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TECHNICAL MEMORANDUM

DETAILED DESCRIPTION OF THE WHEAT ACREAGE ESTIMATION PROCEDURE USED IN THE LARGE AREA CROP INVENTORY EXPERIMENT

By

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Original photography may be purchased from
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1. INTRODUCTION

During the 3 years that the Large Area Crop Inventory Experiment (LACIE) has been in operation, LACIE personnel have developed, tested, and improved the technology and procedures for estimating wheat acreage using data from the Land Satellites (Landsats). In Phase I, techniques were evaluated for the U.S. Great Plains. Phase II was expanded to include estimates of acreage, yield, and production in the United States, Canada, and a wheat indicator region in the U.S.S.R. The Phase III efforts were concentrated on evaluating improved methods representing an increased range of geographic conditions from those of Phases I and II.

The use of satellite data to perform crop inventories utilizing current LACIE technology is dependent on the recognition of satellite-recorded radiance value patterns by an analyst. The subsequent machine classification and wheat acreage estimation accuracy are critically dependent on the analyst's correct identification of wheat signatures. This technical memorandum documents this basic element, the analyst-satellite interface, by presenting a detailed description of the LACIE process for identifying wheat acreage.

2. IMAGERY: COLOR REPRESENTATION OF DIGITAL VALUES

2.1 COLOR METHOD OF PRESENTING PICTURE ELEMENT SPECTRAL SIGNATURE

The Landsat-2 gathers data using an onboard multispectral scanner (MSS), which records reflected radiance values in each of four bands (ref. 1):

MSS channel	Wavelength, μm	Spectrum
1	0.5 to 0.6	Visible green
2	0.6 to 0.7	Visible red
3	0.7 to 0.8	Infrared
4	0.8 to 1.1	Infrared

The basic area resolution element is a picture element (pixel), which corresponds to a 0.45-hectare (1.1-acre) area on the ground. Thus, four values, each of which represents the average radiance value over 1.1 acres measured in a specific band, are recorded for each pixel.

The characteristic reflectance of a pixel in the four bands is called a spectral signature. Spectral signatures of crops and other scene contents are not necessarily unique, nor are they constant. Signatures can change with place and time. For this reason, the signature identification process has not been automated operationally and currently is done visually by analysts. Analysts can relate spatial and temporal information to the digital radiance values for signature identification. To facilitate this analyst identification application, digital values are represented as colors and presented in imagery form. Three colors are used (red, blue, and green), so information from three channels or bands can be presented at one time. Color representation of digital values is not perfect, but it is very effective as a vehicle for providing information.

MSS data are telemetered to the National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC). The GSFC forwards the satellite data on film to the U.S. Department of Agriculture (USDA) and on computer-compatible tape (CCT) to the Lyndon B. Johnson Space Center (JSC). Figure 1 summarizes the analyst-satellite data interface.

2.2 FULL-FRAME IMAGERY

A Landsat full-frame image corresponds to a 185- by 185-kilometer (100- by 100-nautical-mile) area on the ground. Full-frame imagery is created at the USDA Aerial Photogrammetry Field Office at Salt Lake City, Utah, from 70-millimeter archival film supplied by GSFC. Figure 2 is a full-frame image of data acquired July 3, 1977, over Montana. Channels 1, 2, and 4 are used in the composed false-color image; and channel color assignments are blue, green, and red, respectively.

The satellite telemeters the radiance values to GSFC in the range 0 to 63 for each channel. At GSFC, channels 1, 2, and 3 are decompressed logarithmically into the range 0 to 127; channel 4 does not require decompression. Values are mapped directly onto a film positive calibrated to a 16-level-density gray scale: 0 into black, and 127 (or 63) into white. The full-frame color composite is created from these black-and-white images of the individual channels. Full-frame imagery for every Landsat acquisition containing a LACIE segment is provided to JSC for analyst use at least once per biowindow; to fulfill this requirement, cloud cover must be less than 20 percent on the imagery. This imagery is used to monitor episodic events and to give the analyst a large view of the geographical area which includes a LACIE segment. Full-frame imagery usually clarifies the distinction between agricultural and nonagricultural areas.

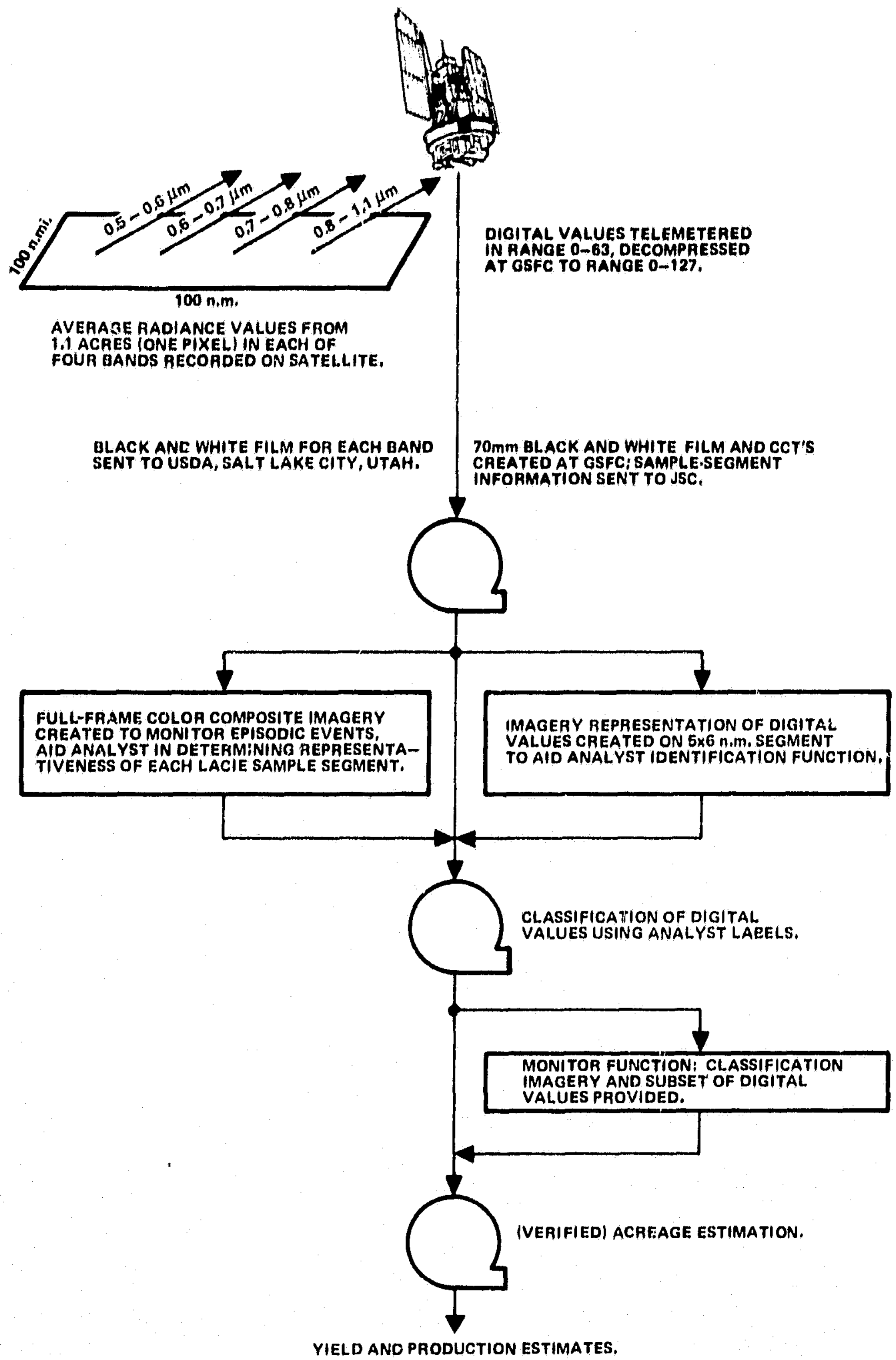

Figure 1.– Diagram showing analyst-satellite interface.

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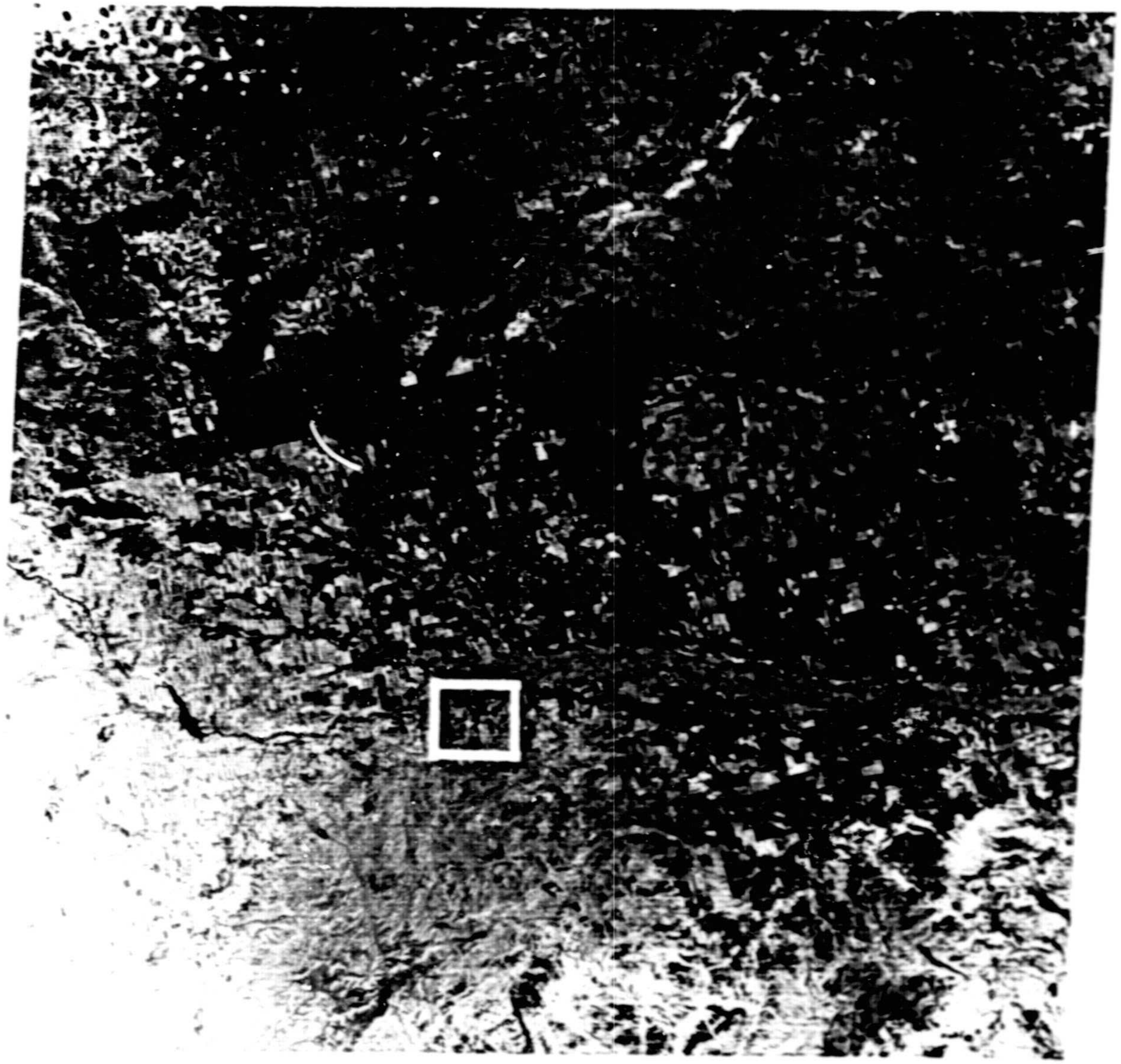

Figure 2.– Landsat full-frame image with outline of LACIE segment 1528, Blaine County, Montana.

2.3 LACIE SAMPLE-SEGMENT IMAGERY

A 9- by 11-kilometer (5- by 6-nautical-mile) LACIE sample segment (segment 1528 in Blaine County, Montana) is outlined within the full frame illustrated in figure 2.

At GSFC, an 18.5- by 20-kilometer (10- by 11-nautical-mile) search area, based on the geographical coordinates of the segment, is extracted from the full-frame digital data and used as a basis for an image edge detection routine to locate exactly and extract the 9- by 11-kilometer LACIE sample segment (ref. 2). In the first process, bias and scale factors are computed from the mean value and standard deviation of each channel over the entire search area. Then, the bias and scale factors are placed in the headers of the CCT's which contain the four digital values for each of the 22 932 pixels in the sample segment; the digital values are extracted from the second process. These CCT's are sent to JSC. Sample segment imagery, which is a color representation of these digital values, is created at JSC on the production film converter (PFC) using the bias and scale factors.

Figure 3(a) is segment 1528 outlined on figure 2. This film product was created from digital values in channels 1, 2, and 4 (two channels in the visible range and one in the infrared range); color assignments, as in figure 2, are blue, green, and red, respectively. This type of image is termed LACIE product 1.

A film product created with channels 2, 3, and 4 (two channels in the infrared range and one in the visible range) is made so that information in channel 3 is available for the analyst. Color assignments in this product are red (channel 2), blue (channel 3), and green (channel 4); polarities are reversed for channels 3 and 4. This product, LACIE product 2, is shown in figure 3(b).

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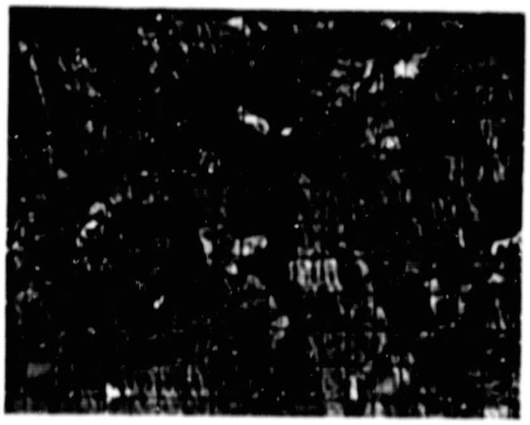
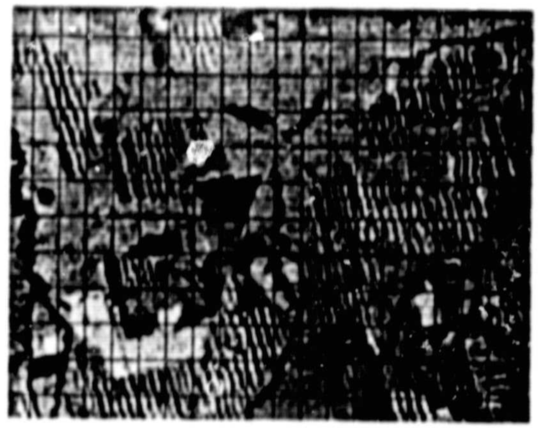
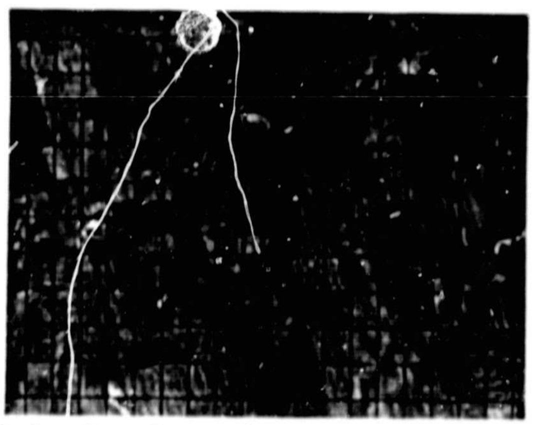


(a) Product 1: channels 1, 2, and 4.



(b) Product 2: channels 2, 3, and 4.



(c) Product 3: channels 1, 2, and 4.

Figure 3.— LACIE sample-segment imagery: segment 1528, July 3, 1977.

The analyst uses imagery for spatial information and for spectral value information. The film products shown in figures 3(a) and (b) are generated to emphasize contrast. These products are excellent for field delineation and enhanced spatial features. However, depending upon the data in the scene, contrast is sometimes achieved at the expense of consistent color depiction of spectral values. Figure 3(c), LACIE product 3, is imagery developed specifically for more consistent color display of spectral signatures; this is essential for accurate identification. Figures 4(a) and (b), imagery of segment 1807, provide an additional comparison of LACIE products 1 and 3. The channels used and the color assignments for product 3 are the same as for product 1, but the method of depicting digital values as colors is different.

For product 1 [figs. 3(a) and 4(a)] and product 2 [fig. 3(b)], each channel is mapped individually onto the designated color-density scale. The bias and scale factors computed at GSFC are used to expand the data range for each channel over the entire color range. Interchannel relation is not necessarily preserved. For product 3 [figs. 3(c) and 4(b)], an overall mean value for the three channels is computed (channel 4 values are doubled before computing this). The overall mean is set at the midpoint of the color-density scale. No bias is used, but there is a scale factor. The entire range of color is not necessarily used for each channel, and interchannel relationship is preserved (refs. 3, 4).

Figures 3(a) and (c) are very similar; however, figures 4(a) and (b) are markedly different. In this case, maximizing contrast has altered the relationship between the channels and changed the spectral signature representation of many of the pixels. Figure 4(a) would be very misleading if used for signature identification.

The use of imagery as a means of implementing the analyst-satellite data interface is fundamental in LACIE. There are

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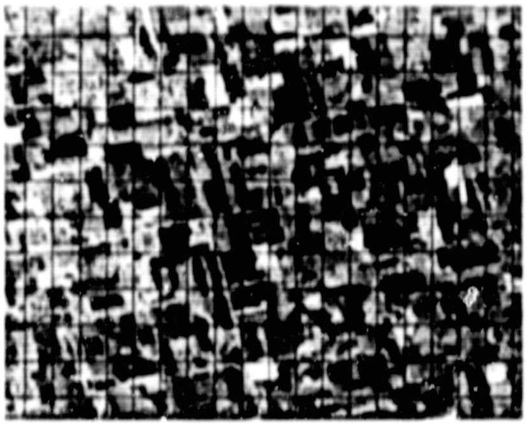
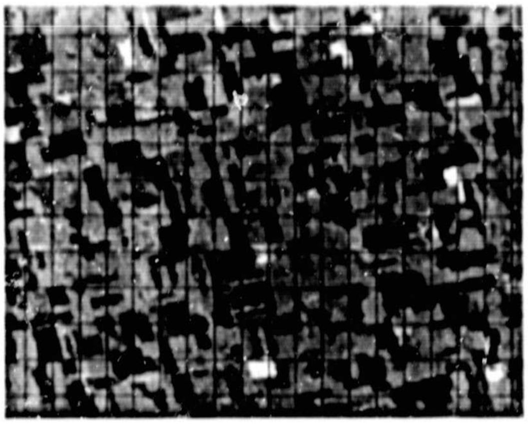


(a) Product 1: channels 1, 2, and 4.



(b) Product 3: channels 1, 2, and 4.

Figure 4.– LACIE sample-segment imagery: segment 1807, Bon Homme County, South Dakota, June 23, 1976.

91 728 digital values for each LACIE sample segment (one value in each of four bands for each of 22 932 pixel locations). If presented in numerical form, this would be overwhelming. For each Landsat acquisition, the analyst has available the 9- by 11-kilometer segment imagery; that is, product 1 (channels 1, 2, and 4), product 2 (channels 2, 3, and 4), and product 3 (channels 1, 2, and 4). Full-frame imagery coverage is usually available for the previous year's acquisitions and occasionally for the current acquisition. Imagery provides a practical means of identifying spectral signatures and separating spatial features.

3. REFERENCE MATERIALS FOR ANALYSIS

The LACIE approach for estimating acreage, yield, and production is shown in figure 5. The average proportion of wheat for sample segments within the stratum is used to obtain an estimate of the stratum proportion of wheat. This is multiplied by the stratum agricultural area to obtain an estimate of the stratum wheat acreage. In LACIE, strata are defined by percentages of agricultural density using Landsat data, soil information, and climatic conditions. A simple random sample within each stratum is used, and a predetermined number of sample segments of specified location are allocated per stratum.

A more detailed view of the exact procedure used to produce an acreage estimate is diagrammed in figure 6. With this diagram as a basis, the following subsections present a review of materials available to aid the analyst in segment analysis.

3.1 ANALYST PACKET FOR SPECIFIC SEGMENT

LACIE personnel at JSC have assembled an analyst packet for every sample segment. The full-frame imagery is used to establish the relationship of the segment to the area specified in the reference material contained in the packet.

The packet contains the following data.

a. Maps: 1:24 000 and 1:250 000 scale.

b. Ancillary data:

- Cropping practices for the Crop Reporting District (CRD).
- Soils data for the CRD.
- Nominal crop calendar for the CRD based on 10-year averages [fig. 7(a)]. Information on average length of crop development stages, the nominal dates when these stages occur, and

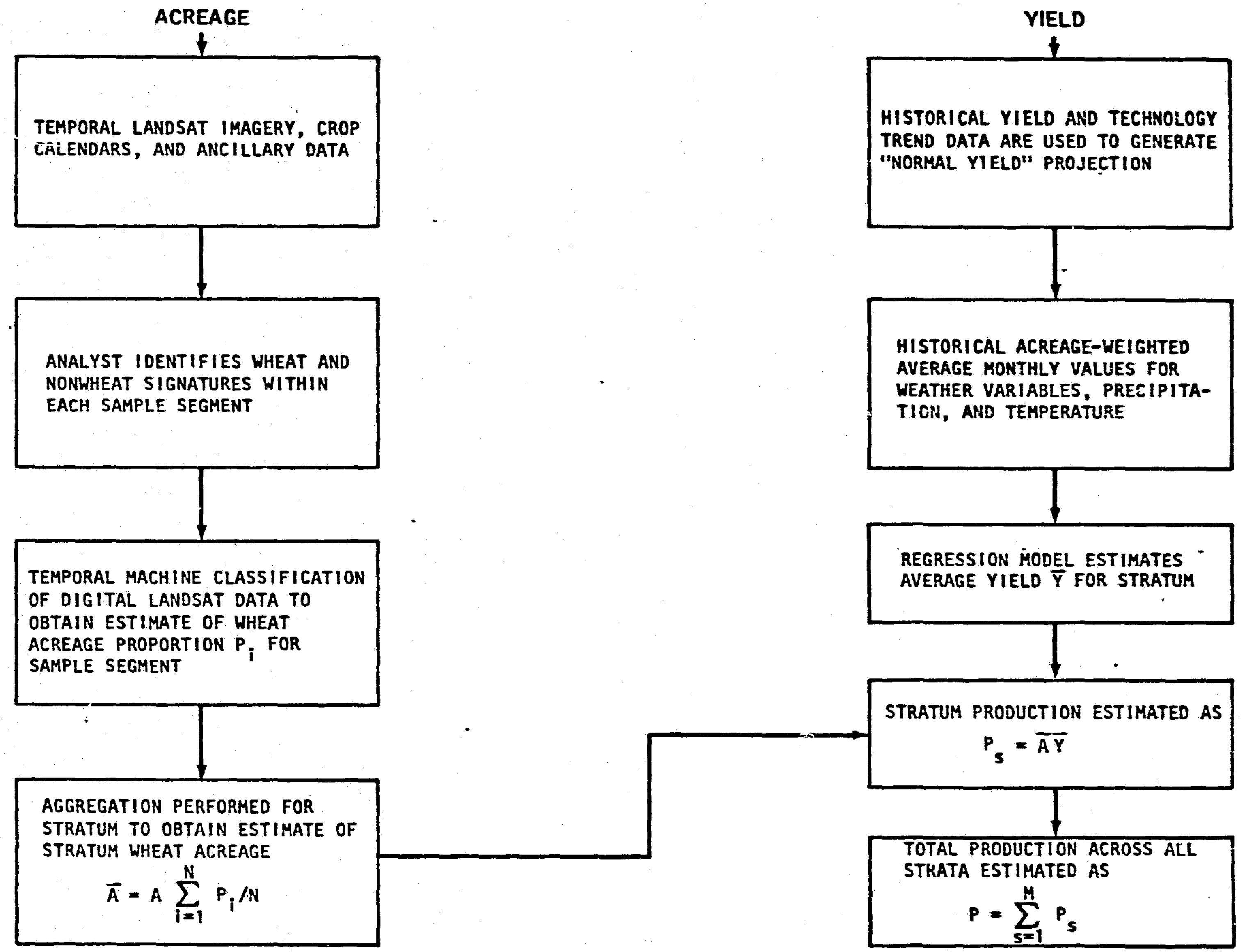


Figure 5.– Flow diagram of LACIE procedure for estimating acreage, yield, and production.

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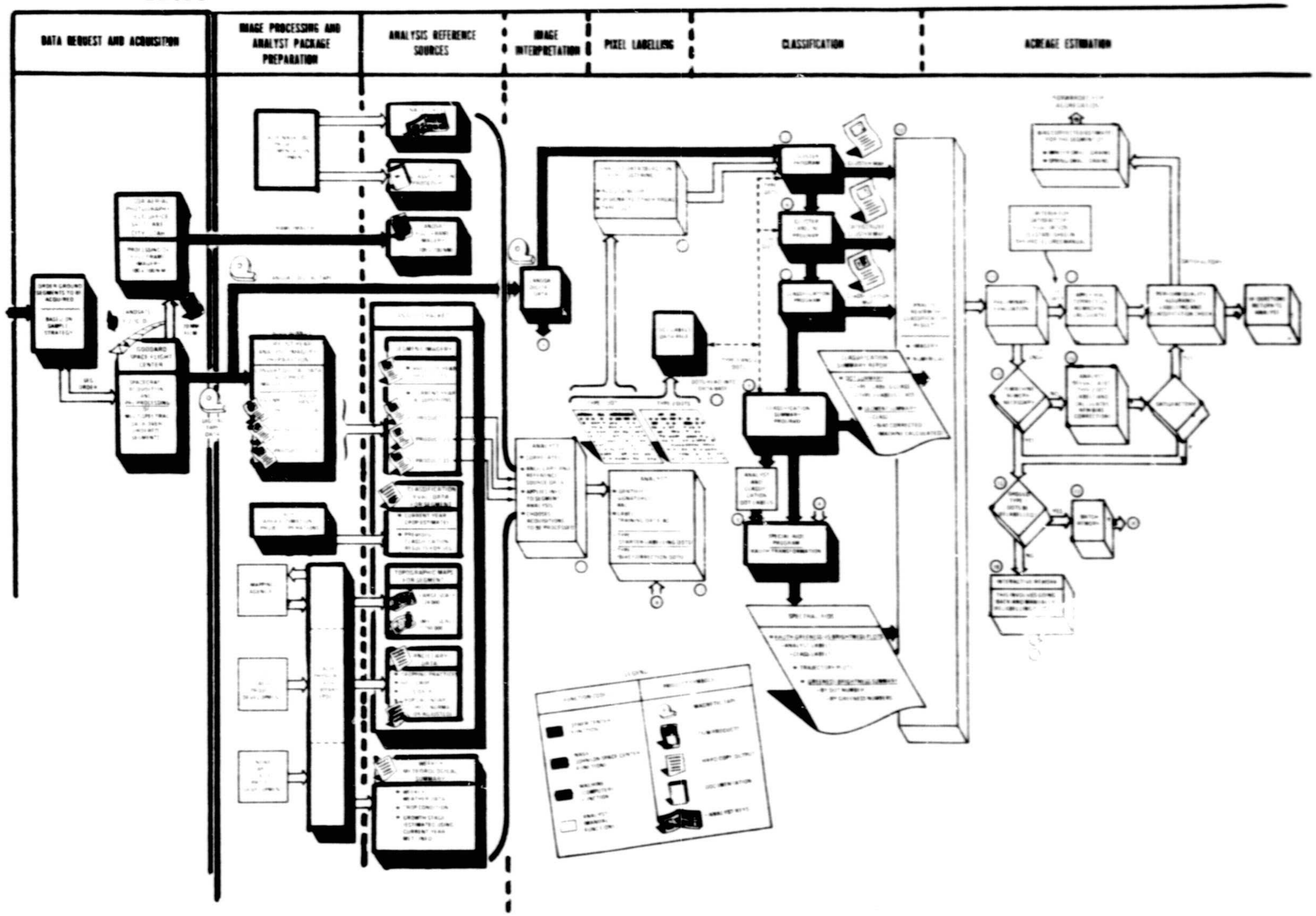

Figure 6.- Schematic diagram of detailed LACIE acreage estimation procedure.

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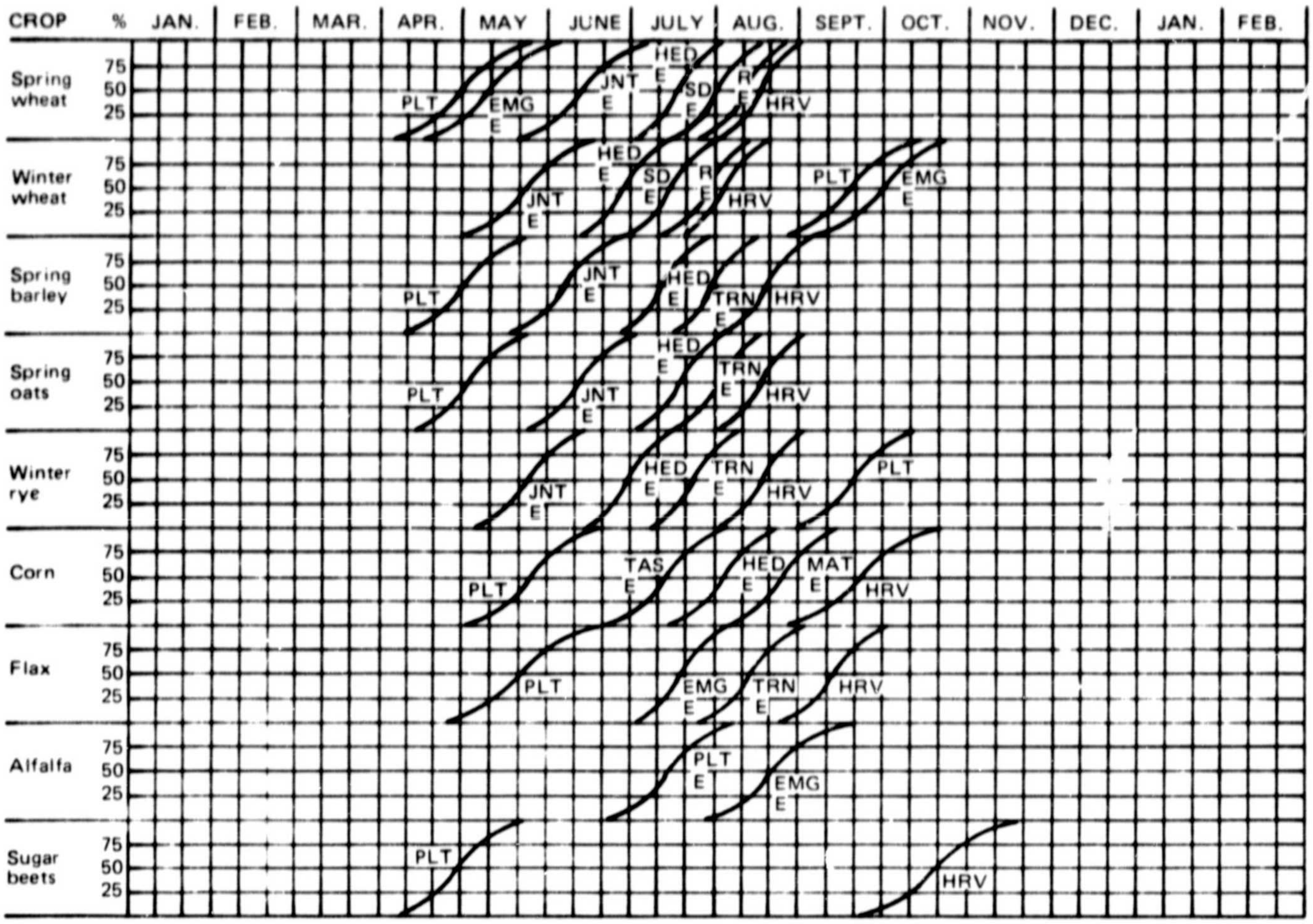
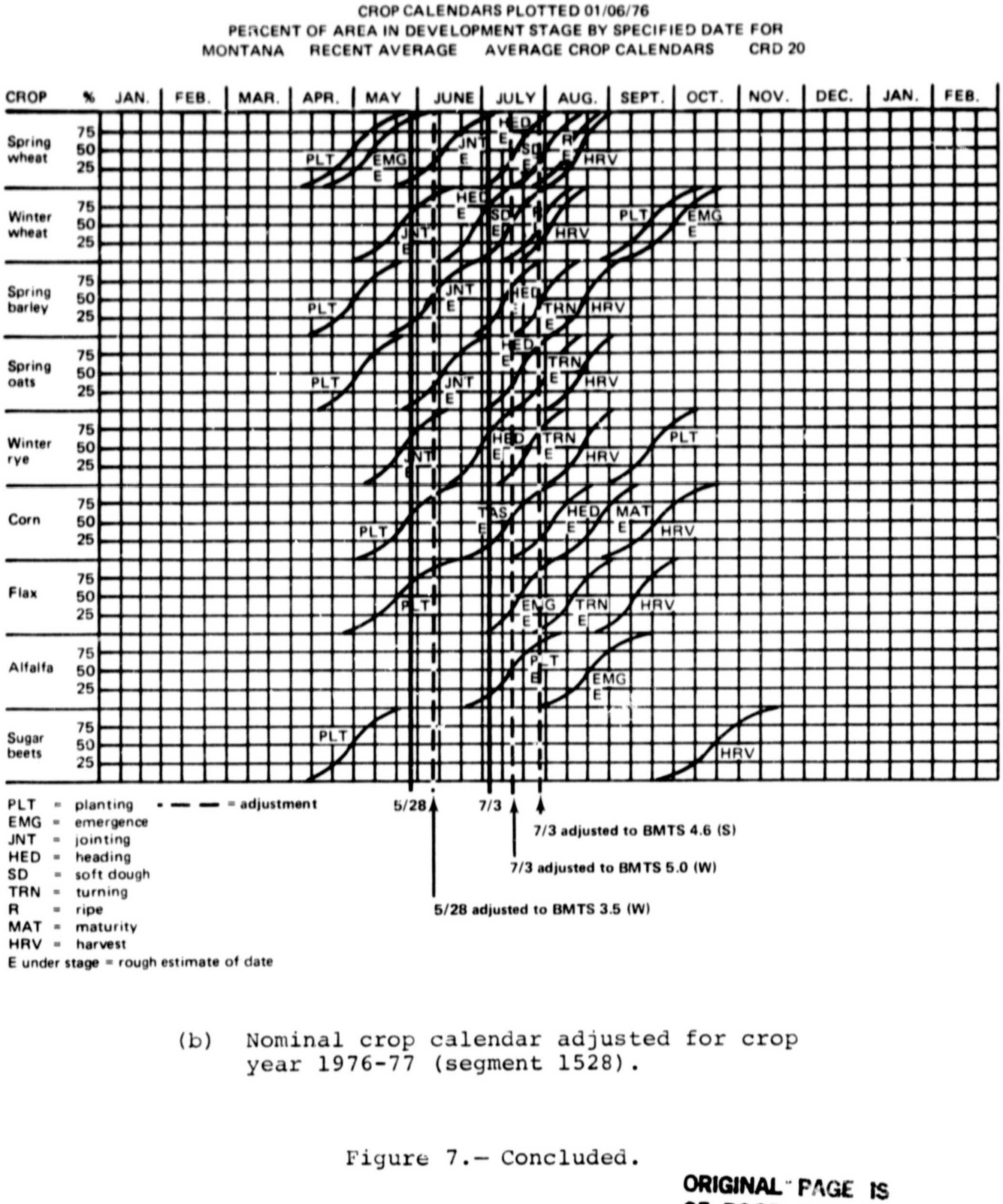
CROP CALENDARS PLOTTED 01/06/76
PERCENT OF AREA IN DEVELOPMENT STAGE BY SPECIFIED DATE FOR
MONTANA RECENT AVERAGE AVERAGE CROP CALENDARS CRD 20



PLT = planting
EMG = emergence
JNT = jointing
HED = heading
SD = soft dough
TRN = turning
R = ripe
MAT = maturity
HRV = harvest
E under stage = rough estimate of date

(a) Nominal (historical) crop calendar.

Figure 7.– Nominal and adjusted nominal crop calendars for CRD 20 (Montana).



(b) Nominal crop calendar adjusted for crop year 1976-77 (segment 1528).

Figure 7.— Concluded.

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the relative growth stages of other crops in the area is presented. Figure 7(b) shows adjustments to the nominal crop calendar. By correlating the year's specific growth stages found on the crop calendar adjustment (fig. 8) from the Weekly Meteorological Summary (ref. 5), the analyst adjusts the nominal crop calendar to be more specific for the current year, as shown in figure 7(b).

- Historical crop percentages for the political subdivision for the previous 4 or 5 years.

c. Imagery for the segment:

- Product 1 for all acquisitions during the past crop year, if available.
- Products 1, 2, and 3 for each acquisition in the current crop year.

d. Machine classification data:

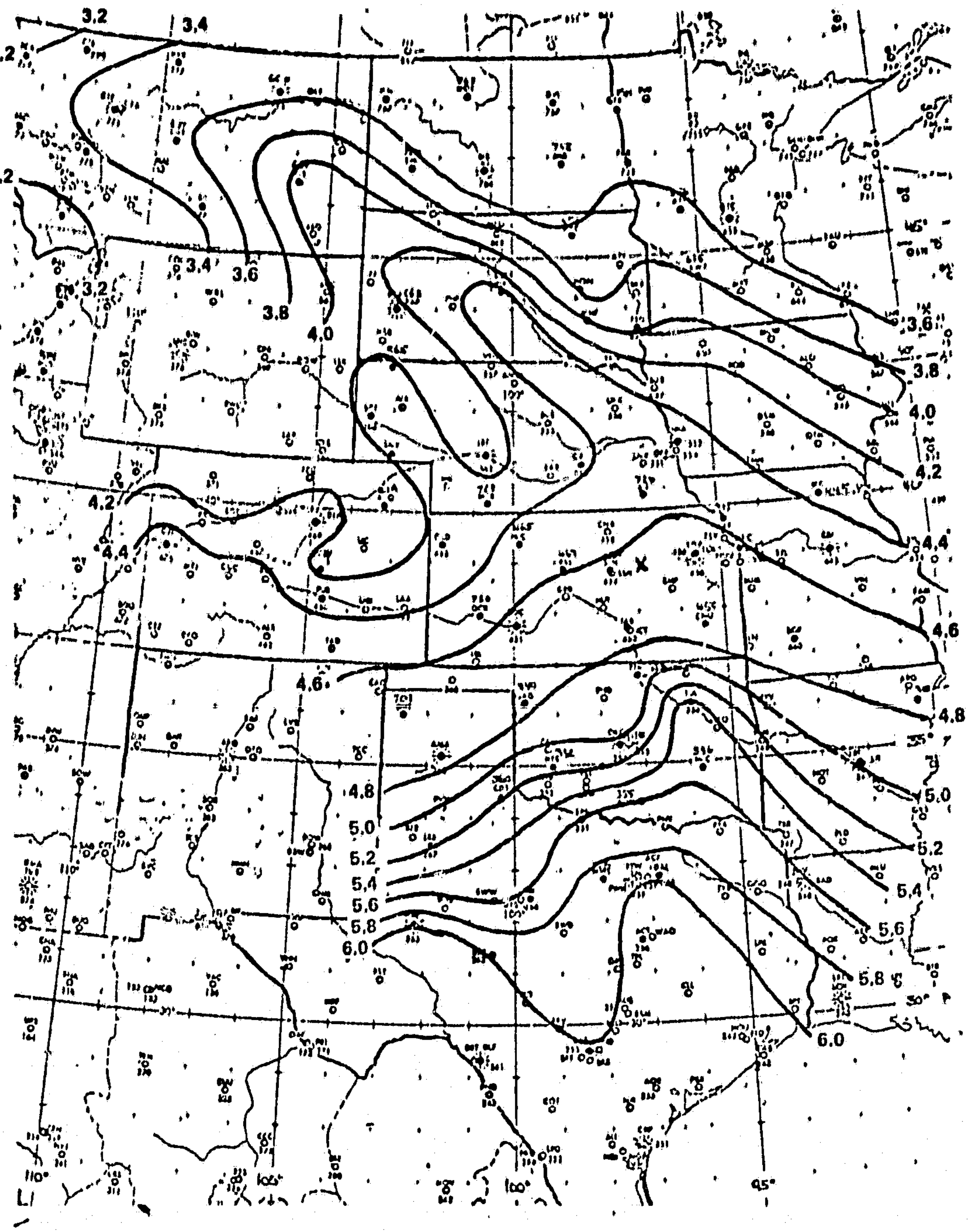
- Previous wheat acreage estimates on the segment.
- Classification products for the most recent estimate.

3.2 GENERAL REFERENCE MATERIAL

Reference materials not included in the analyst packet are available:

a. Weekly Meteorological Summary (ref. 5) — These summaries provide current data on temperature and precipitation, a crop calendar adjustment which reflects the current Robertson Biometeorological Time Scale (BMTS) growth stage of wheat, and a narrative summary for crop and weather assessment on a statewide basis. Episodic events, such as recent rainfall, alter crop signatures; soil reflectivity contributes an indeterminate component to the average reflectance value for an acre recorded by Landsat, and the reflectivity of wet soil differs from that of dry soil. Long-term events, such as

May 29, 1977



The beginning of each growth stage is when approximately 50 percent of the crop has reached one of the following numbered stages.

Growth stage	Description	Growth stage	Description
1.0	Planting	4.0	Heading
2.0	Emergence	5.0	Soft dough
	Dormancy (winter wheat)	6.0	Ripe
	Spring growth (winter wheat)	7.0	Harvest
3.0	Jointing (greening-up period)		

Figure 8.– Example of crop calendar adjustment from Weekly Meteorological Summary. The numbers refer to the Robertson BMTS growth stages for wheat.

drought, affect the expected Robertson BMTS for wheat, as well as expected spectral signatures.

b. Landsat full-frame imagery.

c. LACIE Phase III Classification and Mensuration Subsystem (CAMS) Detailed Analysis Procedures (ref. 6) — This guide is used by all analysts to ensure a consistent decision process.

d. Analyst Interpretation Keys (ref. 7) — A definitive reference for crop signatures, this document gives a representative set of segments over a stratum, along with crop calendars, full-frame imagery, and labels for selected fields.

4. ANALYST DECISION PROCESS

The analyst correlates the available material. Two decisions must then be made prior to machine classification of the segment: (1) selection of the acquisitions to be used for machine processing and (2) specification of the training data to be used as the basis for machine classification. Reference materials are usually consulted at many stages in the decision process. Decisions may be updated as frequently as every 18 days, corresponding to each successive Landsat overflight.

4.1 CHOICE OF ACQUISITIONS TO BE USED IN MACHINE PROCESSING

The analyst may choose to classify a segment using a single acquisition (four channels of data). However, multitemporal classification (classification using data from more than one acquisition) is preferred because it utilizes the temporal separability of the growth cycle of wheat from the growth cycles of confusion vegetation. A maximum of 16 channels of data, or 4 acquisitions, can be used for machine classification.

Acquisitions to be machine processed are chosen according to the following criteria.

a. Imagery quality. Cloudy or hazy imagery is omitted if possible. Acquisitions used for machine classification must be mutually registered.

b. Wheat growth stages.

c. Wheat separability from confusion crops should be maximized by the acquisitions selected.

For example, figure 9 shows a sequence of acquisitions for segment 1528, four of which are selected for classification; figure 2 is the full-frame imagery for segment 1528, acquisition date July 3, 1977; and the crop calendars for the segment are illustrated in figures 7(a) and (b). This segment is a

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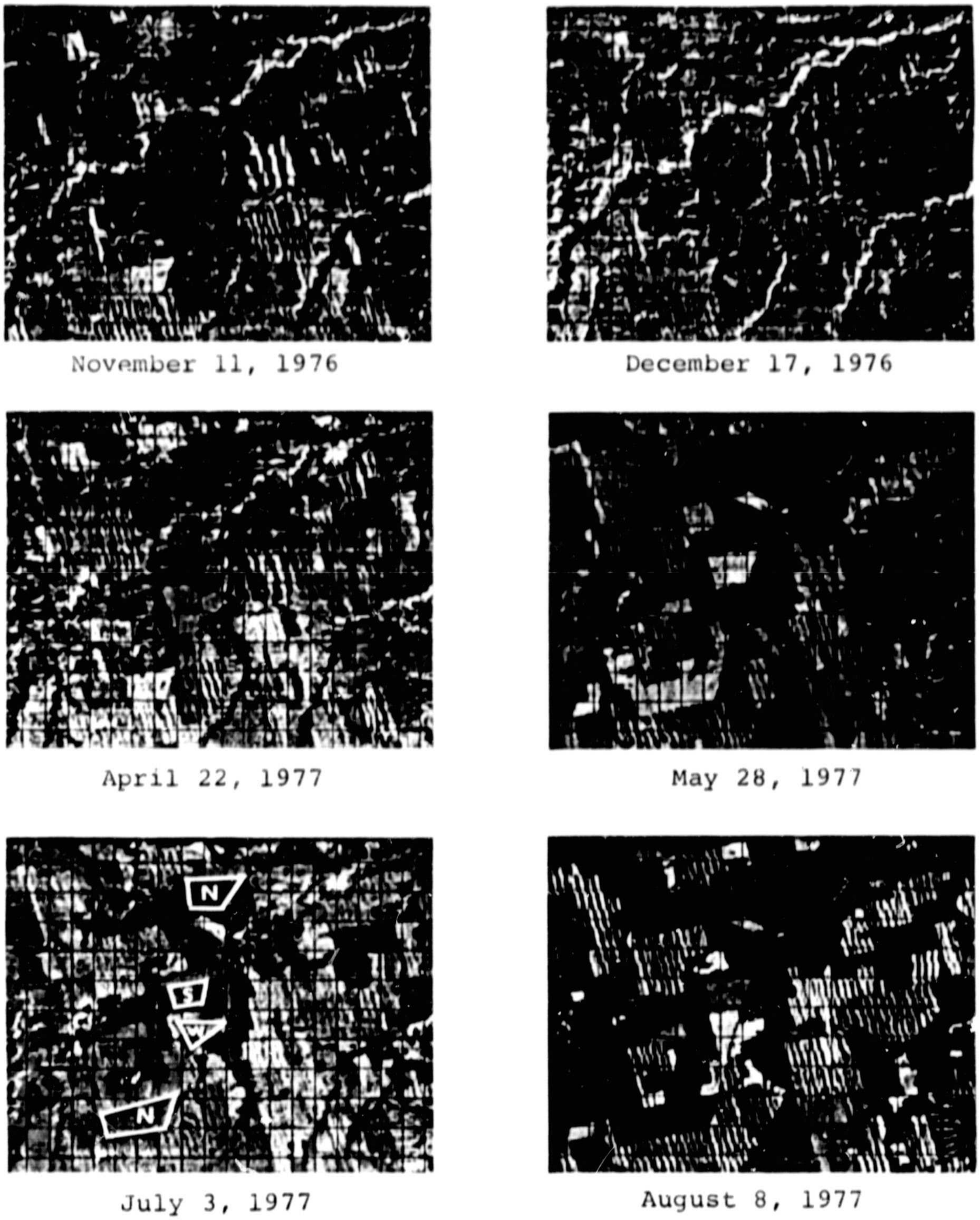


November 11, 1976 | December 17, 1976

April 22, 1977 | May 28, 1977

July 3, 1977 | August 8, 1977

Figure 9.- Sample-segment imagery for segment 1528 at various development stages during the 1976-77 crop year.

mixed-wheat segment, so both winter- and spring-wheat growth patterns must be considered in choosing acquisitions.

According to the crop calendar, winter grain was the only crop in a growth stage on November 11. Stream growth is also evident on the imagery, but multitemporal processing (used wherever possible) should eliminate this confusion factor. According to the crop calendar, winter wheat was in the dormancy stage on December 17. Based on the acquisition-selection criteria, either the November 11 or the December 17 acquisition would be a logical choice for processing. The April 22 imagery was acquired at both the planting stage of spring wheat and a growth stage of winter wheat. This also would be a good processing choice. Notice that if multitemporal processing were done on two of these dates alone (for example, November 11 and April 22) winter grains would be confused with stream growth. The streams would have to be designated other (DO), which is an area outlined to be designated as nonwheat, regardless of the statistical classification results within the area.

The May 28 and July 3 acquisitions are both of good image quality and add separability from natural vegetation (the full-frame imagery shows clear separation) and information on the growth stage of wheat. One of these dates should be used.

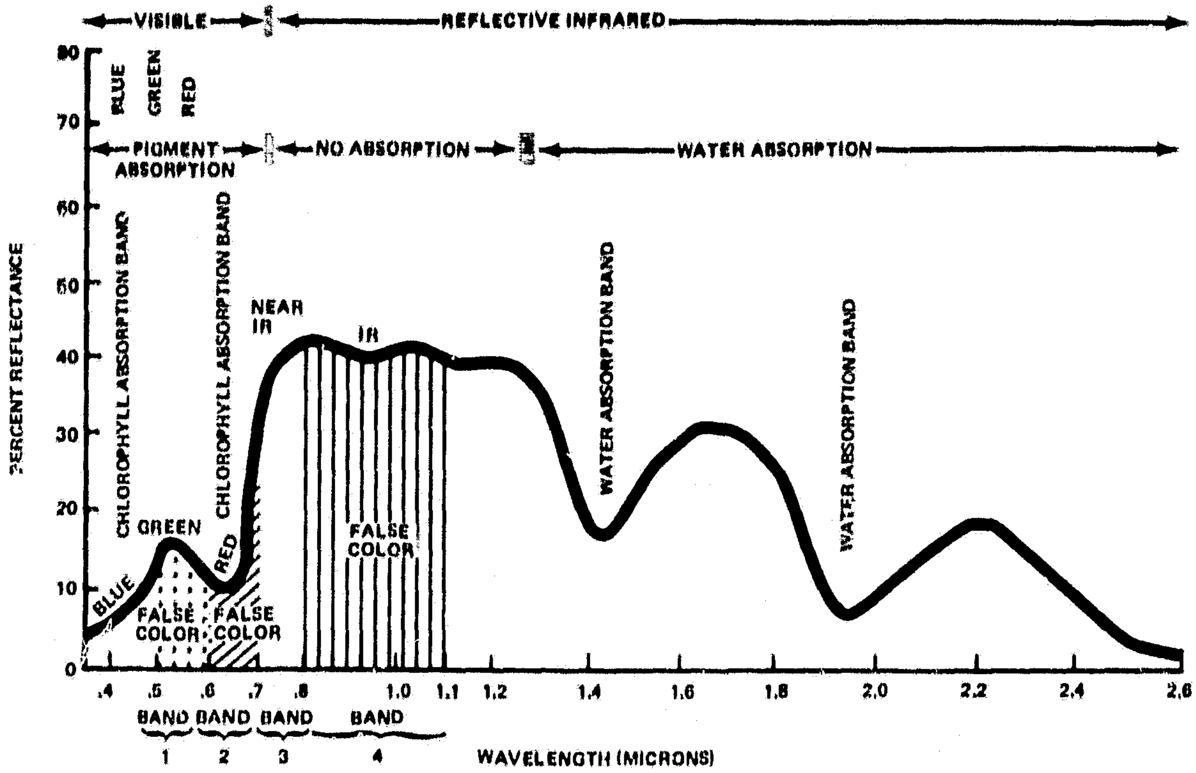
On August 8, the wheat was at a critical stage in development; thus, this acquisition would be a logical choice for inclusion in multitemporal machine processing. At that time, small grains (winter and spring) were ready for harvest or had been harvested, and confusion vegetation could be separated from small grains.

4.2 IDENTIFICATION OF SPECTRAL SIGNATURES IN SCENE

Using all available information, the analyst identifies the spectral signatures in the segment. This is done by correlating the temporal growth stages of small grains and the expected sequence of changes in spectral signatures to the sequence of spectral signatures evident on the imagery. Plant phenology is indicated by a temporal change in the infrared reflectance relative to the reflectance in the visible range. A growing plant has relatively high reflectance in the infrared channels because of scattering from the internal structure of the leaf; green plants have relatively low reflectance in the visible range (green, red) because of absorption by chlorophyll (ref. 8). Figure 10(a) shows a typical curve for green growing vegetation plotted in wavelength versus percentage of reflectance. Since channel 4 (0.8 to 1.1 micrometers) is assigned red in LACIE products 1 and 3 imagery, a red spectral signature on this imagery will reflect healthy green vegetation. Chlorophyll is sensitive to changes in plant condition, such as stress and senescence. Lower chlorophyll content in vegetation results in less absorption in the visible range, thus giving more relative reflectance resulting in a less red signature. Figure 10(b) shows the expected sequence of small-grain signatures for the acquisition dates of figure 9.

For example, follow the field labeled W on the sequence of imagery in figure 9. This is clearly a winter-grain field. The field labeled S follows a spring-grain temporal growth pattern. The fields labeled N do not follow the temporal growth pattern of wheat.

Any events which might affect the evident signatures, such as drought, recent rain, and the irrigated mode of crop practices, must be allowed for in the expected signature.



(a) Reflectance curve of healthy green vegetation.

DATE	WINTER GRAIN	SPRING WHEAT
NOV. 11 TO MAR. 30	PLANTING/EMERGENT STAGE – NO RED TO RED	PREPLANTING – NO RED
APR. 22	VIGOROUS GROWTH STAGE – RED	PLANTING – NO RED
MAY 28	VIGOROUS GROWTH STAGE PERHAPS SOME CHANGE PREPARATORY TO TURNING – RED OR BRICK RED	EMERGENT – RED OR PINK, DEPENDING ON PLANT CANOPY
JULY 3	RIPE STAGE – ORANGE, YELLOW, BROWN	VIGOROUS GROWTH STAGE – RED
AUG 8	HARVEST STAGE – YELLOW, WHITE, TAN	HARVEST OR READY FOR HARVEST – YELLOW, BROWN, OLIVE GREEN, WHITE

(b) Expected spectral signatures for small grains, segment 1528.

Figure 10.– Reflectance curve for vegetation and expected spectral signatures for small grains.

4.3 DEFINITION OF TRAINING SAMPLES

When signatures have been identified and acquisitions have been chosen for machine processing (acquisitions of good quality, which are registered and representative of the wheat growth cycle, as well as capable of gaining maximum separability of wheat from confusion factors in the scene), training samples must be defined for machine classification.

A subset of the 22 932 pixels in the LACIE sample segment is identified and used to train the classifier. In crop year 1975-76, the analysts chose training fields from the spectral signatures in the scene; analysts used training fields to define the stratification of Landsat spectral space. Several fields, preferably in different geographical areas of the sample segment, were selected to approximate a spectral signature. Fields approximating the same spectral signature were grouped by the analyst into subclasses. The subclass mean value and standard deviation in each channel were calculated, and all pixels in the segment were classified using these subclass statistics generated by the training fields.

For crop year 1976-77, the analysts identified individual pixels; spectral stratification was done using a machine clustering process. The image display of a LACIE sample segment has 196 pixels per line and 117 lines; a grid mark appears at the intersection of every 10 pixels and 10 lines. The pixel at the lower right corner of each block of 100 pixels so delineated has been designated a dot. Two preselected random samples of dots were specified to be labeled by the analyst: Type 1 dots were used to initiate the clustering process and to label the clusters generated, and type 2 dots were used for bias correction of the final wheat acreage estimate (section 5.3). The analyst labels a minimum of 30 dots from the random selection specified for type 1 dots. These dots (as in training field selection) were selected to be good samples of spectral signatures; no border or edge pixels were used. Twenty of these labeled dots were selected randomly to initiate clustering.

Clustering is the process of grouping pixels according to some distance measure. The pixel vector ($X = x_1, x_2, \cdots, x_n$; n = number of channels) of each of the 22 932 pixels in the segment was compared with the pixel vector of each of the 20 starting dots ($Y = y_1, y_2, \cdots, y_n$). Each pixel is assigned to the closest starting dot.

$$\text{Distance} = \sum_{i=1}^{m} \left|(y_i - x_i)\right|$$

where m is the number of channels used in clustering.

After all pixels have been assigned, the mean and standard deviation of each cluster are computed for each channel. Clusters can "split and combine" using predefined parameters, to a maximum of 60 clusters. A maximum of 10 passes can be made through the data, assigning pixels to clusters, recomputing cluster statistics, and then splitting clusters (if channel standard deviations are large), merging clusters (if intercluster distances are small), or deleting clusters by eliminating cluster mean vectors (if the cluster populations are too small). After the first pass, pixel vectors are "distanced" from cluster mean vectors (refs. 9, 10). Figure 11(a) is a color-coded cluster map of segment 1528.

Figure 11(b) is a categorized (conditional) cluster map. The mean vector of each cluster has been distance-compared to the dot vector of each of the 30 analyst-labeled type 1 dots and labeled wheat or nonwheat according to the label of the closest dot. If the distance was within a specified threshold of a dot labeled S, W, or N (spring wheat, winter wheat, or nonwheat), the cluster was color-coded green, cyan, or yellow, respectively.

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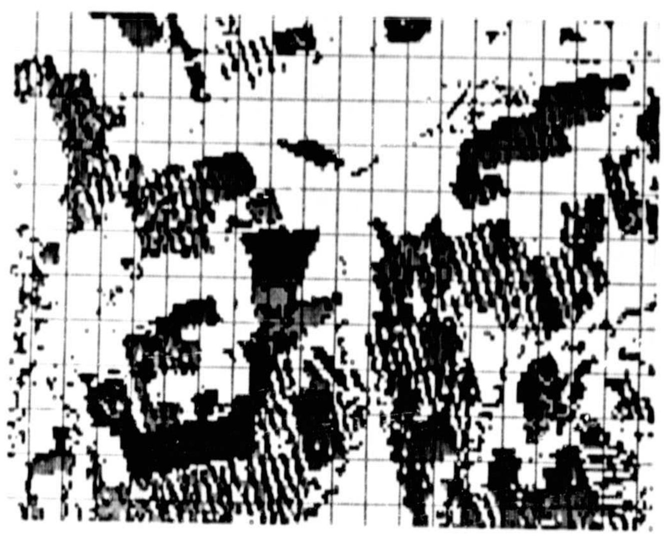
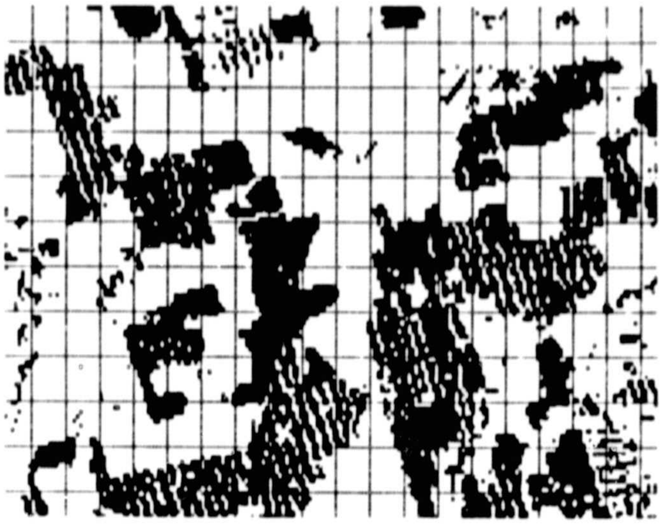
(a) Plain cluster map.



(b) Categorized cluster map.

Figure 11.- LACIE 16-channel classification products for segment 1528.



(c) Classification map.

Figure 11.– Concluded.

If it was not within the threshold, category assignment of the cluster was according to the closest dot, but color coding was unique. The cluster mean value and standard deviation in each channel, with cluster labels assigned as above, are used to classify the segment.

5. MACHINE CLASSIFICATION

5.1 CLASSIFICATION

Pixel-by-pixel classification of all pixels in the segment is performed using the LACIE System (ref. 9). Either subclass or cluster statistics are used to build the LACIE classifier for a segment.

A classifier is a system of subclass density functions, one function for each cluster or subclass. The probability of each pixel in the segment belonging to each subclass is computed; that is, the pixel vector is substituted in each subclass density function and the value of the function is calculated. Values are summed to the category level. Pixel assignment is made to the most likely category and then to the most likely cluster or subclass within that category. Pixel assignment is not directly to the most probable subclass, since the CAMS procedures specify a summation-of-likelihoods classifier. Classification is on a pixel-by-pixel basis; that is, the procedure above is repeated 22 932 times in order to classify a segment; all pixels are classified.

After classification, thresholding is applied to remove from final classification results pixels with low probability of belonging to the assigned subclass (ref. 11).

5.2 CLASSIFICATION RESULTS

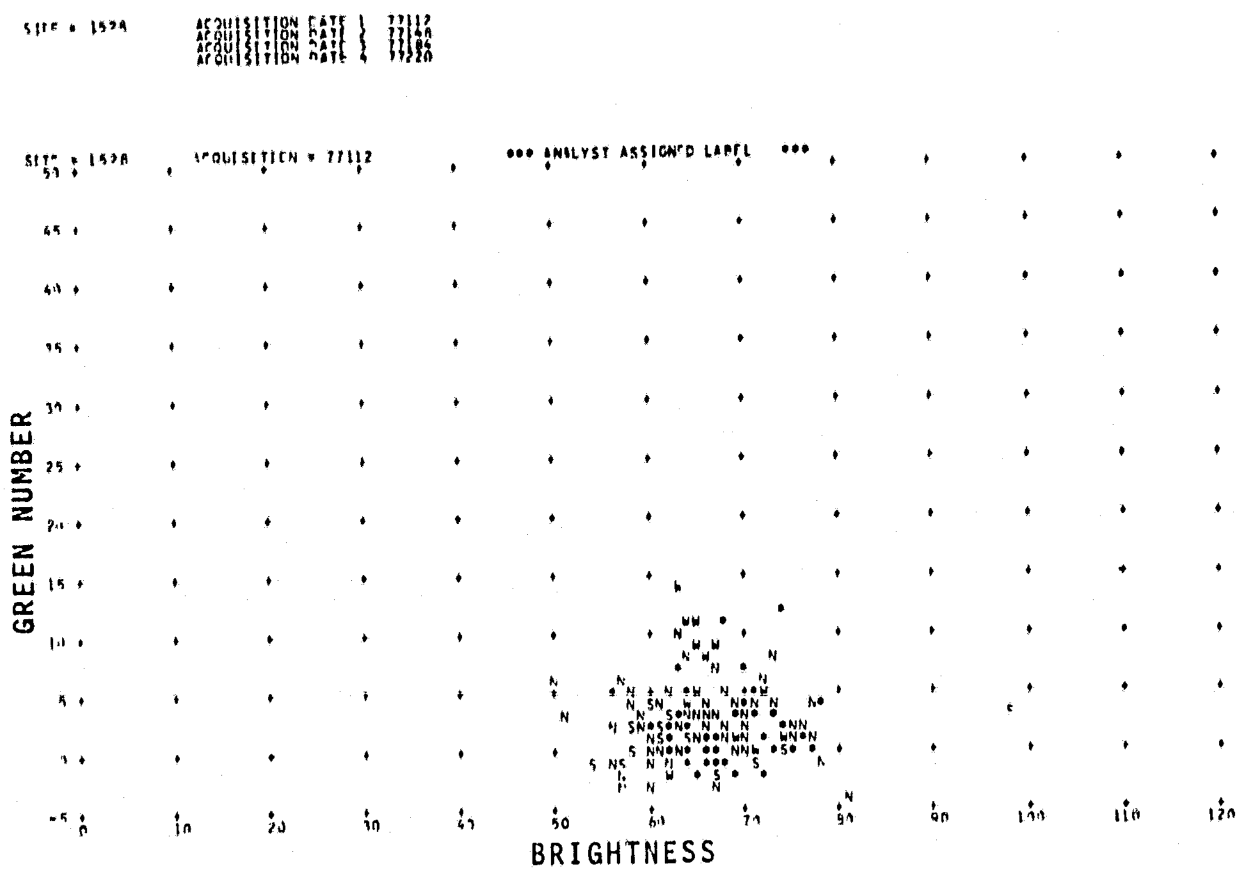
Classification results are presented in the forms of imagery, as shown in figure 11(c), and numerical results. The imagery representation permits the analyst to do a spatial verification (clean field patterns; wheatfields classified as wheat; and natural vegetation, streams, and other crops classified nonwheat). If areas are misclassified, the cluster maps [figs. 11(a) and (b)] permit monitoring of the machine clustering routine and hence of the segment classifier, if classification was based on cluster statistics. On the figure 11(c) classification map, light gray is used for pixels classified nonwheat, medium gray for pixels classified spring wheat, and black for pixels classified winter wheat. Pixels that were thresholded after classification are white on this classification map. Numerical results, wheat acreage estimation for the segment and the classified category of each of the dots or training fields, according to the procedure used to select training samples, are presented. This permits further verification of results in accordance with well-defined procedures (ref. 6).

Spectral aids, based on a transformation of the data (refs. 12, 13), are provided with classification results. These enable the analyst to check the consistency of dot labeling. Spectral data are transformed into two variables: green number and brightness. This information is presented to the analyst in the following forms.

a. Scatter plots — graphic representation of data distribution and the distribution of analyst dot labels for each acquisition used in the classification. Figure 12(a) shows scatter plots of analyst-labeled dots for segment 1528, acquisitions of April 22, 1977; May 28, 1977; July 3, 1977; and August 8, 1977.

b. Trajectory plots — time traces of an individual pixel. One trajectory plot is generated for each of the 209 dots whenever multitemporal processing is used. Figure 12(b) shows sample trajectory plots for a winter-wheat, a spring-wheat, and a nonwheat dot.

c. Numerical values for the dots used as representative trajectory plots in figure 12(b) are presented in figure 12(c).



(a) Scatter plots of analyst-labeled dots.

Figure 12.– Spectral aids, segment 1528.

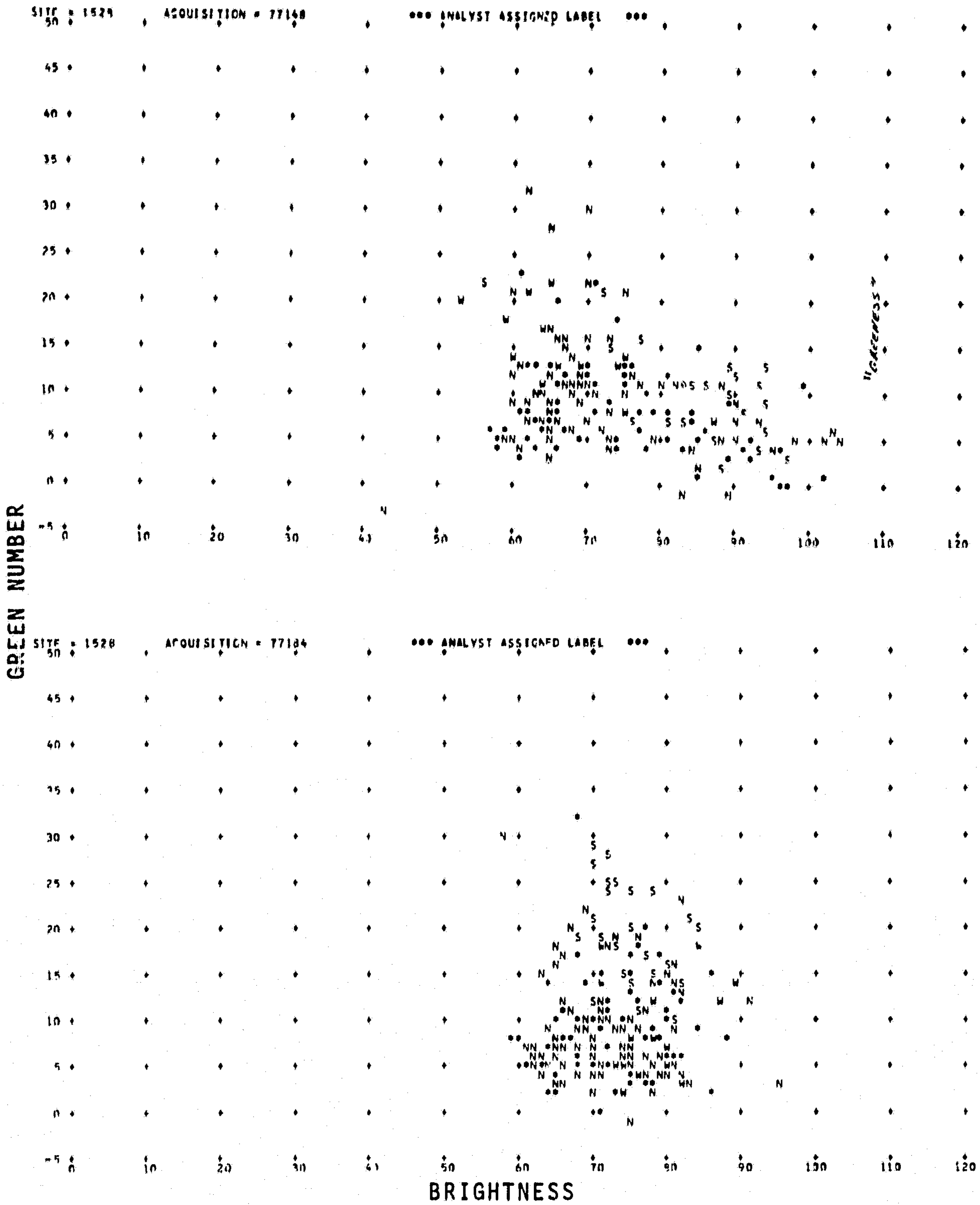


Figure 12.— Continued.

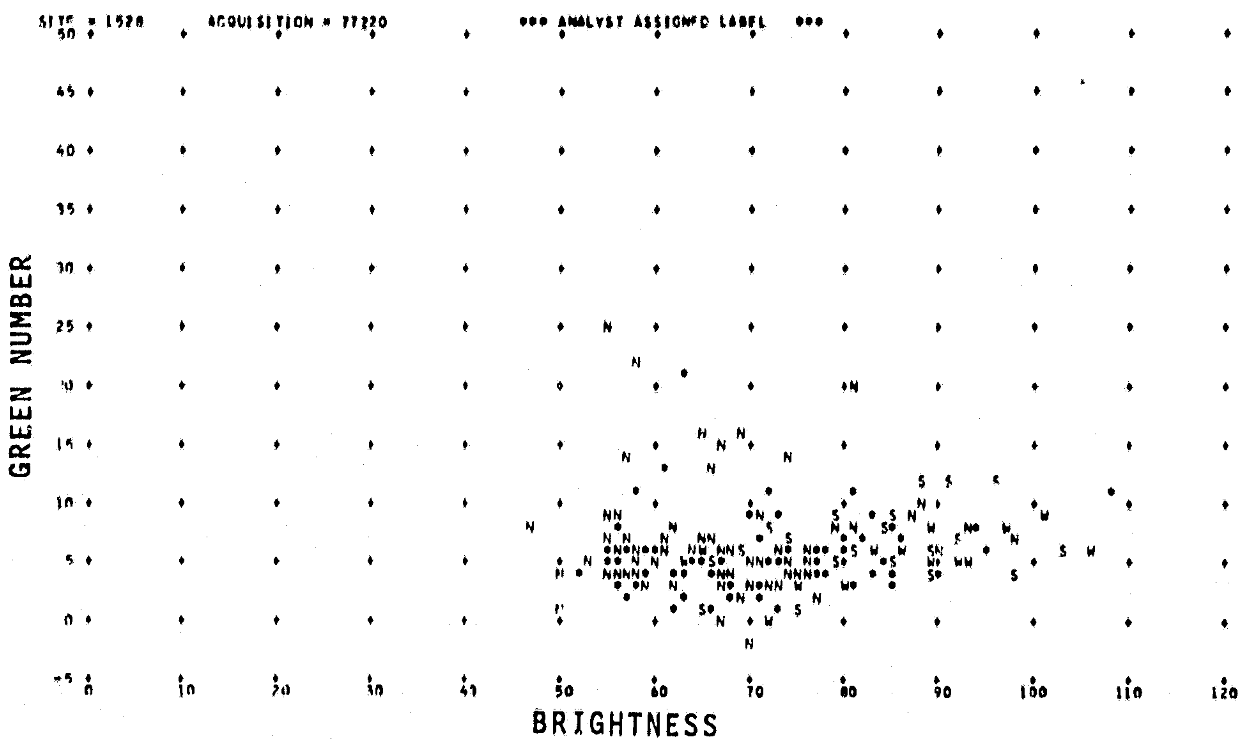


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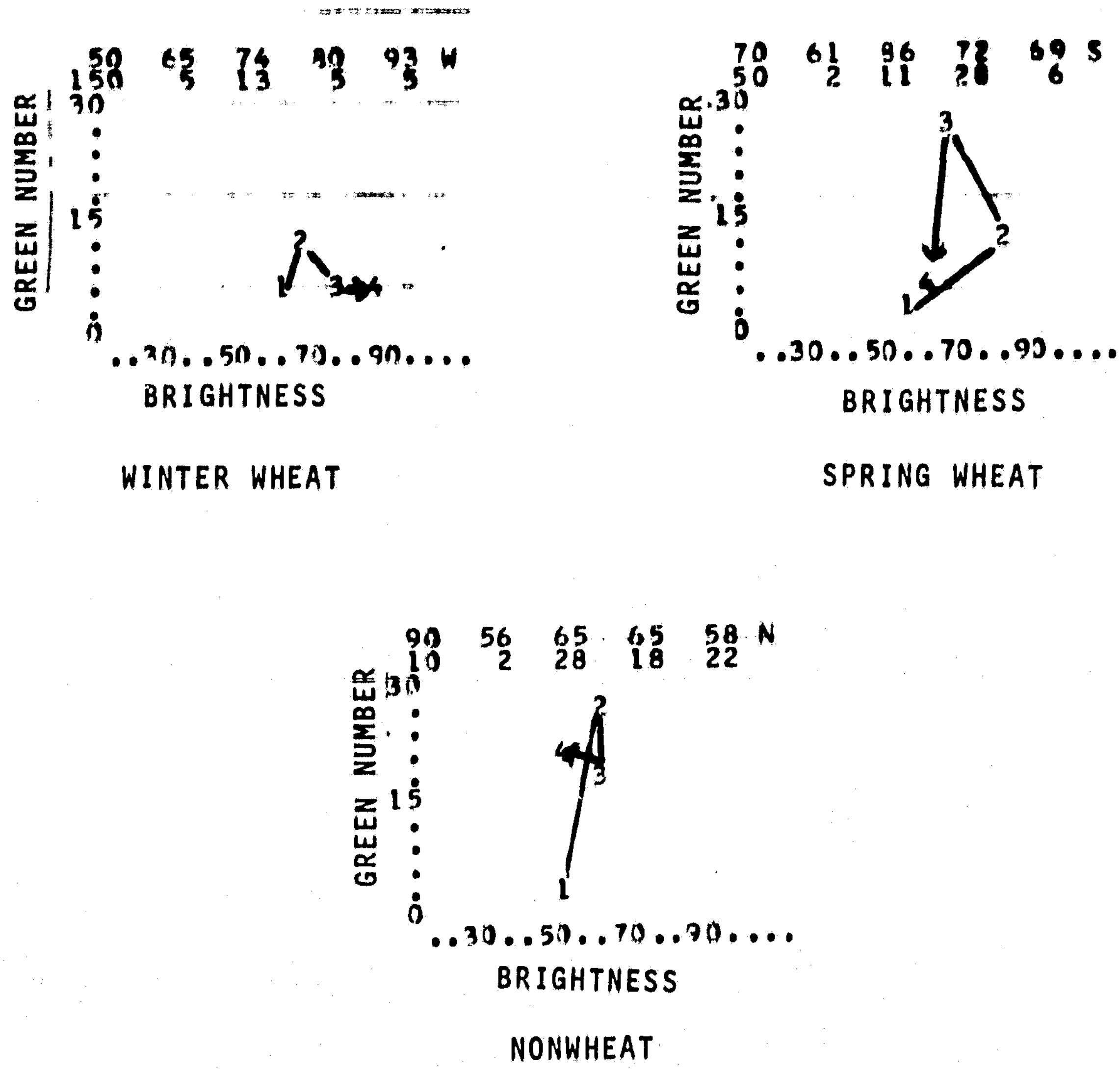
Figure 12.– Continued.



Acquisition 1: Apr. 22, 1977; BMTS 2.5, winter wheat, and 2.0, spring wheat

Acquisition 2: May 28, 1977; BMTS 3.5, winter wheat, and 3.1, spring wheat

Acquisition 3: July 3, 1977; BMTS 5.0, winter wheat, and 4.6, spring wheat

Acquisition 4: Aug. 8, 1977; BMTS 7.0, winter wheat, and 6.0, spring wheat

(b) Trajectory plots of typical winter-wheat, spring-wheat, and nonwheat pixels.

Figure 12.— Continued.

DOT NUMBER	GRID INTERSECTIONS		ANALYST LABEL	CLASSIFIED	ACQUISITION 1		ACQUISITION 2		ACQUISITION 3		ACQUISITION 4	
					G	B	G	B	G	B	G	B
91	50	150	W	W	5	65	13	74	5	80	5	93
119	70	50	S	S	2	61	11	86	28	72	6	69
153	90	10	N	N	2	56	28	65	18	65	22	58

(c) Green number and brightness numerical values, as graphed in (b).

Figure 12.– Concluded.

5.3 BIAS CORRECTION

A classifier bias is introduced in the classification machine-decision process. In crop year 1976-77, a statistical correction factor was applied to the wheat acreage estimation generated by machine classification (ref. 14). To correct for the classifier bias, an independent, preselected, random sample of type 2 dots was labeled by the analyst before machine classification (section 4.3). Each dot specified for this random sample had to be labeled, including border and edge pixels; 60 random dots were labeled for bias correction if one category of wheat was used; 99 dots were labeled if both spring and winter wheat were present. Acreage estimates as classified and as bias corrected are presented to the analyst for verification.

5.4 VERIFIED ACREAGE ESTIMATION SUBMITTED FOR AGGREGATION

An independent check of all dot labels to ensure consistency in labeling was made by a quality assurance team of analysts which did not include the analyst to whom the segment was assigned. If verification of any area by the analyst or by the quality assurance team indicated that a rework would improve accuracy of results, this was done.

The verified acreage estimation for the wheat in the sample segment (in crop year 1976-77, this was a verified bias-corrected acreage estimate) is submitted for aggregation and subsequent use in production estimates (fig. 5).

6. SUMMARY

The use of satellite data for crop inventories, as in LACIE, currently demands intense interaction of the human analyst with the digital data from the satellite. This is implemented by using imagery forms of the digital values. Analysts must be skilled in image interpretation, as well as in the machine processing techniques applied to the digital values.

Data acquired by the Landsat MSS are telemetered to GSFC, where LACIE sample-segment digital information is extracted. An analyst at JSC correlates a variety of ancillary data and applies this to an imagery representation of the digital data for identification of sample-segment scene content. The analyst labels a subset of the 22 932 pixels in the sample segment. Based on this subset of labeled pixels, machine classification of all 22 932 pixels is performed using the digital values. The estimate of wheat acreage proportion for the sample segment is computed. This sample-segment proportion estimate is used to estimate wheat acreage proportions over larger geographical areas and to produce estimations of production.

Experience gained from the 3 years of development in LACIE can serve as a foundation for further progress in the use of satellite data. A detailed examination of the LACIE analyst procedure for identifying wheat and estimating wheat acreage can provide a basis for redefining the analyst-satellite interface, perhaps toward more automated, less intense interaction.

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