	1.18
			C.V.	2.99	5.54	2.95	4.53
Pasture 3		78	Mean	34.56	31.37	46.65	23.51
			St. Dev.	1.01	1.54	1.85	1.56
			C.V.	2.92	4.91	3.97	6.64
Bare Soil 1	7	5	Mean	50.00	53.60	53.60	23.00
			St. Dev.	1.26	1.62	.80	0.
			C.V.	2.52	3.02	1.49	--
Bare Soil 2		83	Mean	37.04	36.75	37.92	16.99
			St. Dev.	1.32	1.57	2.12	.93
			C.V.	3.56	4.27	5.59	5.47
Bare Soil 3		36	Mean	39.72	41.75	42.22	18.86
			St. Dev.	1.28	2.22	2.35	1.72
			C.V.	3.22	5.32	5.57	9.12
Bare Soil 4		9	Mean	43.89	46.56	49.33	22.67
			St. Dev.	1.28	2.98	1.94	1.63
			C.V.	2.92	6.40	3.93	7.19
Bare Soil 5		7	Mean	46.86	49.43	53.14	22.71
			St. Dev.	1.36	.49	1.73	.70
			C.V.	2.90	0.99	3.26	3.08

Table 3.7. Summary of Mixed Trianing Statistics. Segment 1106, 1 July 74. (Continued)

Training Clusters	No. of Train. Fields	No. of Pixels		Spectral Bands 500-600	600-700	700-800	800-1100
Water 1	5	9	Mean	34.11	29.00	42.44	19.44
			St. Dev.	1.73	1.82	3.44	3.06
			C.V.	5.07	6.28	8.11	15.74
Water 2		11	Mean	31.18	22.45	24.45	9.36
			St. Dev.	2.52	3.06	5.76	3.45
			C.V.	8.08	13.63	23.56	36.86
"Unknown"	1	13	Mean	34.23	31.62	42.15	20.08
			St. Dev.	.97	.92	1.46	.47
			C.V.	2.83	2.91	3.46	2.34
TOTAL	38	805					

Table 3.8. *Performance of CALSCAN Classification Using Unedited Training Statistics. Segment 1106, 1 July 74.*

PERFORMANCE BASED ON TRAINING FIELDS (1% THRESHOLD)

Classes Considered	No. of Fields	No. of Pixels Classified As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
Wheat	17	519	54	0	573	90.6
Nonwheat	24	52	570	0	622	91.6
TOTAL	41	571	624	0	1195	91.1
Percent Commission Error:		9.1	8.6			

PERFORMANCE BASED ON FIVE TEST FIELDS (1% THRESHOLD)

Field Number	A.I. Class	No. of Pixels Classified As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
6	Wheat	12	9	0	21	57.1
12	Wheat	22	6	0	28	78.6
20	Non	11	9	0	20	45.0
22	Non	0	40	0	40	100.0
33	Non	12	6	0	18	33.3
	TOTAL	57	70		127	70.1
Percent Commission Error:		40.3	21.4			

PERFORMANCE BASED ON FORTY-THREE TEST FIELDS (1% THRESHOLD)

Classes Considered	No. of Fields	No. of Pixels Classified As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
Wheat	15	281	114	3	398	70.6
Nonwheat	28	92	682	1	775	88.0
TOTAL	43	373	796	4	1173	82.1
Percent Commission Error:		24.7	14.3			

PERFORMANCE BASED ON A SAMPLE OF AI EXPANDED DATA

		No. of Sample Points Classified with Unedited Training As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
No. of Sample Pts. Classified by A.I.' As:	Wheat	138	51	3	192	71.9
	Nonwheat	100	571	11	682	83.7
	TOTAL	238	622	14	874	81.1
Percent Commission Error:		42.0	8.2			

CLASSIFICATION SUMMARY FOR ENTIRE SEGMENT

	Based on CALSCAN				Based on a Sample of A.I. Expanded Data		
	Wheat	Nonwheat	Threshold	TOTAL	Wheat	Nonwheat	TOTAL
	6851	16150	127	23128	192	682	874
Percent of Total	29.6	69.8	0.6		22.0	78.0	
				99% C.I.:	18.4-25.6	74.4-81.6	

Table 3.9. Performance of CALSCAN Classification Using Edited Training Statistics. Segment 1106, 1 July 74.

PERFORMANCE BASED ON TRAINING FIELDS (1% THRESHOLD)

Classes Considered	No. of Fields	No. of Pixels Classified As:			TOTAL	Percent Correct
		Wheat	Nonwheat	Threshold		
Wheat	17	355	6	0	361	98.3
Nonwheat	24	10	434	0	444	97.7
TOTAL	41	365	440	0	805	98.0
Percent Commission Error:		2.7	1.4			

PERFORMANCE BASED ON FIVE TEST FIELDS (1% THRESHOLD)

Field Number	A.I. Class	No. of Pixels Classified As:			TOTAL	Percent Correct
		Wheat	Nonwheat	Threshold		
6	Wheat	17	4	0	21	81.0
12	Wheat	27	1	0	28	96.4
20	Nonwheat	14	6	0	20	30.0
22	Nonwheat	0	40	0	40	100.0
33	Nonwheat	17	1	0	18	5.6
	TOTAL	75	52	0	127	71.7
Percent Commission Error:		45.3	9.6			

PERFORMANCE BASED ON FORTY-THREE TEST FIELDS (1% THRESHOLD)

Classes Considered	No. of Fields	No. of Pixels Classified As:			TOTAL	Percent Correct
		Wheat	Nonwheat	Threshold		
Wheat	15	306	88	4	398	76.9
Nonwheat	28	89	684	2	775	88.3
TOTAL	43	395	772	6	1173	84.4
Percent Commission Error:		22.5	11.4			

PERFORMANCE BASED ON A SAMPLE OF A.I. EXPANDED DATA

	Classes Considered	No. of Sample Points Classified with Edited Training As:			TOTAL	Percent Correct
		Wheat	Nonwheat	Threshold		
No. of Sample Pts. Classified by A.I.'s As:	Wheat	147	45	0	192	76.6
	Nonwheat	94	580	8	682	85.0
	TOTAL	241	625	8	874	83.2
Percent Commission Error:		39.0	7.2			

CLASSIFICATION SUMMARY FOR ENTIRE SEGMENT

	Based on CALSCAN				Based on a Sample of A.I. Expanded Data		
	Wheat	Nonwheat	Threshold	TOTAL	Wheat	Nonwheat	TOTAL
	6300	16450	378	23128	192	682	874
Percent of TOTAL	27.2	71.1	1.6		22.0	78.0	
99% C.I.					18.4-25.6	74.4-81.6	

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Table 3.10. Performance of CALSCAN Classification Using Mixed Training Statistics Segment 1106, 1 July 74.

PERFORMANCE BASED ON FIVE TEST FIELDS (1% THRESHOLD)

Field Number	A.I. Class	No. of Pixels Classified As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
6	Wheat	10	11	0	21	47.6
12	Wheat	25	3	0	28	89.3
20	Nonwheat	8	12	0	20	60.0
22	Nonwheat	0	40	0	40	100.0
33	Nonwheat	17	0	1	18	0.0
	TOTAL	60	66	1	127	68.5
Percent Commission Error		41.7	21.2			

PERFORMANCE BASED ON FORTY-THREE FIELDS (1% THRESHOLD)

Classes Considered	No. of Pixels Classified As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
Wheat	260	131	7	398	65.3
Nonwheat	71	699	5	775	90.2
TOTAL	331	830	12	1173	81.8
Percent Commission Error	21.5	15.8			

PERFORMANCE BASED ON A SAMPLE OF A.I. EXPANDED DATA

	Classes Considered	No. of Sample Points Classified With Mixed Training As: Wheat	Nonwheat	Threshold	TOTAL	Percent Correct
No. of Sample Points Classified By A.I.'s As:	Wheat	128	61	3	192	66.7
	Nonwheat	76	595	11	682	87.2
	TOTAL	204	656	14	874	82.7
Percent Commission Error		37.3	9.3			

CLASSIFICATION SUMMARY FOR ENTIRE SEGMENT

	Based on CALSCAN: Wheat	Nonwheat	Threshold	TOTAL	Based on a Sample of A.I. Expanded Data: Wheat	Nonwheat	TOTAL
	5397	17348	383	23128	192	682	874
Percent of TOTAL	23.3	75.0	1.7		22.0	78.0	
				99% C.I.	18.4-25.6	14.4-81.0	

pasture no. 1, pasture no. 2, bare soil no. 2, and water classes. Increase in CV's was generally attributable to reduced observations per training field and corresponding increases in standard deviation which more than offset the effect due to decreased training field sizes. Generally, mean spectral values by band under both procedures remained relatively constant.

Analysis of performance matrices (Tables 3.8 and 3.9) for the control procedure 1 and the iterative statistics editing procedure 2 show a general improvement in classification performance with procedure 2. Improvements in wheat identification accuracy averaged eight to eleven percent when differences between the two procedures were expressed as a percentage of the most accurate number.* The corresponding wheat accuracy improvement for the five JSC control test fields was 21 percent.

Analysis of classification performance for machine cluster labeling of AI defined training fields (procedure 3) in Table 3.10 indicates generally poorer classification results relative to both procedure 1 (JSC control) and procedure 2. Relative wheat classification accuracy (as defined above) averaged approximately seven percent below that of procedure 1. An exception occurred in the case of the five JSC control procedure test fields where a 7 percent relative improvement was noted. Similar comparison of results showed a relative wheat accuracy drop of 13 to 15 percent for procedure 3 performance relative to that obtained for procedure 2. The poorer classification performance in procedure 3 appears to be attributable to the finer breakdown of wheat and non-wheat subclasses provided by the clustering. In this case, some wheat and non-wheat subclasses (in particular, wheat versus soil) spectral density functions were more similar than in the case of those in JSC control and iterative training statistic definition procedures. Consequently, more confusion between wheat and non-wheat occurred.

In the case of the Ellis segment on the post harvest date utilized, the higher wheat commission error resulting from the higher wheat/non-wheat confusion actually gave a significant improvement in the wheat proportion estimate. Relative proportion estimate improvements of 29 and 18 percent were achieved for procedure 3 versus procedures 1 and 2 respectively. The final proportion estimate for procedure 3 differed by only 1.3 percent (5.9% relative) from the baseline estimate of 22.0 percent wheat derived from an 874 point sample of AI field-by-field classification for the segment.

Color coded CALSCAN output for the classification runs using the three training area selection procedures are shown in Figures 3.2, 3.3, and 3.4.

No specific conclusions can yet be made based on this preliminary test. The following general conclusions and recommendations, however, can be put forth.

1. An increase in classification accuracy was obtained when the training statistics were "edited" prior to the classification run according to procedure 2. It may be that the increase in classification accuracy is correlated to the ability and experience of the analyst. That is, as an analyst becomes more experienced he may not need

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*The number closer to 100 percent. In the case of full segment classification, the 22% wheat proportion figure for the AI sample was used as the most accurate measure of wheat proportion.

Figure 3.2. Color Coded CALSCAN Output Using JSC/LACIE "Control" Procedures to Extract the Training Statistics.*

Class	*Color*
Wheat 1	*red-orange*
Wheat 2	*yellow-orange*
Wheat 3	*yellow*
Wheat 4	*gold*
Riparian	*rust brown*
Pasture 1	*red-violet*
Pasture 2	*blue-violet*
Bare soil 1	*yellow-green*
Bare soil 2	*blue-green*
Bare soil 3	*dark green*
Water	*dark blue*
Unknown	*turquoise*

**CALSCAN is UCB's adaptation of LARSYS A.*

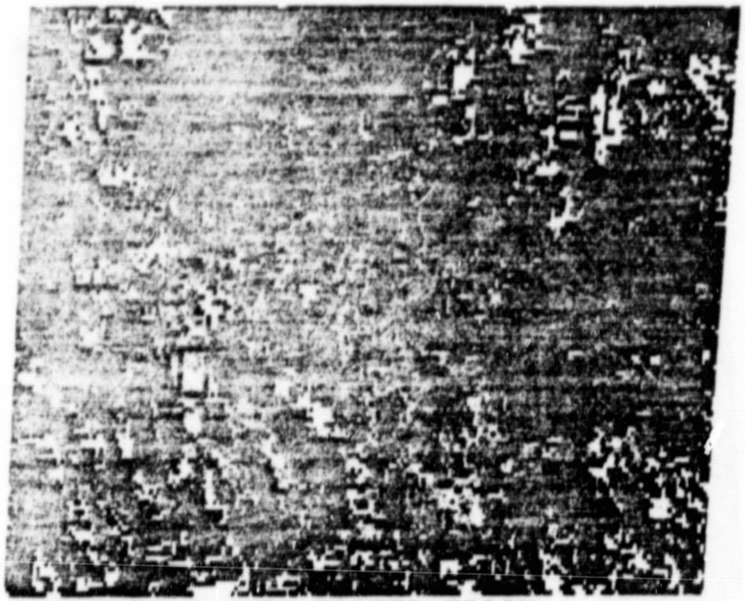

Figure 3.3. Color Coded CALSCAN Output Using the Iterative Procedure Two Modification to Extract the Training Statistics.

Class	*Color*
Wheat 1	*red-orange*
Wheat 2	*yellow-orange*
Wheat 3	*yellow*
Wheat 4	*gold*
Riparian	*rust brown*
Pasture 1	*red-violet*
Pasture 2	*blue-violet*
Bare Soil 1	*yellow-green*
Bare Soil 2	*blue-green*
Bare Soil 3	*dark green*
Water	*dark blue*
Unknown	*turquoise*

**CALSCAN is UCB's adaptation of LARSYS A.*

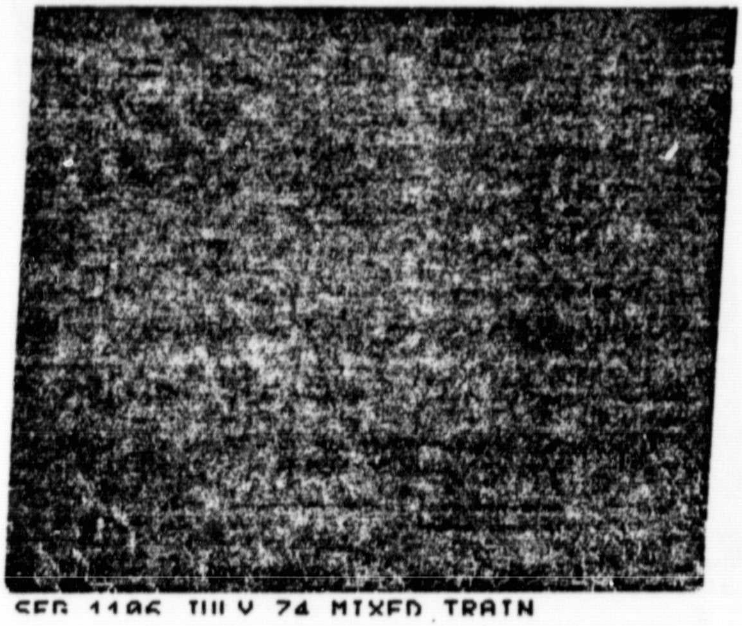

Figure 3.4. Color Coded CALSCAN Output Using the Machine-Labeled Subclasses from Procedure Three Modification to Extract the Training Statistics.

Class	Color
Wheat	brown
Non-wheat	green

to edit his training statistics prior to classification. However, for the inexperienced analyst, procedure 2 may aid him in more rapidly developing skills while decreasing the variation in quality of training statistics provided from the total pool of interpreters.

2. Analysis of the variation in the calculated classification accuracy using the five evaluation criteria indicates that the use of training fields and only five test fields as selected according to JSC/LACIE control procedures is inadequate for reliable evaluation of classification performance.

3. The use of machine subclass labeling does show promise. However, the best method of implementing such a procedure needs to receive further study.

3.3.4 FUTURE WORK

During the next reporting period, processing of the test segments listed in section 3.3.3 by JSC/LACIE control procedures will be completed. In addition, processing of the test segments by the alternative procedures will be initiated.

From analysis of the initial procedure test results, and after discussion with JSC personnel concerning current and possible modification in the JSC/LACIE interpretation procedures, some minor modifications to the UCB initial task design will also be made during the next reporting period.

3.4 SUBTASK C: DEVELOPMENT OF IMAGE REPRESENTATION TECHNIQUES FOR IMPROVED CLASSIFIER TRAINING

3.4.1 OBJECTIVE

The purpose of this subtask is to develop several alternative Landsat data reduction/compression spectral representations and to evaluate their role in improved multitemporal training procedures. These spectral representations function as additional sources of information to the analyst interpreter (AI). As such they should enable the analyst to better identify crop spectral density function components (e.g. those resulting from different wheat subclasses) and to insure that those components of spectral variability are adequately represented and labeled in the spectral training statistics.

3.4.2 APPROACH

Several spectral representations developed from Landsat digital data will be presented singly and in combination to image analysts. Candidate image representations currently in development include multidate unsupervised (ISOCLAS) class maps, multidate band 7 to band 5 ratio maps, and single and multidate component maps (first, second, and third components displayed individually and in combination). The unsupervised class map is designed to present to the analyst one measure of total segment spectral variability. Crop type spectral homogeneity and between crop type confusion patterns should be more apparent to the analyst with this representation. In similar fashion, the 7/5 ratio is intended to provide a refined measure of crop maturity/development rate on a pixel/field basis not otherwise available to the analyst. The principal component display is intended to separate for the analyst dynamic vegetation state signature characteristics from soil background reflectance effects and other signature components.*

Formats of image representation to the analyst include hardcopy prints and/or color monitor display. Color hardcopy is generated by the RSRP light emitting diode film annotator (IGOR). Television monitor display consists of single images (one or more bands) or simultaneous display of up to four separate images (each with one or more bands).

Performance improvement criteria for use of data compression spectral representations in the classifer training/verification process include classification performance, throughput rate, and the degree to which total spectral variability is represented. The impact of performance improvement will be evaluated in conjunction with other improved multi-

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** ISOCLAS is the RSRP adaptation of the JSC ISOCLS unsupervised clustering procedure.*

temporal classifer training procedures considered in Subtask B.

3.4.3 RESULTS

Work in this reporting period has focussed on the definition of compression enhancements to be used in initial evaluation. Specifically, the ISOCLAS unsupervised class map parameter settings and display format have been initially defined and tested as have the band 7 to band 5 enhancements. A principal components data compression procedure has been defined and is nearing implementation. Initial evaluation of these three spectral representations will be performed on Kansas, and to a lesser extent North Dakota, 1974 T&E segment data. Both the Kansas and North Dakota 1973-74 T&E data sets have been placed on the RSRP Data General 840/Color Display System.

3.4.4 FUTURE WORK

Work in the next reporting period will involve the initial evaluation of unsupervised class map, band 7/5 ratio map, and principal component map spectral representations on the Kansas and North Dakota data sets as described above. Additional enhancement procedures will be considered for evaluation including the ERIM Tasselled Cap representation. In partial support of this subtask, Kansas and North Dakota RT&E Segment data for 1975-76 will be made available on the TSTP Data General System.

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APPENDIX A:

LEGEND CODE FOR SIGNATURE EXTENSION LAND USE/ SOIL ASSOCIATION STRATA

APPENDIX A: LEGEND CODE FOR SIGNATURE EXTENSION LAND USE/SOIL ASSOCIATION STRATA

The land use/soil association strata are annotated with a fractional code. The numerator is the land use designation and the denominator is the soil association - soil subgroup designation.

land use code

$\frac{211}{88\text{-A}}$ — soil association-soil subgroup code.

APPENDIX A.1. LAND USE CLASSIFICATION CODE

- 100 - Urban and Built-up Land
  - 110 - Residential, commercial, industrial, institutional, transportational, mixed, open and other.
  - 120 - Strip and clustered settlements.
  - 130 - Resorts.
- 200 - Agricultural Land (more than 15 % of area is cultivated)
  - 211 - Cropland and intensive pasture (more than 75% of the area is cultivated)
  - 212 - Cropland and intensive pasture (more than 50% but less than 75% of the area is cultivated)
  - 213 - Orchard and vineyards.
  - 220 - Extensive agriculture (less than 50% of the area is cultivated)
- 300 - Rangeland (less than 15% of the area is cultivated)
  - 310 - Grassland range
  - 320 - Woodland range
  - 330 - Chaparral range
  - 340 - Desert shrub range
- 400 - Forest Land
- 500 - Water
- 600 - Non-Forested Wetland
- 700 - Barren Land
- 800 - Tundra
- 900 - Permanent Snow and Icefields

Appendix A.2

North Dakota

Soil Association/Soil Subgroup Code

Udic Borolls and Aquolls

1: Agriborolls - Eutroboraff; undulating to rolling; fine-loamy and clayey.

1-A: Kelvin - Bottineau $^{(80-90)}$ Association: (Bottineau County): Undulating to rolling; surface drainage undeveloped; numerous depressions and small lakes.
Minor Soils: Buse$^{(5-15)}$, Parnell, Tetonka $^{(10-20)}$, organic soils (peat).

B: Rolla-Kelvin (Bottineau County): Nearly level to gently sloping and undulating to rolling; surface drainage is into depressions.
Minor soils: Bottineau^{10}.

3: Argiborolls - Haploborolls;level-undulating; fine-loamy.

3-A: Forman$^{(45-60)}$- Aastad$^{(20-35)}$ Association (Sargent County): Well-drained and moderately well-drained, nearly level and undulating soils in loamy glacial till, prismatic blocky subsoil, many enclosed depressions and potholes, generally less than 5 acres in size.
Minor soils: Buse, Hamerly$^{(5-15)}$, (Tetonka, Parnell)^{10}, Cresbard, La Prairie, Lamoure, and Zell.

4: Argiborolls - Haploborolls; undulating to hilly; fine-loamy.

4-A: Forman-Buse Association (Sargent County): Well-drained to excessively drained, undulating and rolling soils in loamy glacial till.
Minor soils: Aatad. Tetonka, Parnell.
AWC* .17; less than 35% slope.

5: Argiborolls - Haploborolls - Natriborolls: level; clayey and fine-silty.

5-A: Overly-Beardon Association (Sargent Co.): Nearly level to very gently undulating, occassionaly poorly drained depressions.
Minor soils: Gardena, Glyndon, Colvin, and Perella, Hamerly, Svea. Parent material: water-laid silty clay loams and silt loams.

Overly-Fargo Association (Sargent County): Moderately well-drained soils to poorly drained soils in old silty and clayey lake sediments.
AWC .17

*AWC = available water capacity

6: Calciaquolls; level; fine-silty; saline

6-A: Bearden-Glyndon Association (Walsh County): Moderately saline association. Deep, nearly level, somewhat poorly drained and moderately well-drained, silty and loamy soils that are saline.
Minor soils: Colvin, Perella, Non-saline Bearden, Glyndon.

7: Calciaquolls - Haploborolls; level; coarse-silty and fine silty.

7-A: Gardena - Overly Association: Well-drained soils in old, silty and clayey lake sediments, nearly level and slightly depressional areas.
Minor soils: Tetonka, Bearden, and Glyndon soils.
AWC .15

B: Gardena - Glyndon Association (Sargent County): Moderately well-drained soils in old silty lake sediments; deep, nearly level soils.
Minor soils: Borup, Perella, Tetonka, Overly, and Hecla.
AWC .14

C: Gardena - Spottswood - Wessington Association: Well-drained loamy soils underlain by sands and gravel.
Minor soils: Hecla, Maddock, Borup, Stirum, Arveson.
AWC .14

Gardena^{30}- Glyndon^{25} Overly^{20}Association: Level, moderately well-drained and somewhat poorly drained, medium textured soils in old glacial lakebeds.
Minor soils: Aberdeen, Exline.

D: Embden^{40}- Glyndon^{40}- Egeland^{10} Association (Cass County): Nearly level, well-drained or somewhat poorly drained loams and fine sandy loams.
Minor soils: Gardena, Eckman.

Overly - Gardena Association (Ransom County): Nearly level, moderately well-drained loams to silty clay loams.

E: Gardena^{50}- Glyndon^{30} - Eckman^{5} Association (Cass County) : Nearly level, well-drained to somewhat poorly drained loams.
Minor soils: Embden, Renshaw, Egeland.
Parent material: Medium textured lake sediments.

F: Bearden^{30} - Overly^{30} - Fargo^{30} Association (Cass County): Nearly level, moderately well-drained to poorly drained silt loams and clays.
(Fargo is more poorly drained than the Bearden and Overly soils.)
Parent material: Moderately fine textured or fine textured lake sediments.

Aberdeen Association (Cass County): Nearly level, somewhat poorly drained silty soils that have a clay pan.

G: Lankin^{46}- Gilby^{35} Association (Walsh County): Deep, nearly level to gently sloping, somewhat poorly drained and poorly drained loamy soils.
Minor soils: Towner, Antler, Rockwell, Tonka.

H: (See 7-G)

I: Glyndon^{73}- Gardena^{14} Association (Walsh County): Deep, nearly level to gently sloping moderately well-drained and somewhat poorly drained loamy soils.
Minor soils: Borup, Colvin, Perella.

J: Bearden^{65} - Overly^{28}- Association (Walsh County): Deep, nearly level to gently sloping, somewhat poorly drained and moderately well-drained silty soils.
Minor soils: Colvin, Perella, Fargo.

Bearden^{70}- Glyndon^{26} Association (Walsh County): Deep, nearly level, moderately well-drained and somewhat poorly drained calcareous clayey and loamy soils.
Minor soils: Perella, Saline Bearden, Glyndon.

Overly^{64}- Bearden^{26} - Fans Association: Deep, nearly level, moderately well-drained and somewhat poorly drained silty and clayey soils on alluvial fans.
Minor soils: Fairdale, La Prairie.

K: (Bottineau Co.)

L: Gardena-Glyndon Association (Bottineau Co.)

M: (Roltte Co.)

N: Overly-Bearden Association (Tower Co.)

O: Gardena-Glyndon Association (Pembina Co.)

P: Glyndon Association.

8: Calciaquolls - Haploborolls - Argialbolls; level; fine-loamy and clayey.

8-A: Hamerly^{30}- Svea^{24}- Barnes^{23}- Association (Walsh Co.): Deep, nearly level to rolling, somewhat poorly drained to well-drained loam soils.
Minor Soils: Vallers, Tonka, Manfred, Parnell

Cresbard[60] - Hamerly[20] - Svea[15] Association (Walsh Co.): Deep, nearly level, moderately well-drained and somewhat poorly drained loamy soils:
Minor soils: Vallers, Tonka, Parnell.

B: Hamerly-Svea-Barnes Association (Cavalier Co.):

C: Hamerly-Svea-Tetonka Association(Rolette and Cavalier Co.):

D: Hamerly-Barnes-Tetonka Association (Tower and Cavalier Co.):

E: Hamerly-Barnes-Tetonka Association (Tower and Cavalier Co.):

9: Haplaquolls - Calciaquolls; level; clayey and fine-silty; vertic.

9-A: Hegne[74] - Fargo[20] Association (Walsh Co.): Deep, nearly level to gently sloping, poorly drained clayey soils.
Minor soils: Grano.

B: Wahpeton - Cashel - Fargo Association (Walsh Co.): Deep, nearly level to gently sloping, moderately well-drained to poorly drained clayey soils on flood plains and low terraces.

C: Fargo-Bearden Association (Bottineau Co.)

D: Fargo-Bearden Association (Pembina Co.)

E: Fargo-Bearden Association (Pembina Co.)

F: Hegne-Fargo Association (Grand Ford Co.)

G: Fargo Association (Trail and Cass Co.)

10: Haploborolls; level; fine-loamy over sandy or sandy-skeletal and fine-loamy.

10-A: Renshaw[35] - Brantford[29] - Sioux[12] Association (Walsh Co.): Shallow, nearly level to steep, excessively drained and well-drained loamy soils underlain by sand and gravel.
Minor soils: Arvilla, Coe, Vang, and Divide

B. Walsh[60] Association (Walsh Co.): Deep, level to sloping, well-drained and moderately well-drained loamy soils formed in shaly alluviums.

C: Renshaw - Divide Association (Bottineau and Rolette Cos.):

D: Walsh-Brantford Association (Pembina Co.):

E: Kelvin-Bottineau Association (Cavalier Co.):

F: Fargo Association (Cavalier Co.):

G: Brantford Association (Ramsey Co.):

H: Renshaw-Divide Association (Eddy Co.):

I: Renshaw Association (Ransom Co.):

J: Renshaw-Hecla Association (Kiddler Co.):

12: Haploborolls: undulating-rolling; fine-loamy.

12A: Barnes^{55}- Buse^{30} Association (Walsh Co.): Deep, gently undulating to steep well-drained and excessively drained loamy soils on the Edenburg moraine.
Minor soils: Parnell, Tonka, Svea, Embden.

B: (Pierce and Benson Co.):

C: (Ramsey Co.):

D: (Stutsman Co.):

E: (Sheridan Co.):

14: Haploborolls - Calciaquolls; level-undulating; coarse-loamy

14-A: Emrick^{45}-Larson^{25} Association (Wells Co.): Level to undulating, moderately well-drained, medium textured, claypan soils on uplands.
Minor soils: Miranda, Heimdal, Tonka, Parnell.

Egeland-Embden Association (Wells Co.): Level to undulating, well-drained and moderately well-drained, moderate to coarse textured soils on sandy plains.
Minor soils: Letcher, Arvilla, Ulen, and Hamar.

B: See Emrick-Larson Association (14-A) (Wells Co.):

C: LaDelle^{30}Association (Wells Co.): Level, well-drained, medium-textured soils on lacustrine plains.
Minor soils: (Emrick, Larson)^{38}, Overly^{7}, Exline, Renshaw, Aberdeen Heimdal, Egeland and Embden.

D: Heimdal^{43} - Emrick^{25}-Fram ^{26} Association (Wells Co.): Level to undulating, well-drained to moderately well-drained, medium textured soils on glacialfluvial materials.
Minor soils: Tonka, and Borup.

E: see (14-D).

15: Haploborolls - Calciquolls; level-undulating; fine-loamy.

15A: Barnes^{50}-Svea^{35} Association (Sargent, Wells Ward, and LaMoure Cos.): Well-drained, undulating soils in loamy glacial till; prismatic-blocky subsoil.
Minor soils: Buse, Parnell, Hamerly, Tetonka, Vallers, Cresbard, Cavour, Tonka.
AWC .17

B: Barnes^{55}- Svea^{25}- Parnell^{8} Association (Walsh Co.): Undulating to rolling, well-drained and moderately well-drained, medium-textured soils on glacial uplands; and poorly drained moderately fine textured soils in enclosed morainic depressions.
Minor soils: Buse, Cresbard, Cavour, Nutly, Grano, Colvin.

C: Svea^{40}- Hamerly^{25}- Barnes^{20} Association (Cass Co): Nearly level to undulating, well-drained to somewhat poorly drained loam.
Minor soils: Buse, Vallers, Tetonka, and Parnell.

D: Renshaw^{45}- Arvilla^{20}- Lamoure ^{15} Association (Wells Co.): Level, somewhat excessively drained to poorly drained, moderately coarse textured to moderately fine textured soils on gravelly terraces and in outwash channels.
Minor soils: Colvin, Benoit, and Divide

E: Barnes-Svea Association: (see 15-A).

F: Barnes-Hamerly Association (Renville Co.):

G: (McHenry Co.) soils on glacialfluvial materials.
Minor solis: Tonka, and Boreys.

H: Bottineau Co.)

I: (Bottineau Co.)

J: Barnes-Svea Association (Rolette and Tower Cos.):

K: Barnes-Hamerly Association (Rolette and Tower Cos.):

L: Svea-Hamerly Association (Cavalier and Benson Cos.):

M: Cresbard-Barnes-Cavour Association (Cavalier and Benson Cos.):

N: Barnes-Hamerly Association (Ramsey Co.):

O: Barnes-Hamerly Association (Benson Co.):

P: Barnes-Hamerly Association (Benson Co.):

Q: Svea-Hamerly Association (Benson Co.):

16: Haploborolls - Calciaquolls - Haploquolls; level; coarse - loamy and sandy.

16-A: Hecla-Renshaw Association (Sargent Co.): Well-drained sandy and loamy soils underlain by gravel and sand, and wet, loamy and clayey soils in depressions and ponded areas.
Minor soils: Sioux, Gardena, Glyndon, Maddock, Borup, Colvin, Perella, Stirum, Arveson.
AWC .14

B: Hecla-Hamar-Ulen Association (Ransom, Cass, and Richland Cos.): Nearly level and gently undulating, moderately well-drained to poorly drained sandy soils.
Minor soils: Embden, Tiffany, Arveson
AWC .10

C: Exline-Aberdeen Association: Solodized soils in old, clayey lake sediments; nearly level, often ponded soils due to restricted surface runoff and internal drainage.
Minor soils: Dimmick and Bearden
AWC .16

D: Embden-Hecla-Ulen Association (Walsh Co.): Deep, nearly level to sloping, moderately, well-drained and somewhat poorly drained loamy and sandy soils.

E: Embden-Glyndon Association (McHenry Co.):

F: Hecla-Hamar Association (Botteneau Co.):

G: Hecla-Hamar Association (Bottineau Co.):

H: Maddock-Barnes Association (Bottineau and Pierce Co.):

I: Hecla-Hamar Association (Pierce Co.):

J: Embden-Ulen Association (Rolete Co.):

K: Cresbard-Cavour Association (Pierce Co.):

L: Embden-Glyndon Association (Grand Forks Co.):

M: Hecla-Hamar Association (Eddy Co.):

N: Maddock-Barnes Association (Foster Co.):

O: Embden-Tiffany Association (Richland Co.):

P: Ulen-Hecla Association (Richland Co.):

Q: Ulen-Stirum Association:

R: Embden-Ulen Association

S: Maddock-Barnes Association:

T: Hecla-Hamar Association (Kiddler Co.):

18: Natriborolls; level-undulating; clayey and fine-loamy.

18-A: Barnes-^{50} Cresbard^{30} Association (La Moure and Dicky Cos.): Nearly level to undulating, medium-textured, well-drained soils and level moderately well-drained and somewhat poorly drained soils that are moderately deep to a clay pan; on glacial till plains.
Minor soils: Svea, Tonka, and Cavour.

B: Edgeby Association (La Moure and Dicky Co.): Nearly level to undulating, moderately well-drained and well-drained soils formed inglacial till; moderately deep and deep to shale.
Minor soils: Barnes, Cavour, Cresbard, Tonka, Exline.

Typic Borolls and Ustrothents

19: Argiborolls; level-undulating; fine-loamy

19-A: Williams^{70}- Noonan^{10} Association (Burleigh Co.): Nearly level to undulating, well-drained, medium-textured soil and moderately well-drained claypan soils on glacial till plains.
Minor soils: Niobell^{5}, Lehr, Parshall, Miranda, Parnell, Tonka.

B: Williams^{55}- Max^{25} Association (Burleigh Co.): Nearly level to rolling, well-drained, medium-textured soils on glacial till plains.
Minor soils: Arnegard, Lehr, Parnell, Tonka, Colvin.

C: Williams^{60}-Bowbells^{30} Association (Ward Co.): Well-drained and moderately well-drained, nearly level, very dark brown loamy soils formed in glacial till
Minor soils: Tonka, Parnell.

Williams^{60}- Niobell^{30} Association (Ward Co: Well-drained, nearly level loamy soils formed in glacial till.
Minor soil: Noonan^{10}.

D: Williams-Bowbells Association (Ward Co.): (See 19-C).

E: Williams Association (Divide Co.):

F: Williams Association (Williams Co.):

G: Roseglen Association (Divide Co.):

H: Williams-Cresbard Association (Divide Co.):

I: Cresbard-Cavour Association (Burke Co.):

J: (Foster Co.)

K: (McKenzie Co.)

L: Williams Association (Emmons and McIntosh Cos.):

M: Morton-Williams Association (Emmons and McIntosh Cos.):

20: Argiborolls-Argialbolls-Haploborolls: level-undulating; fine-loamy and clayey.

20-A: Barnes-Svea Association (McIntosh Co.):

21: Argiborolls-Haploborolls; level-rolling; fine-silty and fine loamy.

21-A: Agar-Williams-Zahl Association (McLean Co.):

B: Agar Association (Emmons Co.):

23: Argiborolls-Haploborolls-Ustorthents: level-rolling; fine-loamy.

23-A: Williams^{50}-Max^{25}-Zahl^{10} Association (Burleigh Co.); Nearly level to steep, well-drained medium-textured soils on glacial till plains. Depressions common.
Minor soils: Arnegard, Parnell, Tonka & Regan.

B: Lehr^{55}-Wabek^{13}-Manning^{12} Association (Burleigh Co.); Nearly level to steep, somewhat excessively drained and excessively drained, medium-textured and moderately coarse textured soils on outwash plains.
Minor soils: Tansem, Roseglen, Regan, Colvin, Harriet and Williams.

C: Oahe-Sious Association (Divide Co.):

D: Williams-Zahl Associations (Williams Co.):

E: Williams-Zahl Association (Divide Co.):

F: Oahe-Roseglan Association (Divide Co.):

G: Williams-Zahl Association (McLean and Mercer, Oliver Cos):

H: Williams-Zahl Association (McKenzie Co.):

24: Argiborolls-Natriborolls-Ustorthents; level-rolling; fine loamy.

24-A: Rhoades^{35}- Moreau^{10} Association (Bowman Co.): nearly level to gently sloping, deep and moderately deep, moderately well-drained and well-drained, loamy soils that have a claypan and clayey soils.
Minor soils: Absher, Amor, Arnegard, Belfield, Cabba, Doglum, Ekalaka, Flasher, Grail, Korchea, Rucley, Regent, Shambo, Stady, Vebar, Velva.

Rhoades^{25}- Absher^{20} Association (Bowman Co.): Nearly level to gently sloping deep and moderately deep, well-drained and moderately well-drained, loamy soils that have a claypan.
Minor soils: Arnegard, Belfield, Boxwell, Cabbart, Chanta, Daglum, Fleak, Ekalaka, Grail, Glendine, Harve, Kremlin, Marmarth, Moreau, Rhame.

Promise-Moreau Association (Stark Co.): Deep or moderately deep, well-drained clayey soils, nearly level soils in uplands swales and on valley terraces, and soils of the uplands that have slopes between 2 and 9%.
Minor soils: Bainville and Midway

Rhoades-Promise-Moreau Association (Stark Co.): Deep to shallow, well-drained, loamy or clayey soils, nearly level to sloping soils.
Minor soils: Regent-Belfield.

B: Farland-Savage-Rhoades Associations (Stark Co.): Deep, well-drained or moderately well-drained, loamy or clayey soils, some of which have a claypan, nearly level soils on stream terraces.

C: Morton-Rhoades-Flasher Association (Billings Co.):
Minor soils: Arnegard, Patent, Moline, Bainville.

D: See 24-C.

E: Morton-Rhoades-Flasher-Bainville-Flasher-Patent Association (Billings Co.):

F: (Stark Co.):

G: Belfield^{20}- Rhoades^{20}-Amor Association (Bowman Co.): Nearly level to gently sloping, deep and moderately deep, well-drained and moderately well-drained, loamy soils and loamy soils that have a clay pan.
Minor soils: Arnegard, Cabba, Daglum, Flasher, Grail, Manning, Moreau, Reader, Regent, Parshall, Stady, Tally and Vebar.

H: Amor-Reeder-Cabba Association (Bowman Co.) Nearly level to strongly sloping, moderately deep and shallow, well-drained loamy soils.

I: Morton-Rhoades Association (Morton Co.):

J: Rhoades-Morton Association:

25: Argiborolls-Ustorthents: level-rollings, loamy.

25-A: Roseglen^{20}- Tamsen^{20}- Savage^{15} Association (Burleigh Co.): Nearly level to rolling, well-drained, mainly medium-textured soils on lake plains and terrace.
Minor soils: (Belfield, Daglum).^{8}, Rhoades, (Liken, Parshell)^{7}, Temvik, Arnegard, Lehr, Straw, Weener.

Heil^{35}- Rhoades^{25} Association (Burleigh Co.): Level, poorly drained and moderately well-drained, mainly fine-textured soils in lake Basins and outwash channels.
Minor soils: Savage^{20}, Tansem, Roseglen, Parshall, Daglum, Belfield.

B: Mortons-Regent-Grail Association (Stark Co.): Deep, well-drained silty or clayey soils on uplands that are disected by swales and drainage ways.
Minor soils: Bainville.

C: Morton-Vebar-Arnegard Association (Stark Co.) Deep, well-drained, loamy and moderately sandy soils, nearly level to sloping, on uplands and in small drainage ways and swales in the uplands.

D. (Kidder Co.)

E: Morton-Williams Association (Morton Co.):

F: Morton Association (Oliver Co.)

G: Vebar Association (Oliver Co.)

H: Savage-Wade-Farland Association

I: Morton-Regent Association:

27: Argiborolls-Ustorthents; level-rolling, clayey and fine-loamy.

27-A: Morton Arnegard, Chama Association (Golden Valley Co.):
Minor soils: Bainville, Flasher.

B: Agar-Raber Association:

C: Raber Association:

30: Haploborolls-Argiborolls-Ustipsamments; level-rolling; loamy and sandy.

30-A: Parshall-^{40} Lihen^{20}- Flaxton^{10} Association (Burleigh Co.): Nearly level to rolling, well-drained, mainly moderately coarse textured soils on outwash plains and sand mantled uplands.
Minor soils: Livona, Harriet, Shaw, Rhoades.

B: Telfer^{35}- Lihen^{35}- Seroco^{10} Association (Burleigh Co.): Nearly level to hilly well-drained and excessively drained mainly coarse textured soils on sand mantled uplands.
Minor soils: Flaxton, Livona, Arveson, Temvik, Heil.

C: Colvin^{35}- Vallers^{25}- Lamoure^{15} Association (Ward Co.): Poorly drained, level, loamy soils formed in alluvium and glacial till.
Minor soils: Renshaw, Lehr, Divide, Benoit, Hamerly, Parnell.

Manning^{40}- Lihen^{30} Association (Ward Co.): Well-drained, nearly level to undulating moderately sandy soils formed in glacial outwash.
Minor soils: Telfer, Lehr, Wabek, Benoit.

D: Vebar-Williams Association (McKenzie Co.)

E: Vebar Association

32: Haploborolls-Ustorthents-Argiborolls; undulating-hilly; fine-loamy.

Buse^{45}- Barnes^{40} Association (La Moure and Logan Co.): Steep to rolling, excessively drained to well-drained, medium-textured soils on morainic hills; poorly drained soils in scattered closed depressions.
Minor soils: Svea, Nutley, Sioux, Renshaw, Parnell and Grano.

B: Sioux^{50}- Baines^{45} Association (Wells Co.): Hilly, excessively drained to well-drained, medium textured soils on gravelly terminal moraines.
Minor soils: Renshaw, Arvella

Barnes^{62}- Buse^{15} Association (Wells Co.): Rolling to hilly somewhat excessively drained and well-drained, medium textured soils on glacial moraines.
Minor soils: Parnell^{10}, Vallers, Sioux, Colvin, Lamoure.

C: Max^{40}- Williams^{30} Association (Ward Co.): Well-drained, rolling to strongly sloping, loamy soils formed in glacial till.
Minor soils: Zahl^{10}, Bowbells^{10}, Parnell^{10}.

Max^{40}- Zahl^{20} Association (Ward Co.): Well-drained, hilly loamy soils formed in glacial till.
Minor soils: Bowbells^{15}, Williams,^{15}, Parnell^{10}

Nutley^{40}- Sinai^{40} Association (Ward Co.): Well-drained, moderately well-drained, level to gently sloping, clayey soils formed in glacial lacustrine sediments.
Minor soils: Williams, Max, Zahl, Parnell

Wabek^{60}- Association (Ward Co.): Excessively drained, rolling and hilly, moderately sandy soils formed in glacial outwash.
Minor soils: Manning, Max,Zahl

D: Zahl-Williams Association (Divide Co.):

E: Zahl-Williams Association (McHenry Co.):

F: Buse-Barnes Association (McHenry Co.):

35: Ustorthents-Argiborolls; undulating-steep; loamy; shallow.

35-A: Flasher^{55}- Vebar^{25} Association (Burleigh Co.): Rolling to steep, well-drained and excessively drained, mainly moderately coarse textured soils on sandstone uplands.
Minor soils: Sen, Werner, Williams

B: Sen^{55}- Weiner^{20}- Morton^{10} Association (Burleigh Co.): Gently sloping to hilly well-drained, medium-textured soils on soft shale and siltstone uplands.
Minor soils: Arnegard, Daglum, Flasher, Rhoades.

C: Williams^{45}- Vebar^{15}- Flasher Association (Burleigh Co.): Gently undulating to steep, well-drained, medium-textured soils on glacial till and excessively drained, moderately coarse textured soils on sandstone uplands.
Minor soils: Arnegard, Grail, Regan, Sen, Werner

C-2

35D: Temvik^{35}- Mandan^{20}- Werner^{15} Association (Burleigh Co.): Nearly level to steep, well-drained, medium -textured soils on terraces, and uplands.
Minor soils: Linton, Sen, Arnegard, Flasher, Williams and Vebar.

E: Bainville-Flasher Association (Stark Co.): Shallow, excessively drained loamy or moderately sandy soils, sloping to steep
Minor soils: Vebar

Bainville-Midway Association: Shallow, excessively drained, loam or clayey soils; rolling to steep.
Minor soils: Moreau, Morton, Flasher

Bainville-Flasher Association (Billings Co.):

F: Vebar-Flasher Association (Bowman Co.): Nearly level to gently undulating moderately deep, well-drained and shallow, excessively drained, sandy and loamy soils.

G: Reeder-Brandenburg-Cabba Association (Bowman Co. and Slope Cos.): Gently sloping to strongly sloping moderately deep and shallow, well-drained and excessively drained, loamy soils.

H: Zahl-Williams Associaton (Montrail Co.)

I: Bainville-Zahl Association (Williams and Montrail Cos.)

J: Bainville-Morton Association

K: Bainville-Rhoades Association

L: Flasher-Bainville-Rhoades Association:

Borollic Aridisols and Torriorthents

44: Torriothents-Camborthids-Natrargids; undulating-hilly; loamy and clayey; shallow.

44-A Ekalaka-Rhame-Zeona Association (Bowman Co.) Nearly level to gently undulating, deep and moderately deep, well-drained, loamy soils and loamy soils that have a claypan and deep, excessively drained, sandy soils.

B: Dilts-Lisam-Shale Outcrop Association (Bowman Co.): Gently sloping to hilly, shallow well-drained, clayey soils and shale outcrops.

C: Rhame-Fleak Association (Bowman Co.): Nearly level to gently undulating moderately deep, well-drained, loamy soils, and shallow excessively drained, sandysoils.

Psamments

181: Psamments: Undulating-rolling; sandy

181-A: Valentine-Hecla Association (Sargent Co.): Sandy soils in a chopping area where differences in elevation are generally less than 10 feet. Minor soils: Arveson and Gannett.

Valentine Association (Sargent Co.): Sandy soils in a chopping area where differences in elevations are 20 to 40 feet.

B: Maddock-Hamar Association (Ransom and Richland Cos.): Gently undulating to hilly somewhat excessively drained to poorly drained, sandy soils
Minor soils: Hecla, Ulen.

Rockland

184: Badland-torriorthents: undulating-steep; loamy and clayey.

184-A: Rough broken land-Bainville-Patent Association (Billings Co.):

B: Cabbart-Alshir Association (Bowman Co.): Hilly to steep, shallow and deep moderately well-drained and well-drained, loamy soils and loamy soils that have a claypan.

Cabbart-Badlands-Yawdim Association (Bowman Co.): Steep to very steep, shallow, well-drained, loamy and clayey soils and bad land.

Soils of Major Flood Plains and Bordering Terraces

D-A: Harvelon -Lahler-Banks Association (Burleigh Co.): Nearly level, moderately well-drained and somewhat excessively drained, fine-textured to coarse textured soils on bottom lands
Minor soils: Lallie and Riverwash

B: Zahl^{35} - Max^{30} Williams^{20}- Velva^{15} Association: Well-drained, level to steep, loamy soils formed in glacial till and well-drained, level, loamy soils formed in alluvium.

C: Havre -Toby-Glendive Association: Nearly level, deep, well-drained loamy soils.

D: Havre -Farland-Banks Association (McKenzie Co.)

E: (Cavalier Co.)

F: Walsh-Edgeley -Buse Association:

G: (Foster Co.)

APPENDIX B:

SPECTRAL BIOPHASE DETERMINATION

APPENDIX B: SPECTRAL BIOPHASE DETERMINATION

In order to better evaluate the signature extension stratification per Task I (see Section 2.0), work is being performed to more precisely determine the actual segment/date - specific spectral biophase of the wheat crop within a given stratum. Efforts to date have utilized band 7 to band 5 ratio histogram plots. These plots were developed using identified wheat clusters defined by unitemporal ISOCLAS* runs on specific test segments.

Starting from a bare soil state for a planted wheat field, a 7/5 ratio of .80 to .95 will usually be observed. As the wheat crop emerges and the percentage of canopy cover increases the 7/5 ratio likewise increases. This change can be attributed to an increase in the mass of actively metabolizing vegetation which in turn causes an increase in incident energy absorption by chlorophyll in band 5 and an increase in reflectance in band 7 as the canopy covers exposed soil. The 7/5 ratio peak of approximately 4.0 seems to correspond to the late-jointed -- early headed stage of wheat development. The ratio then decreases during the turning stage to approximately .90 to .99. Figure B.1 shows a typical graph of the 7/5 ratio for wheat as observed in the Kansas T & E data.

In order to determine if two segments are spectrally biophased - matched on a given date, the 7/5 ratio is histogramed for all identified wheat clusters by ISOCLAS. Figure B.2 shows the histogram plots for Grant 1036 and Haskell 1065 Kansas T & E segments for 9 May 1974 and 27 May 1974. Comparison of the histograms indicates that Haskell is slightly ahead of Grant in wheat stage development on 9 May and significantly ahead of Grant on 27 May. These data suggest that the segments should be considered to be in different climatic strata.

This technique of determining spectral biophase of a segment is not yet fully developed. So far 7/5 histogram plots have only been generated on a segment basis. Future work will generate the plots on a strata basis. Final conclusions can not be drawn until more data has been processed.

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*ISOCLAS is UCB's adaptation of JSC's unsupervised clustering algorithm ISOCLS.

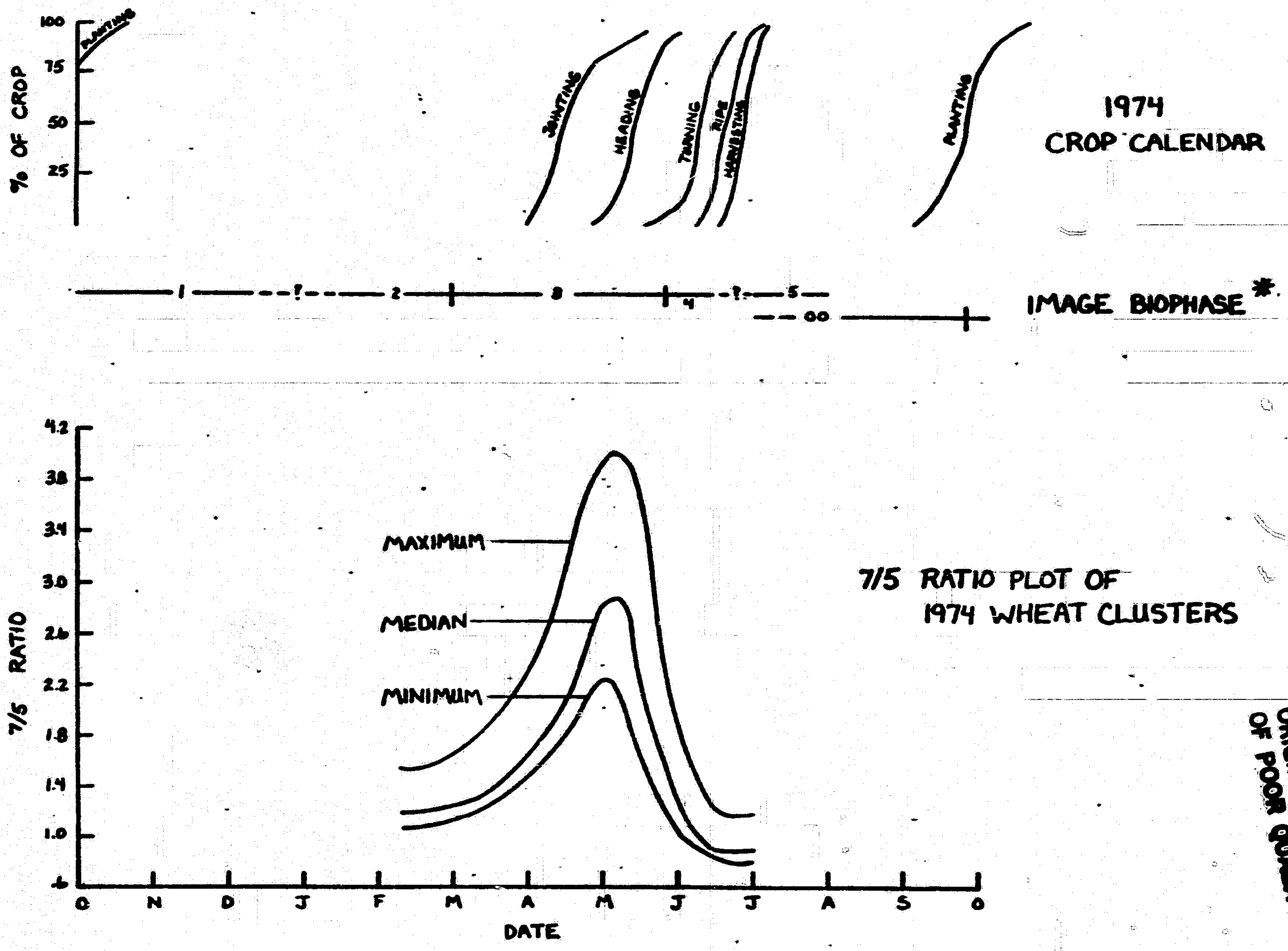

Figure B.2. A Typical Band 7 to Band 5 Ratio Plot of 1974 Identified Wheat Cluster Means Over the Growing Season is Compared to the 1974 Crop Calendar Plot and the Image Biophase Plot.*

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*See Hay and Thomas, 1976a, Section 2.

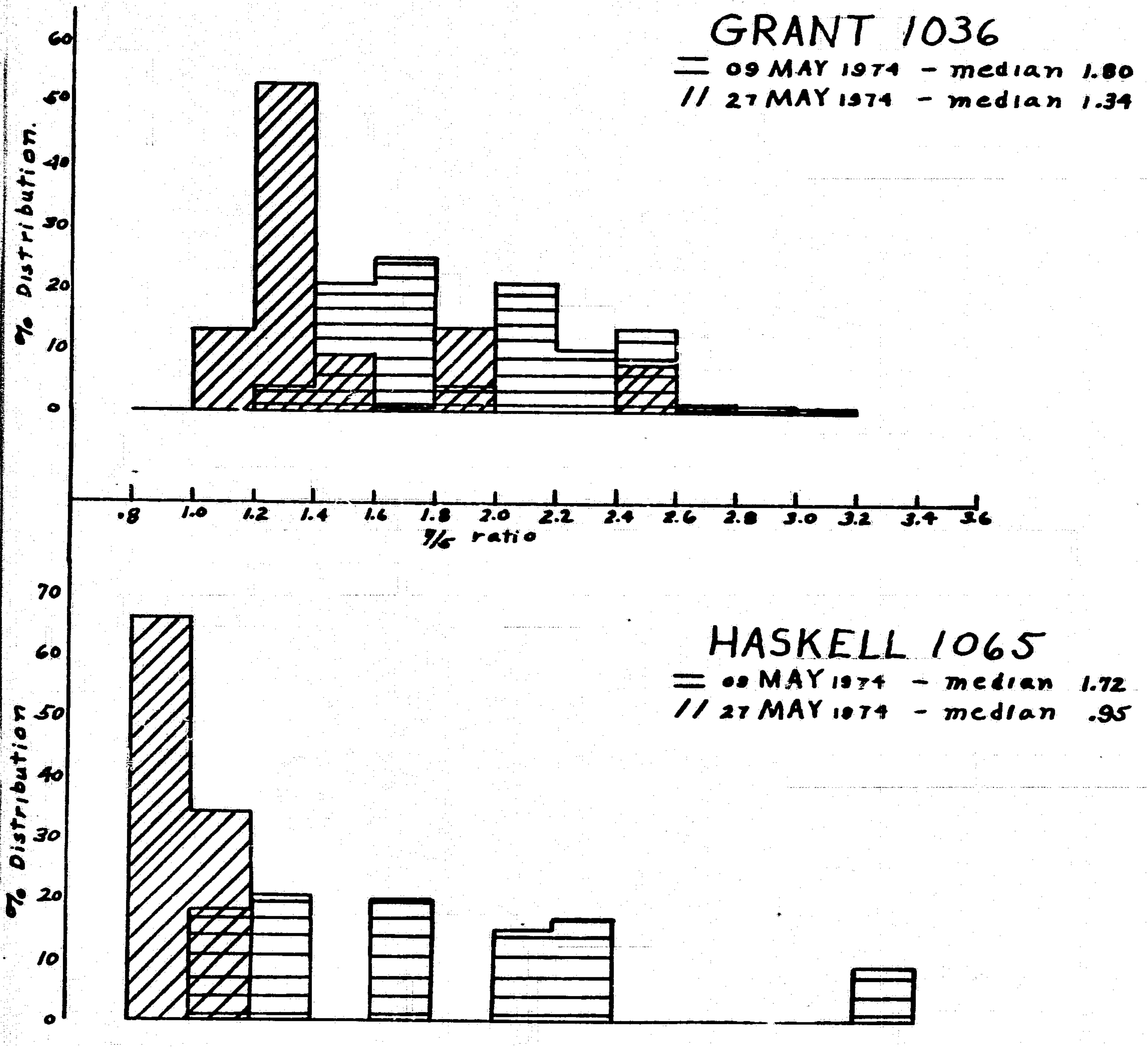

Figure B.2. Histogram Plots of the Band 7 to Band 5 Ratio of Identified Wheat Clusters Means for Grant 1036 and Haskell 1065 Kansas T & E Segments for 9 May 1974 and 27 May 1974.