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MONITORING THE VERNAL ADVANCEMENT AND RETROGRADATION (GREEN WAVE EFFECT) OF NATURAL VEGETATION

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Greenbelt, Maryland 20771

TEXAS A&M UNIVERSITY
REMOTE SENSING CENTER
COLLEGE STATION, TEXAS

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by

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16. Abstract

This regional study monitors the vernal advancement and retrogradation of natural vegetation (green wave effect) using ERTS observations throughout the Great Plains Corridor. The green wave effect is charted by using the relatively homogeneous rangeland vegetation systems of the Mixed Prairie region in the central United States as phenological indicators. ERTS multispectral scanner data and ground observations collected from the network of ten test sites are used to measure vegetation changes during the life-time of ERTS-1. Attention is given to observing seasonal drought and other bioclimatic influences which impact upon management and production in agriculture. The overall objective of this investigation is to determine the effectiveness of ERTS-type data in monitoring the vegetation conditions of direct concern to rangeland management and agri-business decisions in this region.

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PREFACE

Natural vegetation systems occupy broad areas of the Great Plains and their behavior provides a reliable indicator of seasonal drought and other bioclimatic influences which impact on the agricultural management and production activities of major economic importance to this region of the United States. The overall objective of this investigation is to determine the effectiveness of ERTS-type data for monitoring these vegetation systems as phenological indicators and to assess the value of this new information source relative to rangeland management and agri-business decisions in the Great Plains.

The project employs an extensive test site network to monitor vegetation and climatic conditions from south Texas to North Dakota. Evaluation of hypotheses basic to this endeavor involves analysis of spectral and temporal data, with primary emphasis on the use of quantitative MSS measurements.

The initial effort has verified that the proposed project is viable and that stated objectives are obtainable with the available quality and quantity of ground observations, aircraft imagery, and ERTS-1 data being received.

This activity has been responsible for development of related activities using ERTS-1 data from the Great Plains, especially for Texas. The spin-off projects have been user-generated, consequently, these ERTS data are impacting directly on established application efforts. It is recommended that these unscheduled demands for ERTS data be recognized as an important avenue to high priority application areas.

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MONITORING THE VERNAL ADVANCEMENT AND RETROGRADATION (GREEN WAVE EFFECT) OF NATURAL VEGETATION

1.0 SUMMARY

Texas A&M University is conducting an ERTS-1 regional study in which the vernal advancement and retrogradation of natural vegetation (green wave effect) is monitored using ERTS observations throughout the Great Plains Corridor of the central United States. The green wave effect is being charted by employing the relatively homogeneous rangeland vegetation systems of the extensive Mixed Prairie as phenological indicators. ERTS multispectral data and ground observations collected from a network of ten test sites are used to measure vegetation change during the lifetime of ERTS-1. Attention is given to observing seasonal drought and other bioclimatic influences which impact on management and production in agriculture. The overall objective of the investigation is to determine the effectiveness of ERTS-type data for monitoring the vegetation conditions of direct concern to rangeland management and agri-business decisions in the Great Plains.

This report details the progress of the project during the initial six months of operation. The following achievements are significant indicators of the successes

being realized in this expansive study.

1.1 Ground Observations and Reporting Network

A network of ten test sites have been established within the Great Plains, extending from south Texas through North Dakota within the Mixed Prairie region. Each site is an established rangeland test area of a state agricultural experiment station or the USDA, and each is monitored by experienced rangeland specialists. The periodic data collected in conjunction with each satellite overpass consist of photographs of selected subsites, weather information, percentage green vegetation, standing plant biomass, percentage plant moisture, visually dominant species, and phenology of dominant species. These measurements are compiled and computer processed to form continuously updated site data summary reports graphically portraying the progression of the green wave effect for direct comparison with the ERTS data analysis results. The ground observations acquired to date have documented the autumnal phase of the vegetation throughout the Great Plains Corridor.

1.2 Data Handling System

A comprehensive and efficient data flow network has been established to assemble the sequential data acquired from the ground site network and ERTS. The system provides for cataloging and filing operations on both data types in computer compatible formats; assembly of ground measurements according to time and latitude parameters; processing of ERTS MSS measurements for site location and spectral characteristics on a subsite integrated basis; photo analysis of black and white and color products; and a periodic data summary reporting procedure. The data handling system provides data product for internal analysis and for the users in the Great Plains. The system is formalized by a series of processing request forms which insure accurate and timely processing of the data from all sites.

1.3 Data Analysis

The data analysis activities have progressed rapidly along several areas. The data presently available is restricted to the fall season of 1972. Preliminary evaluation of autumnal phase ground observations suggest that the sampling procedures at the Great Plains Corridor network of test sites are adequate to show relatively small temporal changes in aboveground vegetation biomass and vegetation condition.

Preliminary analysis of black and white imagery suggests that detail in vegetation patterns is much greater than originally anticipated. A preliminary analysis of single band imagery and digital data at two locations in the vicinity of the College Station test site shows that woodland, grassland, and cropland areas are easily delineated. Computer derived grey-scale maps from MSS digital data are useful in identifying terrestrial feature patterns of natural and cultivated lands important in site locations. Single band imagery and digital data are believed to have important application for synoptic land use mapping and inventory.

Initial evaluations of multiband (color composite) imagery shows the expected enhancement of detail and information content of ERTS MSS data. The use of multiband imagery greatly improves the value of MSS imagery for applications requiring synoptic land use mapping. First order evaluations of vegetation condition and condition changes are possible using color composite imagery. Quality control in processing of the color composites limits these data for quantitative determinations.

Preliminary statistical evaluation of MSS digital data from two locations suggest that the coefficient of variation (CV) for Band 5 mean reflectance data is useful in determining the homogeneity of a vegetative scene. CV's ranged from about 5% for uniform grassland to more than 20% for woodland-grassland areas with variable ground cover. The relatively low CV value for a uniform scene appears also to be indicative of a desirable signal-to-noise ratio, enhancing the potential usefulness of the data for quantitative "signature" analysis.

Initial ratio analysis, using Band 5 and 7 data, suggests the applicability of these data for the detection of temporal changes in the "greenness" of a vegetative scene. Significant shifts in total reflectance from August 30 to December 16 as an apparent result of a decreased solar angle, indicate the necessity of data normalization. A solar-angle model has been implemented and tested against these data with good results.

1.4 Related Activity

The Texas A&M University involvement in this project and in the ERTS Phenology Satellite Experiment (MMC 159) has become well known throughout Texas. This fact, coupled with the published information that the Remote Sensing Center maintains a NOAA Browse File of ERTS-1 data, has led to several instances where various users have sought assistance in employing ERTS-1 measurements. One of the most rapidly developing of these is a USDA project addressing boll weevil and bollworm eradication in Texas. This is a problem of enormous economic importance in the Southwest. The proposed eradication program requires agricultural land use information and vegetation mapping indicating both species distribution and developmental stages. ERTS data, complimented by aerial photography, appear to be ideally suited to this information need and Texas A&M University is working with a USDA research team to develop the required information product.

The ERTS-1 data are also being used in studies of dredging activities in Galveston Bay; for studies of fresh water bodies in Texas toward possible use in a state-wide inventory; and for natural resource assessment in cooperation with the SCS (USDA). These ERTS-1 related activities are supported by NASA Grant NSG 44-001-001.

1.5 Comment

The Great Plains Corridor study has shown significant progress toward realization of an information source directly applicable to preparing range forage condition indexes and reports on seasonal development supportive of rangeland and dryland farming activities. The project was delayed during the early stages due to lack of data from NASA, however the data flow is presently excellent and the data handling system is operating at near capacity. No major difficulties have been encountered in executing the Data Handling Plan nor are any presently anticipated which would prevent reaching the objectives of this study.

2.0 INTRODUCTION

The Great Plains Corridor Study provides an assessment of the utility of satellite-acquired data for determining seasonal parameters of plant communities. ERTS data are employed to detect onset of growth, green biomass changes, onset of summer drought stress, and drought duration. Correlations are made for the phenophase-dependent reflectance patterns with soils, elevation, moisture, and temperature and other factors important in determining the quality of rangeland scenes. Assessment of regional drought, along with other positive and negative rangeland production factors, is made in support of development of range forage indexes for improving the Range Feed Condition Reports issued by USDA (ARS) and other range and crop management information.

The Great Plains Corridor concept is central to this experiment because it satisfies the requirements for such a phenology study and maximizes the opportunities for acquiring usable cloudfree data from ERTS-1. The Mixed Prairie, which essentially outlines the Great Plains Corridor, is the largest of the four major grassland associations of North America. This vast grassland forms a well-defined corridor through the Central United States (Fig. 2-1). It extends from the subtropics at its southern most extent

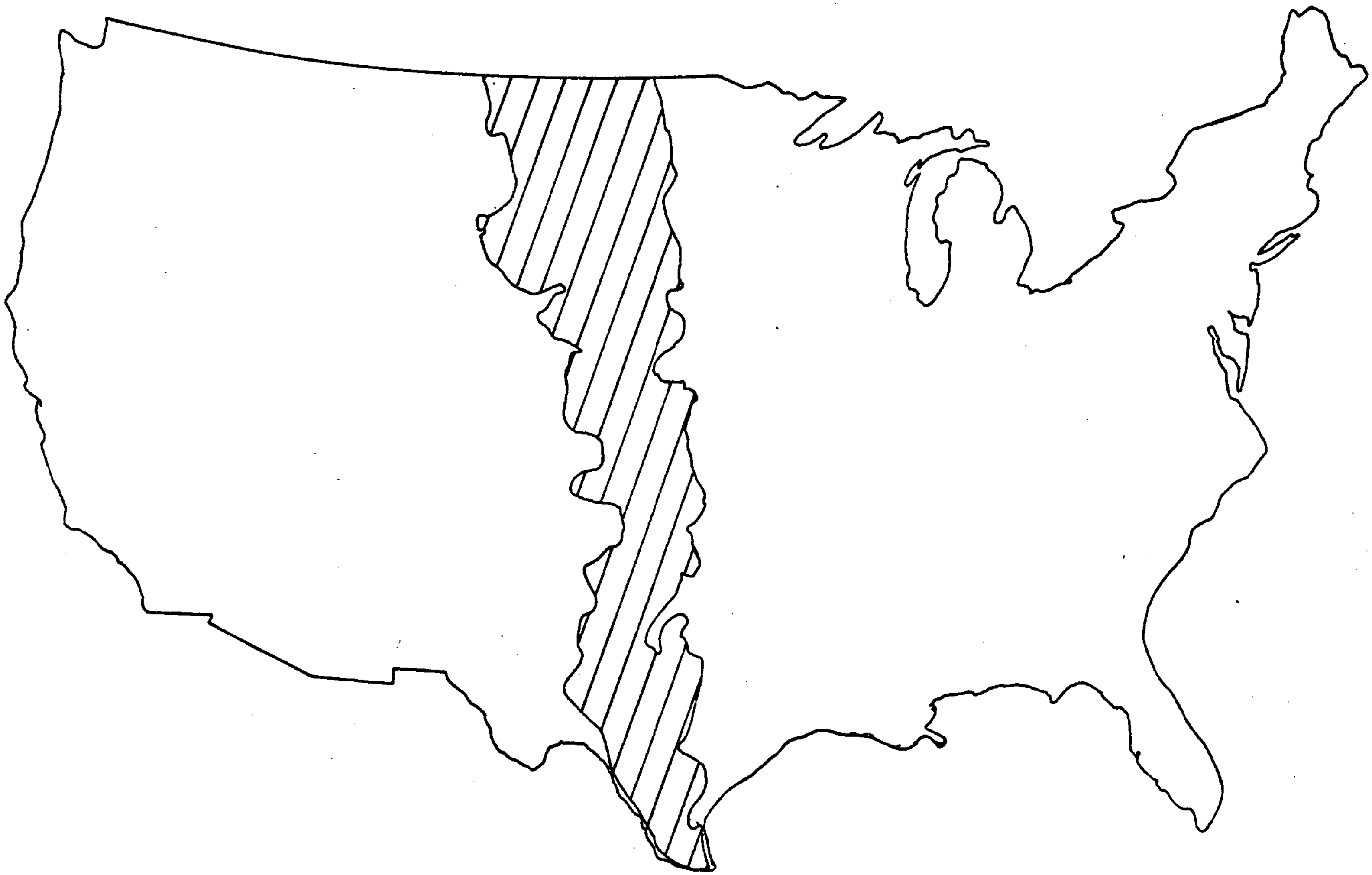


Figure 2-1. United States Mixed Prairie Grassland Association

in southern Texas to the subarctic of central Canada and is an extremely valuable national asset for cropland and rangeland uses. About two-thirds of the Mixed Prairie is rangeland, which produces more than one-third of the range beef cattle in the United States.

The climate of the Great Plains is generally described as having both dry winters and summers; however, accumulated winter precipitation coupled with abundant spring rains normally provide adequate moisture for the expression of vernal changes, even during drought periods. Maximum precipitation occurs in May and June and most of the vegetative growth is made as the result of rainfall during this period. Consequently, the vernal advancement through the midcontinent is normally dependent only upon temperature and this phenological development has been characterized as the "green wave". The continuation of favorable growth conditions is dependent upon seasonal distribution of rainfall, with a normal retrogradation of vegetational growth due to summer drought.

Livestock and grain production, primary commodities of the agriculturally oriented Great Plains, may be drastically influenced by seasonal and periodic drought or other adverse weather. For example, regional planting dates often are delayed due to cool temperatures in late spring. Production may be reduced due to early frost. Hail often causes severe local damage to crops and pastures. Heavy spring rainfall frequently causes local or regional flooding. The extent and intensity of both negative and positive production factors are observable as changes in the status of native vegetation in the Great Plains region.

Tremendous managerial and economic benefits could accrue from an operational system for detecting and analyzing the status of natural vegetation within the vast reaches of the Great Plains. The corridor formed by the Mixed Prairie of the Great Plains is ideally suited for maximum utilization of the parameters measurable by ERTS in the evaluation of such an operational system.

Particular emphasis is being given to detecting the south-north vernal advancement and ensuing retrogradation of vegetation with the onset of summer drought. The vast extent of the corridor is important to the evaluation of certain bioclimatic generalizations and of time as a discriminating factor. Successful testing of these generalizations requires a regional approach and provides an ideal opportunity for evaluating regional applications.

The program is concerned with testing several specific hypotheses important in evaluating the feasibility of an operational system for monitoring natural vegetation systems:

Hypothesis Number 1: *Time is an important factor in the discrimination of broad landforms, soil associations, vegetation types and other natural resource features.*

Hypothesis Number 2: *Using time as a discriminant factor, the vernal advancement and retrogradation of vegetation (green wave effect) can be recognized from repetitive multispectral satellite imagery.*

Hypothesis Number 3: *Parameters obtainable by ERTS are suitable for modeling integrated gradients from natural vegetation systems over broad areas.*

Hypothesis Number 4: *Vegetation system parameters are adequately unique to provide a new information source for regional agri-business use.*

3.0 PROGRAM APPROACH AND STATUS

The approach being employed centers upon an extensive test site network throughout the Mixed Prairie region. The ten test site network employs existing research stations of state Agricultural Experiment Stations or the United States Department of Agriculture. This approach permits use of the extensive background information available for the sites, highly experienced field personnel, existing instrumentation at the sites, and a wide variety of rangelands needed to evaluate the established hypotheses. The ongoing research at each of the ten stations in the Great Plains Corridor is oriented to the study of rangelands--those natural vegetation systems used for grazing. Consequently, the results of the program are rapidly and effectively applied to ongoing work by the resident organizations.

The following outline describes the general approach and status of the program:

1) Validation test sites for collecting ground truth data at the time of each satellite pass have been established within the corridor formed by the Mixed Prairie of the Great Plains, extending from south Texas northward through North Dakota. Each of the eight primary sites represents major grassland types which have common and unique features, and each site is large relative to the ERTS

resolution. Well-established vegetation, soil, and climatic data are available for all locations. All stations are well staffed with professional personnel who are collecting the ground data required in this study.

2) High resolution aerial imagery has been obtained for each of the ten test sites for at least one date during the autumnal period. Two high altitude and two low altitude flights are scheduled. Aircraft imagery is required to maximize information on the vernal advancement and retrogradation of vegetation within the Corridor and to accurately characterize the test sites.

3) Test sites are being characterized in regard to vegetation, soils, management history, and climate. Local weather and growth conditions are collected on a continuing basis for each station. All data are arrayed in a computer compatible format.

4) Seasonal variations in measurable parameters of ERTS are being compared with seasonal trends in phenological development and physiological status of dominant rangeland plants. Multiple regression procedures are being utilized to assess the impact of seasonal environment on the integrated reflectance characteristics of dominant vegetation. In addition, extensive evaluations of the influence of plant water status, soils, chlorophyll and other pigment contents

are being performed at Texas locations.

5) A time-line of plant development is being constructed for each site to establish the vernal advancement and retrogradation throughout the Corridor. ERTS MSS imagery and digital data of the site are used to construct the equivalent time-line using both absolute reflection and ratios as the defining parameters. The spectral data are being correlated to the test site measurements to establish the feasibility of using this technique to extend the sample data on a regional basis.

6) Using information derived from ERTS-1 and associated activities, a comprehensive review is being conducted of potential applications and the impact of an operational satellite on agricultural and agri-business activities of the Great Plains region. Special attention is being given to factors affecting the ranching and livestock industry; however, attention is also being given to the impact of bioclimatics in dryland crop production. Flow charts are being developed to illustrate how "phenological indicator" data may be employed in the real time situation.

3.1 Ground Observations

The following sections briefly describe the Great Plains Corridor Test Site Network and summarizes the status of ground data collection.

3.1.1 Great Plains Corridor Test Site Network

An effective rangeland test site network was established within the Great Plains Corridor region during the initial phases of the ERTS-1 investigation. This test site network consists of ten study sites (Fig. 3-1), nine of which lie within the Mixed Prairie grassland association. The headquarters study site at College Station, Texas occurs within the closely allied but somewhat more humid True Prairie grassland association.

With the exception of the College Station and Weslaco study sites, which are at elevations of 314 and 225 ft., respectively, the Great Plains Corridor test site elevations span only 1800 ft., from Texas through North Dakota. Their elevations range between 1100 and 2900 ft.

Loamy soils predominate on most of the study areas within the Corridor. However, one southern site (Woodward) and one northern site (Sand Hills) are dominated by sandy soils. Two southern sites (Sonora and Throckmorton) and one northern site (Cottonwood) are dominated by clayey soils.

Important community dominants within the Corridor include warm-season grasses (bluegrama, buffalograss, sideoats grama, and big and little bluestems) and cool-

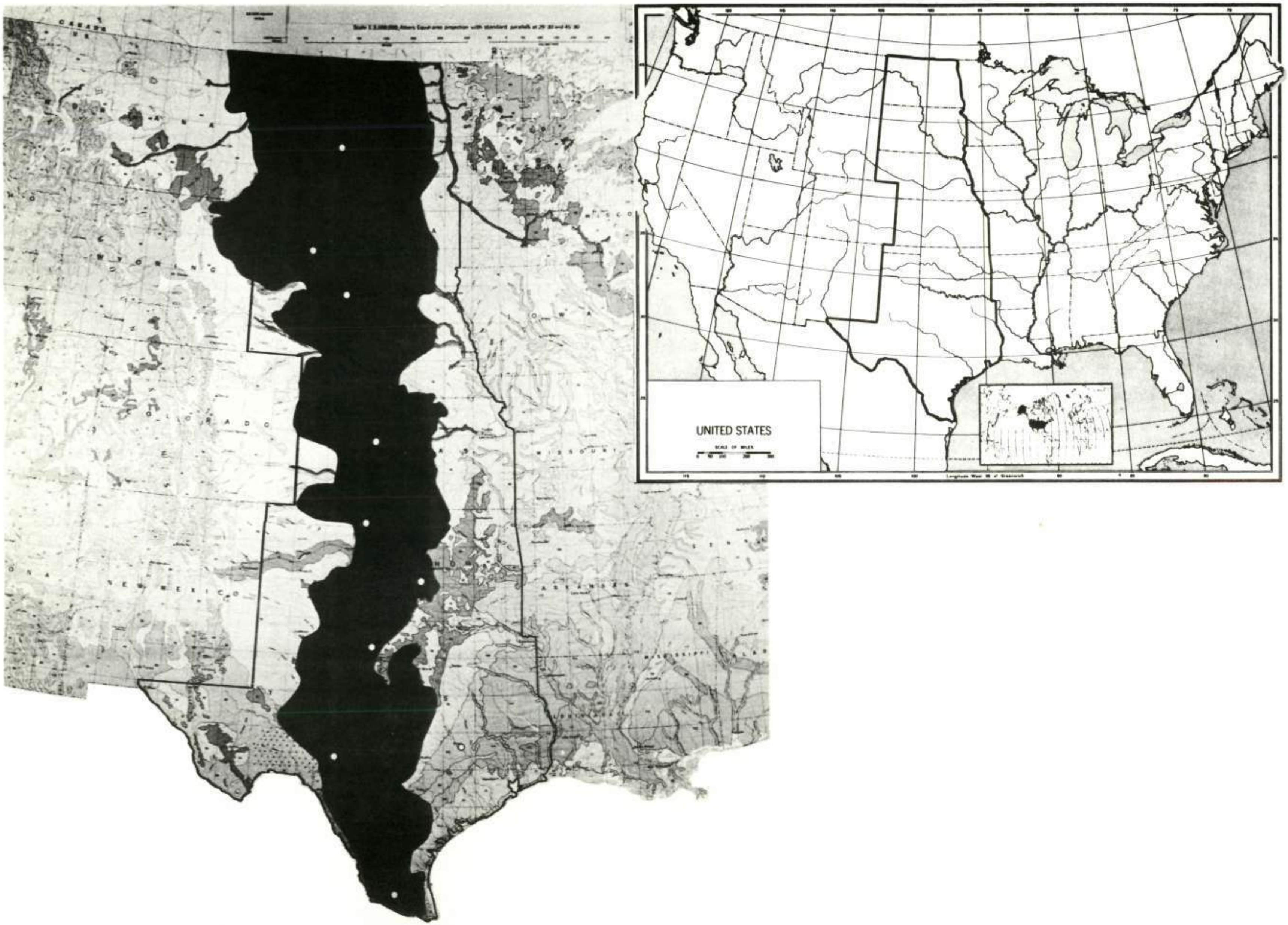


Figure 3-1. Great Plains Corridor and test site network.

season grasses (western wheatgrass, needle-and-thread, and Texas wintergrass). <u>Stipa</u> and <u>Bouteloua</u> genera are considered to be characteristic of the Mixed Prairie and are present throughout the association. The relative homogeneity of the Great Plains Corridor and of the included study sites, in terms of climate and soils as evidenced through vegetation expression, is demonstrated in figures 3-2 and 3-3.

Most of the test site areas are essentially treeless, but overuse of the prairie in the past has led to invasion of trees and shrubs in some areas. Most notable of these are the Weslaco and Sonora study sites where woody legumes and other undesirable brush species have changed the prairie into a brushland type. Climax dominant grasses have mostly been replaced by less desirable species at these locations. However, the understory vegetation retains many features of the Mixed Prairie. Brush invasion is evident but less prominent on several of the remaining study sites (Fig. 3-3).

3.1.2 Ground Observation Data Received

After the successful launch of the ERTS-1 satellite, the Great Plains Corridor test site cooperators were provided with a schedule of satellite overpass for

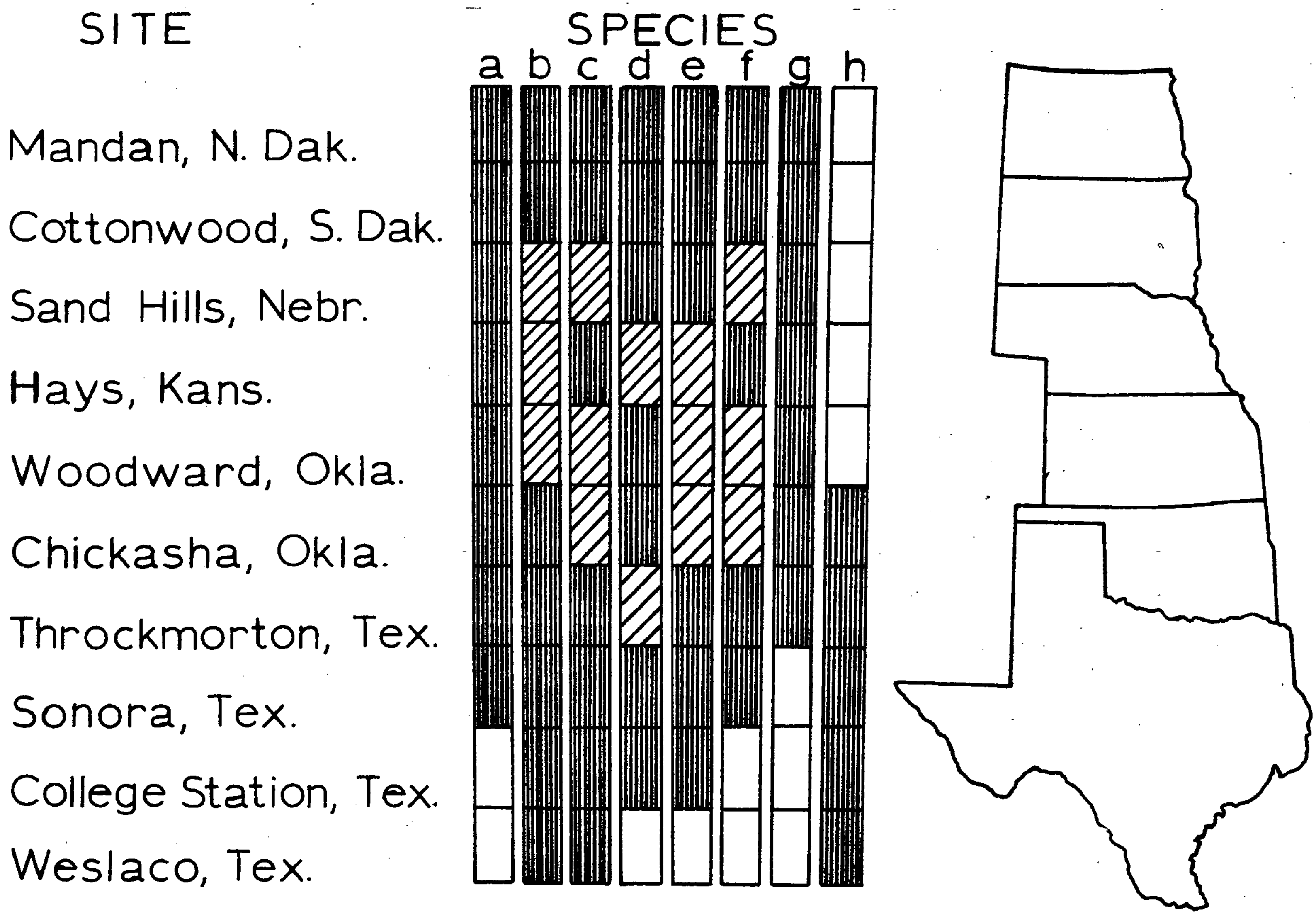


Figure 3-2. Occurrence of eight dominant grasses on the Great Plains Corridor test sites (vertical stripes), or within the region indicated (diagonal stripes). Dominant grasses are: a)blue grama, b)sideoats grama, c)buffalograss, d)little bluestem, e)big bluestem, f)western wheatgrass, g)needle-and-thread, h)Texas wintergrass.

1 6
2 7
3 8
4 9
5 10

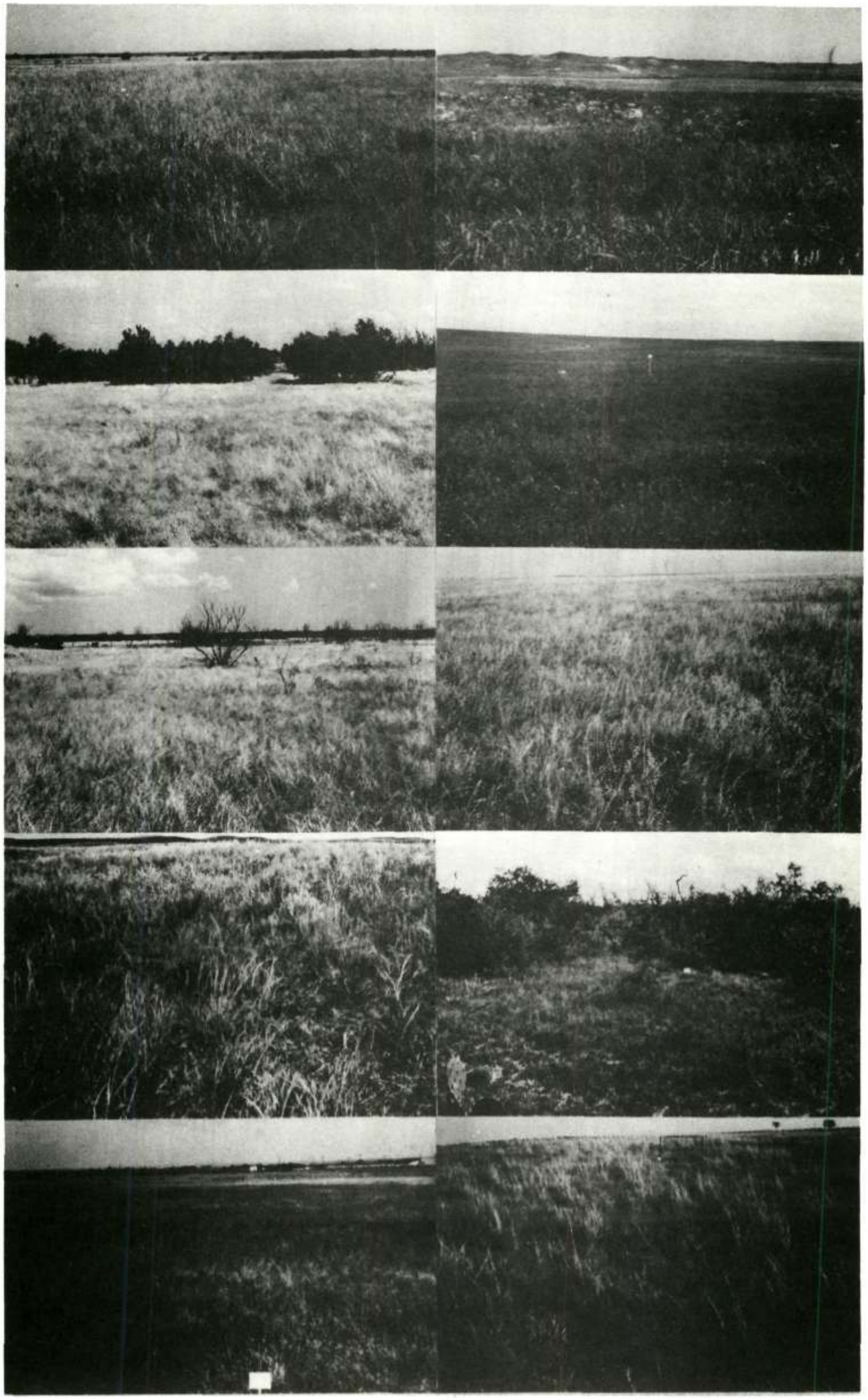


Figure 3-3. Great Plains Corridor test sites-1. College Station, Tex.; 2. Sonora, Tex.; 3. Throckmorton, Tec.; 4. Woodward, Okla.; 5. Hays, Kans.; 6. Sand Hills, Nebr.; 7. Cottonwood, S.D.; 8. Mandan, N.D.; 9. Weslaco, Tex.; Chickasha, Okla.

their individual study sites. Beginning with Cycle No. 1 the cooperators were instructed to obtain specific ground data on the day of each satellite overpass ± 3 days. The ground data collection was not requested during the winter dormant season, which followed the first hard frosts. A pre-greenup sample has been requested for the first spring data.

The sampling procedure (APPENDIX A) involves taking four photographs, clipping the vegetation from a square meter plot, and recording other vegetational and climatic conditions on each of at least five separate sampling sites at each of the ten study sites.

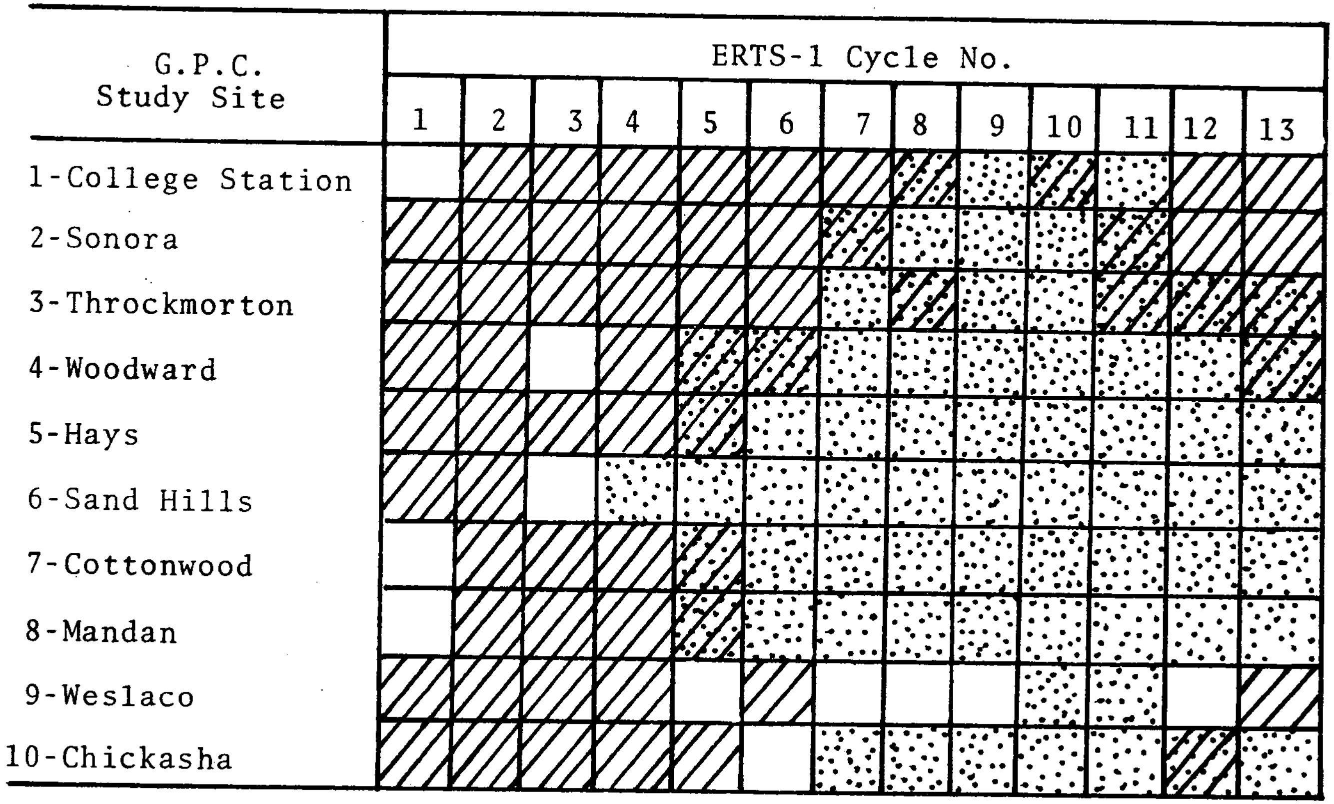
Ground truth data acquired from each of the test site cooperators during the period covered by this report is revealed in Figure 3-4.

3.2 Remote Sensing Data

3.2.1 Data Handling Procedures

Remote sensing data for the ERTS-1 Great Plains Corridor project includes aerial photography and ERTS-1 imagery (black and white and color) and magnetic digital computer tapes. Terrestrial photographic remote sensing data was discussed in section 3.1.2.

Figure 3-4. Ground Truth Data Received From Test Sites*



* Hatched blocks indicate ground data collected;

Stippled blocks indicate dates bounded by first killing frost in the fall and last killing frost in the spring.

Following receipt of the first few sets of ERTS-1 data products, routine procedures were developed for in-house handling of these products. These routine activities are outlined as follows:

1) All remote sensing data products are logged in when received
2) Black-and-white standing order images are evaluated for cloud cover and apparent test site data quality
3) The images are trimmed and placed in see-through protective folders and filed in the Remote Sensing Center film library
4) Weekly in-house imagery evaluation reports are prepared
5) Using the evaluation information retrospective product orders are placed
6) Weekly in-house product receipt reports are prepared, which list all ERTS-1 data products received during that week
7) Color composite images are cataloged and filed for subsequent evaluation and interpretation
8) Magnetic digital computer tapes are labeled and transfered to the Data Analysis Lab for processing, after they have been logged in

9) Once a month a computer generated product receipt and evaluation index is produced which lists all ERTS-1 data products received and gives the determined quality evaluations for each image

10) Aerial photographic products are labeled according to test site(s), evaluated for test site data quality, and filed in the Remote Sensing Center film library for subsequent analysis.

The receipt, utilization, and products of the various remote sensing and other data and data product components for the ERTS-1 Great Plains Corridor Project are described in an operational flow chart (Fig. 3-5).

3.2.2 Data Received

The ERTS-1 imagery and tape receipts and orders "quick-look" chart (Fig. 3-6) presents the status of the ERTS data inventory and data requests at the end of this reporting period. By March 27, 1973 the following ERTS-1 data products that contained the Great Plains Corridor test sites had been received from NASA/GSFC: 107 sets of four black-and-white standing order images, 28 color composite prints, three color composite transparencies, and 26 sets of

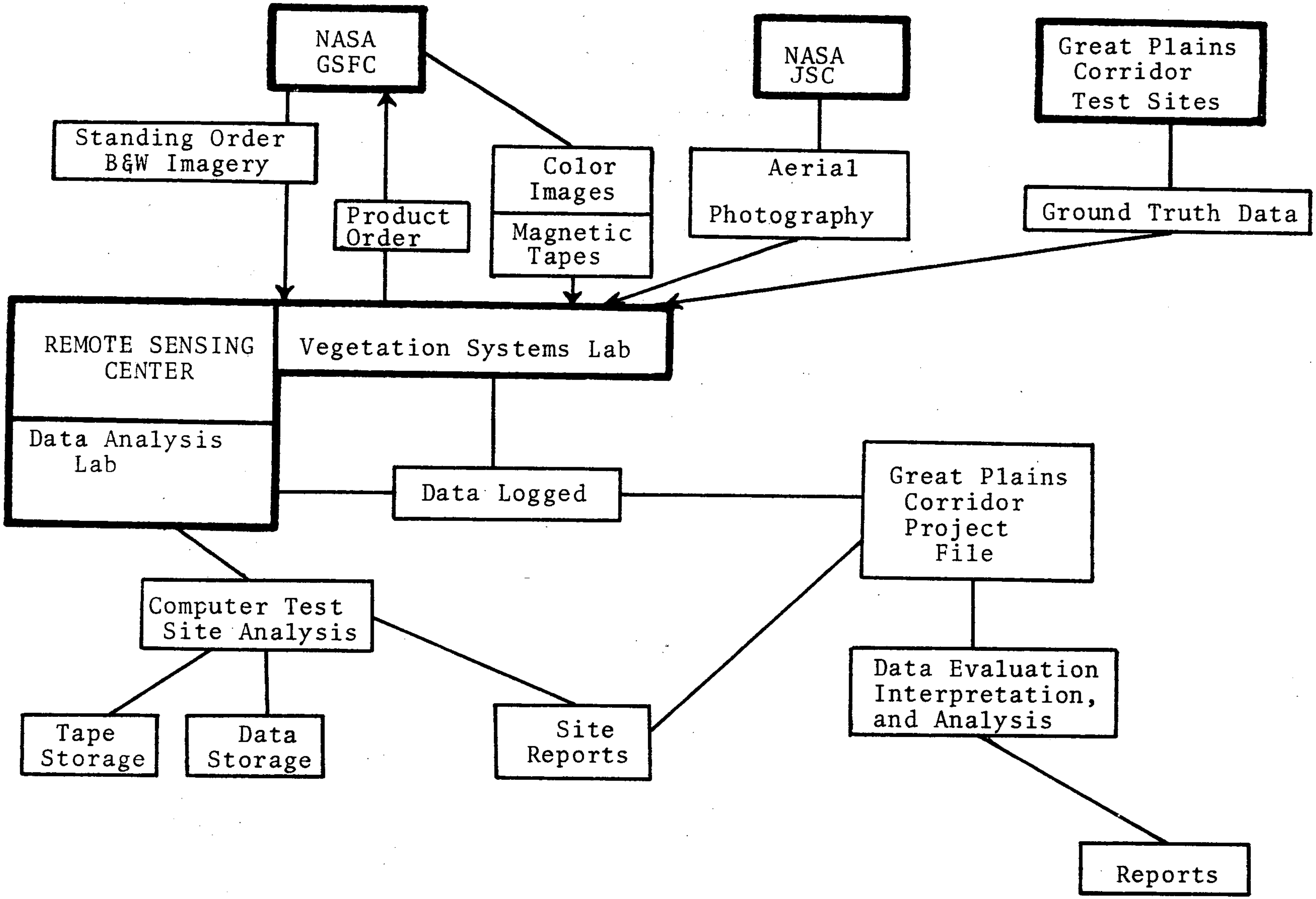
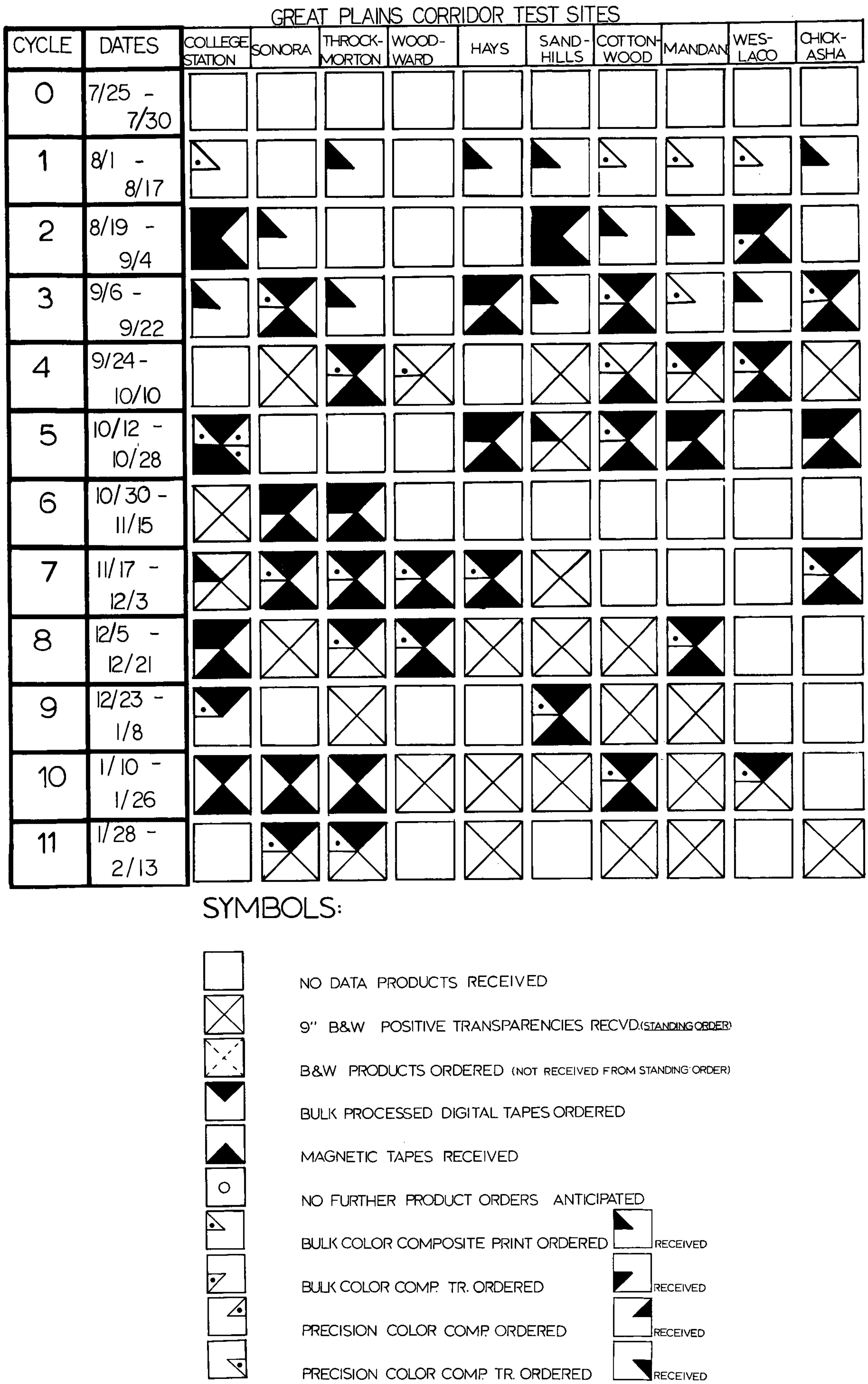


Figure 3-5. Operational flow chart for the ERTS-1 Great Plains Corridor Project.

Figure 3-6. ERTS-1 IMAGERY AND TAPE

RECEIPTS AND ORDERS



four magnetic computer tapes.

Five retrospective data requests have been placed since the last reporting period. These were sent on January 26, March 2, March 9, March 21, and March 26, 1973.

These bring the total of the retrospective data requests to nine by the end of this reporting period.

Aerial photographs of the ERTS-1 Great Plains Corridor test sites obtained by NASA/JSC that have been received by the end of this reporting period are presented in Tables 3-1 and 3-2. Preliminary evaluations of the relative quality of the aerial photographs for test site characterization and condition monitoring are also given in these two tables. Some type of aerial photography has been received for all of the Great Plains Corridor test sites.

Table 3-1. Coverage Dates[1] and Relative Quality[2] of NASA 9 1/2" Aerial Photography Received

Great Plains Corridor Test Site	Color IR Positive Transparencies				Color Positive Transparencies	
	1:120,000 scale		1:60,000 scale		1:120,000 scale	
	Date	Quality	Date	Quality	Date	Quality
1. College Station	10-2-72	G	10-2-72	G	10-2-72	G
2. Sonora	5-31-72 8-21-72 9-11-72	P G P	5-31-72 9-11-72	P	5-31-72 8-21-72 9-11-72	P G P
3. Throckmorton	5-31-72 9-11-72	P F	5-31-72 9-11-72	P F	5-31-72 9-11-72	P F
4. Woodward	5-31-72 8-31-72 9-11-72	G P P	5-31-72 8-31-72 9-11-72	F P P	5-31-72 9-11-72	F P
5. Hays	5-31-72 8-18-72 9-19-72	G G F	5-31-72 8-18-72 9-19-72	G G G	5-31-72 8-18-72 9-19-72	F G F
6. Sandhills	5-31-72 9-19-72	F F	5-31-72	F	5-31-72 9-19-72	F F
7. Cottonwood	5-31-72 9-14-72	G G	5-31-72 9-14-72	G G	5-31-72 9-14-72	G G
8. Mandan	5-31-72 9-14-72	G G	5-31-72 9-14-72	P G	5-31-72 9-14-72	P G
9. Weslaco	8-31-72	G	8-31-72	P	8-31-72	G
10. Chickasha	5-31-72 8-18-72	G F	5-31-72 8-18-72 9-12-72	G F G	5-31-72 8-18-72 9-12-72	G F G

[1] Dates are those shown on the duplicate photography.

[2] See "Key" on page following Table 3-2.

Table 3-2. Coverage Dates[1] and Relative Quality[2] of NASA 70mm Aerial Photography Received

Great Plains Corridor Test Sites	Color Positive Transparencies								B & W Positive Transparencies							
	Type 1[2]		Type 2[2]		Type 3[2]		Type 4[2]		Type 1[2]		Type 2[2]		Type 3[2]		Type 4[2]	
	Date	Q[3]	Date	Q[3]	Date	Q[3]	Date	Q[3]	Date	Q[3]	Date	Q[3]	Date	Q[3]	Date	Q[3]
1. College Station			10-5-72	G									10-2-72	G		
2. Sonora	6-1-72	P	8-21-72 9-11-72	F P	6-7-72	P	9-11-72	P	6-1-72 6-7-72	P P	7-23-72 8-21-72 9-11-72	G G P	8-21-72	G	8-21-72	G
3. Throckmorton			5-31-72 9-11-72	G P	5-31-72	G	9-11-72	P			5-31-72 9-11-72	G P	5-31-72	G	5-31-72	G
4. Woodward			5-31-72 9-11-72	G P	5-31-72	G	9-11-72	P			5-31-72 9-11-72	G P	5-31-72	G	5-31-72	G
5. Hays			5-31-72	G	5-31-72	G	9-19-72	F			5-31-72 8-18-72 9-19-72	G F F	5-31-72 8-18-72 9-19-72	G G F	5-31-72 8-18-72 9-19-72	G G F
6. Sand Hills			5-31-72	G	5-31-72	G	9-19-72	G			5-31-72 9-19-72	G F	5-31-72 9-19-72	G F	5-31-72 9-19-72	G F
7. Cottonwood			5-31-72	G	5-31-72	G	9-14-72	G			5-31-72 9-14-72	G G	5-31-72 9-14-72	G G	5-31-72 9-14-72	G G
8. Mandan			5-31-72	G	5-31-72	G	9-14-72	G			5-31-72 9-14-72	G G	5-31-72 9-14-72	G G	5-31-72	G
9. Weslaco			8-31-72	G							8-31-72	G	8-31-72	G	8-31-72	F
10. Chickasha			5-31-72 9-12-72	G G	5-31-72	G	9-12-72	G			5-31-72 9-12-72	G G	5-31-72 9-12-72	G G	5-31-72 9-12-72	G P

[1]Dates are those shown on the duplicate photography.
[2]See "Key" on following page.
[3]"Quality"

SYMBOLS USED FOR TABLES 3-1 AND 3-2

AERIAL PHOTOGRAPHIC PRODUCTS

Relative quality determinations include these three categories:

G - good, the image includes the test site and is of high quality with little or no cloud cover

F - fair, the image includes the study site but the photography is of low quality or contains excessive cloud cover

P - poor, the image is of little or not use due to "missing" the study site partially or completely, or is poor quality photography, or contains excessive cloud cover

70mm aerial photographic products

Color Positive Transparencies

Type 1 - 2443 with no filter

Type 2 - 2443 with filter(s)

Type 3 - SO-356 with no filter

Type 4 - SO-356 with filter(s)

B & W Positive Transparencies

Type 1 - 2402 with no filter

Type 2 - 2402 with filter 25A

Type 3 - 2402 with filter 57

Type 4 - 2424 with filter 89B

3.3 Data Flow

Processing of ERTS-1 MSS data is accomplished primarily by digital computer analyses. Distinct stages of these analyses are being performed upon receipt of digital ERTS MSS data, at periodic intervals, and as a continuing process to enhance the knowledge derived from the satellite data. Additional manual interpretation of imagery is performed to provide a quick evaluation of data quality and site location, as well as for obtaining a qualitative characterization of the phenology and site parameters with respect to surrounding indicators.

In this ERTS-1 study concurrent ground measurements are available and the data from network sites is processed in terms of their composite subsites. Specific digital computer analyses include statistical estimation of spectral signature means and covariances and computation of phenological indicator parameters. For the network sites where ground measurements are available, statistical analysis of variance, regression, and correlation analyses will be conducted to determine the degree of relationship between the phenological indicator parameters and the vegetation measurements. Computer generated summary reports are prepared as a result of these analyses.

The Texas A&M University Data Processing Center is utilized for the greater part of the data analyses. The Data Processing Center supports a "third generation" IBM 360/65 computer with 2.5 Megabytes of storage, 24 high speed disc drives, 6 magnetic tape drives, 4 high speed printers and 3 card readers. The system operates in an OS/MVT multiprogram environment in which 7 batch jobs may be processed concurrently, and it also has a remote job entry (RJE) capability.

The receipt utilization, and products of various data and data product components are described in an operational flow chart (Fig. 3-5). A detailed data handling plan has been formulated for the routine routing of data received from the NASA Data Processing Facility. The plan is operational for ERTS-1 data handling and is graphically presented in Fig. 3-7. Standing product orders are included for image products of the principal test sites. Upon receipt of imagery at the Remote Sensing Center Vegetation Systems Lab (VSL), the data is logged and a file is prepared for the data. Evaluation of the image quality with respect to the test site in terms of cloud cover, image noise, and site locatability is also performed. For those satellite passes where evaluation of the imagery is favorable, digital image products will be ordered.

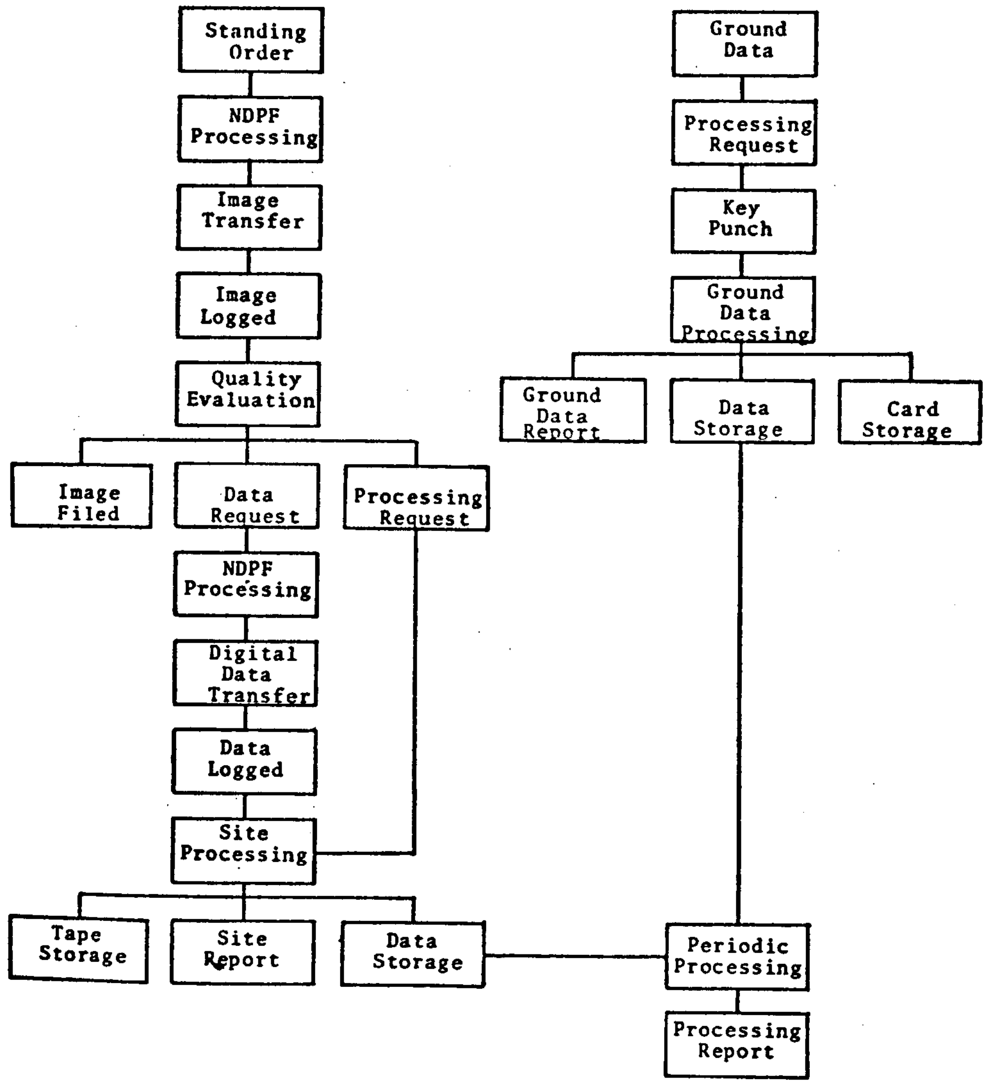


Figure 3-7. ERTS Data Handling Plan

Digital data tapes are logged into the data file upon receipt and an internal investigator data processing request is generated by the VSL. The data tapes accompany the processing request to the Data Analysis Laboratory (DAL) where site processing, in accordance with the request, are performed. This is a two step process. First the data from an 32.2 km square are extracted from the digital tapes and are stored on high speed discs storage. Also in this step band intensities are related to letters with varying ink densities and a computer generated grey-scale map (Fig. 3-8) is generated. Site coordinates are noted from the grey-scale printout and the second step of site processing which computes site radiance means and covariances is performed. In this step, a site processing report (Fig. 3-9) is generated and the computer data catalog is updated. Digital data tapes are filed at the (DAL) and the site processing report, together with the data processing request, are returned to the VSL cooperating investigator. A copy of the site report is maintained on file.

Ground data is received periodically from network site cooperators. This data is cataloged and a computer processing form prepared. From this processing form, the

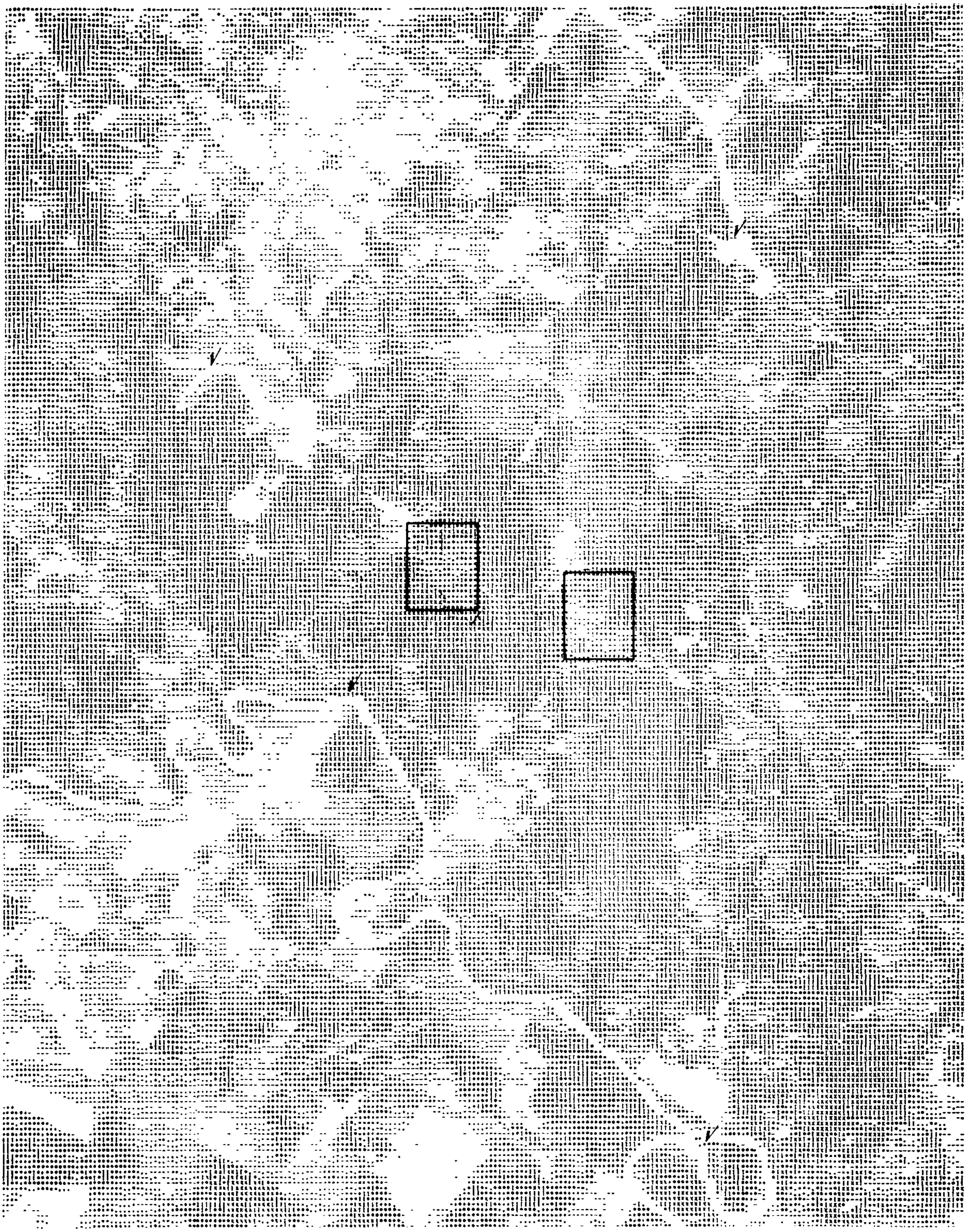


Figure 3-8. A portion of a 20 mi. X 20 mi. computer processed grey-scale map for landmark and test site location (1092-16305, MSS-5)

```
GREAT PLAINS CORRIDOR

   SITE   GP 1        0.6 BY  0.8 MILES

CENTER AT  30 DEGREES  39 MINUTES NORTH LATITUDE
           96 DEGREES  23 MINUTES WEST LONGITUDE
IMAGE NUMBER 1092-16305
ERTS-1, 092 DAYS SINCE LAUNCH
TIME(GMT) 16 HOURS 30 MINUTES 50 SECONDS
TAPE 3 OF  4 TAPES
DATA RECORD LENGTH  3296
ANNOTATION TAPE NUMBER SI113709
NCPF CODE 00100111
ADJUSTED SCAN LINE LENGTH 3240
THE HEADING OF THE SATELLITE (INCLUDING YAW) IS 189 DEGREES.

FRAME CENTER 30 DEGREES 13 MINUTES N LATITUDE
             96 DEGREES 45 MINUTES W LONGITUDE
LINE  525 IS THE FIRST LINE CONTAINING DATA FROM THE SITE.
CELL  519 OF TAPE 3 IS ON THE WEST EDGE OF THE SITE.
THE WIDTH OF THE SITE IS   16 CELLS.
THE SITE EXTENDS FOR   16 SCAN LINES.

THE SITE CONTAINS    256 CELLS.
```

RADIANCE(MWATTS/SQCM-STR-MICROMETER)

	MEAN	STANDARD DEVIATION	WAVELENGTH (MICROMETERS)
BAND 1	4.76	0.36	.5 - .6
BAND 2	3.06	0.47	.6 - .7
BAND 3	4.07	0.29	.7 - .8
BAND 4	4.00	0.26	.8 -1.1

NORMALIZED COVARIANCES

	BAND 1	BAND 2	BAND 3	BAND 4
BAND 1	1.000	0.773	0.594	0.518
BAND 2	0.773	1.000	0.683	0.531
BAND 3	0.594	0.683	1.000	0.657
BAND 4	0.518	0.531	0.657	1.000

Figure 3-9. Site Processing Summary Report

data is punched onto data cards which are used for the ground data processing. Upon completion of the processing program, a report is generated (Fig. 3-10), the computer data catalog updated, and the data cards filed. The report is returned to the VSL cooperating investigator.

On some periodic basis (e.g. seasonally), the image and digital tape logs are computer filed and a cross referenced catalog generated. Also on a periodic basis a summary data analysis report is generated, summarizing the time history of the computed parameters for the data sites. This report is distributed to the principal and co-investigators and the individual site cooperators.

Continuing data analyses will be provided for statistical correlation and regression analysis of data; statistical significance testing will be performed, as well as other analyses relating to information content.

TEST SITE 4 SAND HILLS, NEBRASKA MOISTURE TABULATION

DATE 8/25/77 238

SUB-SITE	FRESH WT (GR)	DRY WT (GR)	MOIST. (GR)	MOIST. (O/O)	O/O GREEN EST.	GREEN BIOMASS
1	164.5	74.2	90.3	54.9	65	48.2
2	220.9	115.7	105.2	47.0	75	86.8
3	231.2	118.2	113.0	48.9	60	70.9
4	499.4	252.5	246.9	49.9	65	164.1
5	338.6	168.4	170.2	50.0	75	126.3
TOTAL (GRAMS)	1454.6	729.0	725.6			496.3
MEAN	290.9	145.8	145.6	49.9	68.0	99.3
MEAN (KG/HECTARE)	2909.0	1458.0	496.2			993.0
MEAN (LB/ACRE)	2593.1	1299.7	442.1			885.2
STD. DEV.	132.8	68.4	64.5	2.7	6.7	46.1

DATE 9/07/77 251

SUB-SITE	FRESH WT (GR)	DRY WT (GR)	MOIST. (GR)	MOIST. (O/O)	O/O GREEN EST.	GREEN BIOMASS
1	178.0	84.0	94.0	52.9	50	42.0
2	168.0	82.0	86.0	51.0	65	53.3
3	356.0	182.0	174.0	48.9	60	109.2
4	393.0	202.0	191.0	48.6	70	141.4
5	298.0	162.0	136.0	45.0	60	97.2
TOTAL (GRAMS)	1393.0	712.0	681.0			443.1
MEAN	278.6	142.4	68.8	49.0	61.0	88.6
MEAN (KG/HECTARE)	2786.0	1424.0	488.0			886.0
MEAN (LB/ACRE)	2483.4	1269.4	435.0			789.8
STD. DEV.	102.2	55.0	46.7	2.8	7.6	40.9

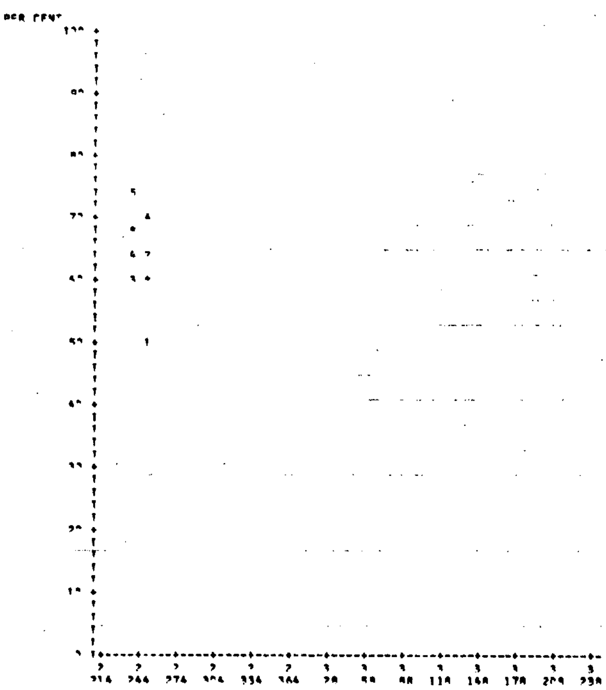


Figure 3-10. Ground Data Summary Report

4.0 ANALYSIS ACTIVITIES

4.1 Ground Observations During Autumnal Phase

An evaluation of the ground truth data obtained during the first autumnal phase of the ERTS-1 Great Plains Corridor project reveals that the sampling technique being used is capable of monitoring gross temporal vegetation changes at the test sites.

Autumnal phase vegetation measurements were obtained from all ten test sites in conjunction with ERTS-1 coverage. The tabulation below (Table 4-1) shows the range of dates for satellite coverage for all ten GPC test sites and corresponding cycle numbers.

Table 4-1. Range of dates for satellite coverage for the ten GPC test sites corresponding with cycle numbers 1-14.

Cycle No.	Dates	Cycle No.	Dates
1	Aug. 1-Aug. 17, 1972	8	Dec. 5-Dec. 21, 1972
2	Aug. 19-Sept. 4, 1972	9	Dec. 23-Jan. 8, 1973
3	Sept. 6-Sept. 22, 1972	10	Jan. 10-Jan. 26, 1973
4	Sept. 24-Oct. 10, 1972	11	Jan. 28-Feb. 13, 1973
5	Oct. 12-Oct. 28, 1972	12	Feb. 15-Mar. 21, 1973
6	Oct. 30-Nov. 15, 1972	13	Mar. 5-Mar. 21, 1973
7	Nov. 17-Dec. 3, 1972	14	Mar. 23-Apr. 8, 1973

Ground data analysis activities to date have been primarily limited to preparation of data summaries and graphs of specific data for all of the test sites.

4.1.1 Green Biomass

Of the parameters being measured to monitor vegetation condition, green biomass is probably the most sensitive for detecting significant changes. Green biomass, as used here, is the quantity of aboveground herbage (grasses and forbs) that is green and is expressed on a dry weight basis. In this investigation the green biomass values are derived by integrating two independently determined factors - dry biomass (total standing herbage) and percentage green estimates (see Appendix A).

Green biomass (Fig. 4-1) for the Texas test sites averaged about 1300 lb/acre in late summer, 850 lb/acre in mid-autumn, and 100 lb/acre in early winter. The Oklahoma and Kansas test site green biomass determinations averaged 1100 lb/acre in late summer, 450 lb/acre in mid-autumn, and by mid-December the vegetation was almost totally dormant, averaging only 50 lb/acre of green vegetation. The northern test sites produced an average green biomass of 800 lb/acre in mid-August and 100 lb/acre in October, just prior to the onset of winter

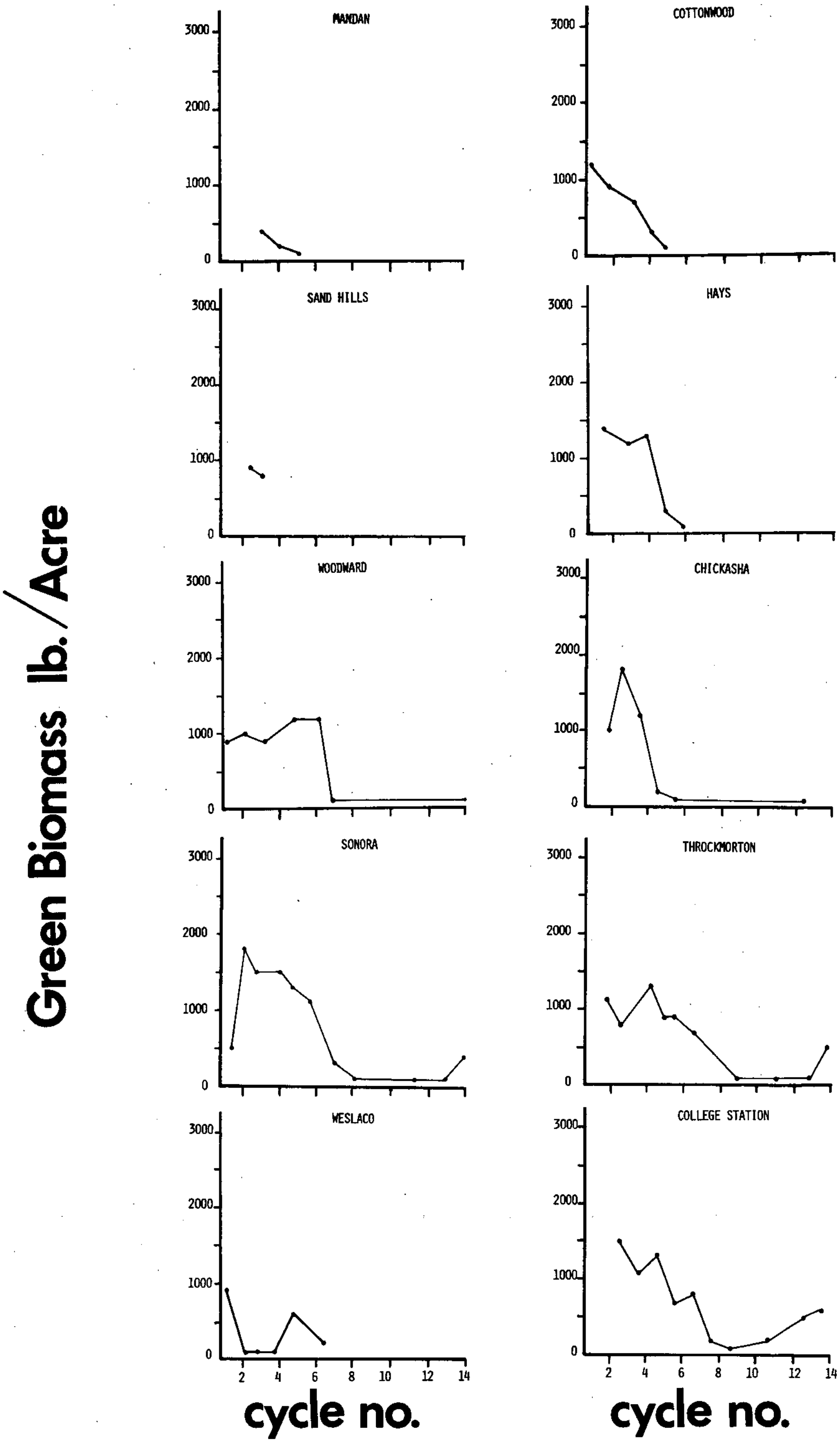


Figure 4-1. Green biomass at ten Great Plains Corridor test sites as measured for ERTS-1 overpass cycles 1-13.

dormancy. Late autumn green biomass at the mid and northern sites resulted primarily from the growth of cool season species. Sampling was generally not accomplished during the winter dormancy period.

4.1.2 Standing Dry Biomass

Although green biomass serves as an effective index for describing the amount of live plant material, it does not reveal the quantity of dry or total standing herbage. Total standing herbage, expressed on a dry weight basis, provides a measure of the amount of vegetation covering the ground surface and is called "dry biomass". With this information and a knowledge of the type and growth habits of the vegetation that exists on a site, inferences can be made concerning the amount of vegetative ground cover, as well as, height and density of the herbage.

Figure 4-2 shows the variations in dry biomass for the ten test sites that correspond with ERTS-1 overpass cycle numbers 1-13.

Dry biomass remained more stable from season to season throughout the Great Plains Corridor than green biomass. In general, the quantity of total standing herbage gradually declined as the autumnal phase progressed.

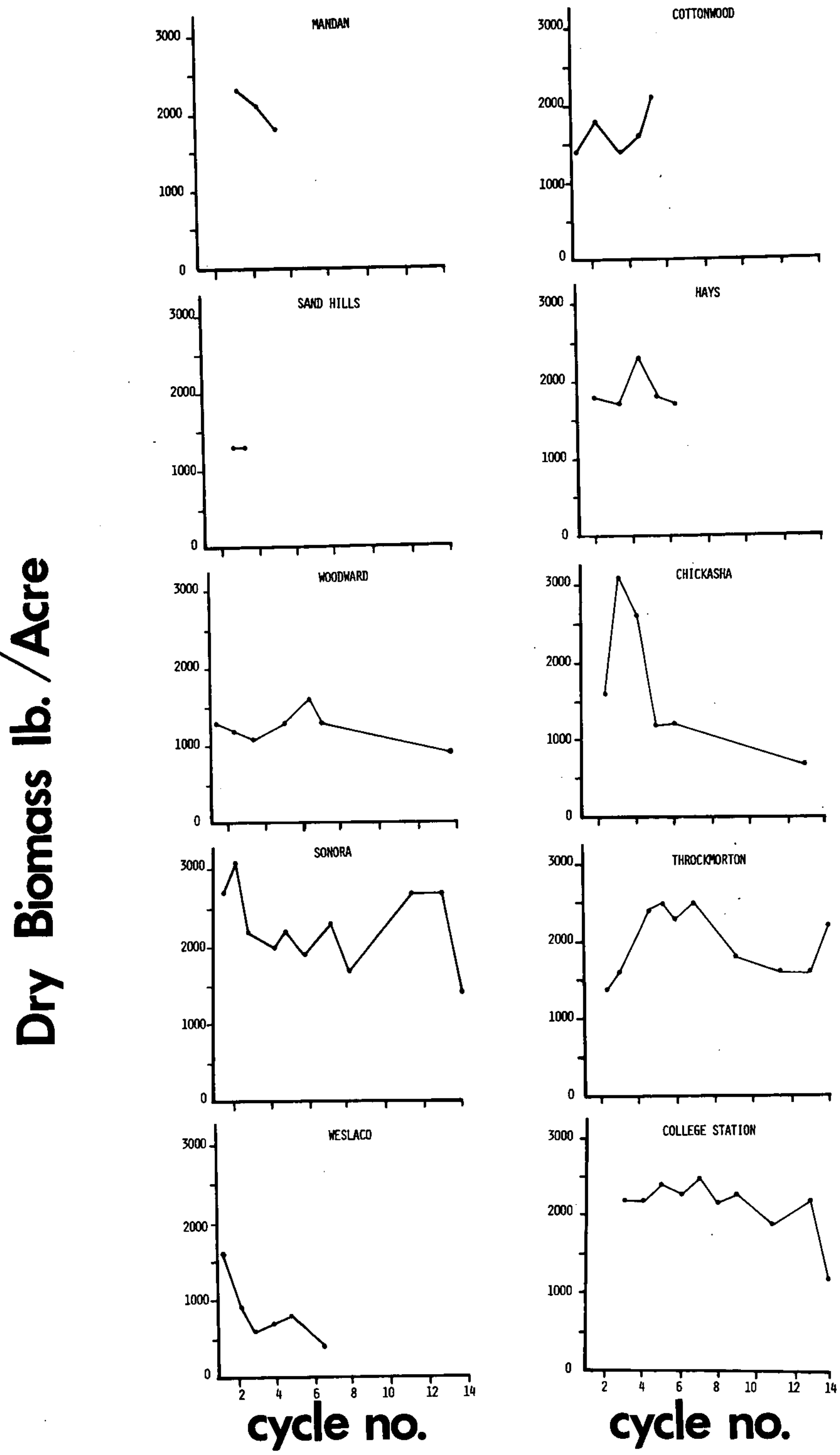


Figure 4-2. Dry biomass (total standing herbage expressed on a dry weight basis) at ten Great Plains Corridor test sites for ERTS-1 overpass cycles 1-13.

However, some test sites, such as Throckmorton and Hays, experienced an increased production of herbage in mid-autumn with a subsequent relatively rapid decline.

Dry biomass for the Texas sites averaged about 2100 lb/acre in late summer, 1700 lb/acre in mid-autumn, and 1500 lb/acre in early winter. The test sites in Oklahoma and Kansas averaged 1600 lb/acre in late summer, 1500 lb/acre in mid-autumn, and about 1000 lb/acre by December. The three northernmost test sites averaged 1700 lb/acre dry biomass in mid-August and experienced a general decline before becoming winter dormant.

4.1.3 Other Vegetation Parameters

Moisture content of the vegetation is being monitored at all ten test sites at the time of each satellite overpass during the growing seasons, since it is known that moisture stress directly influences spectral reflectance properties of plants. Figures 4-3 and 4-4 show plant moisture content measurements obtained during the autumnal phase at the College Station and Throckmorton test sites, respectively. These sites are examples of the kind of information available from all test sites.

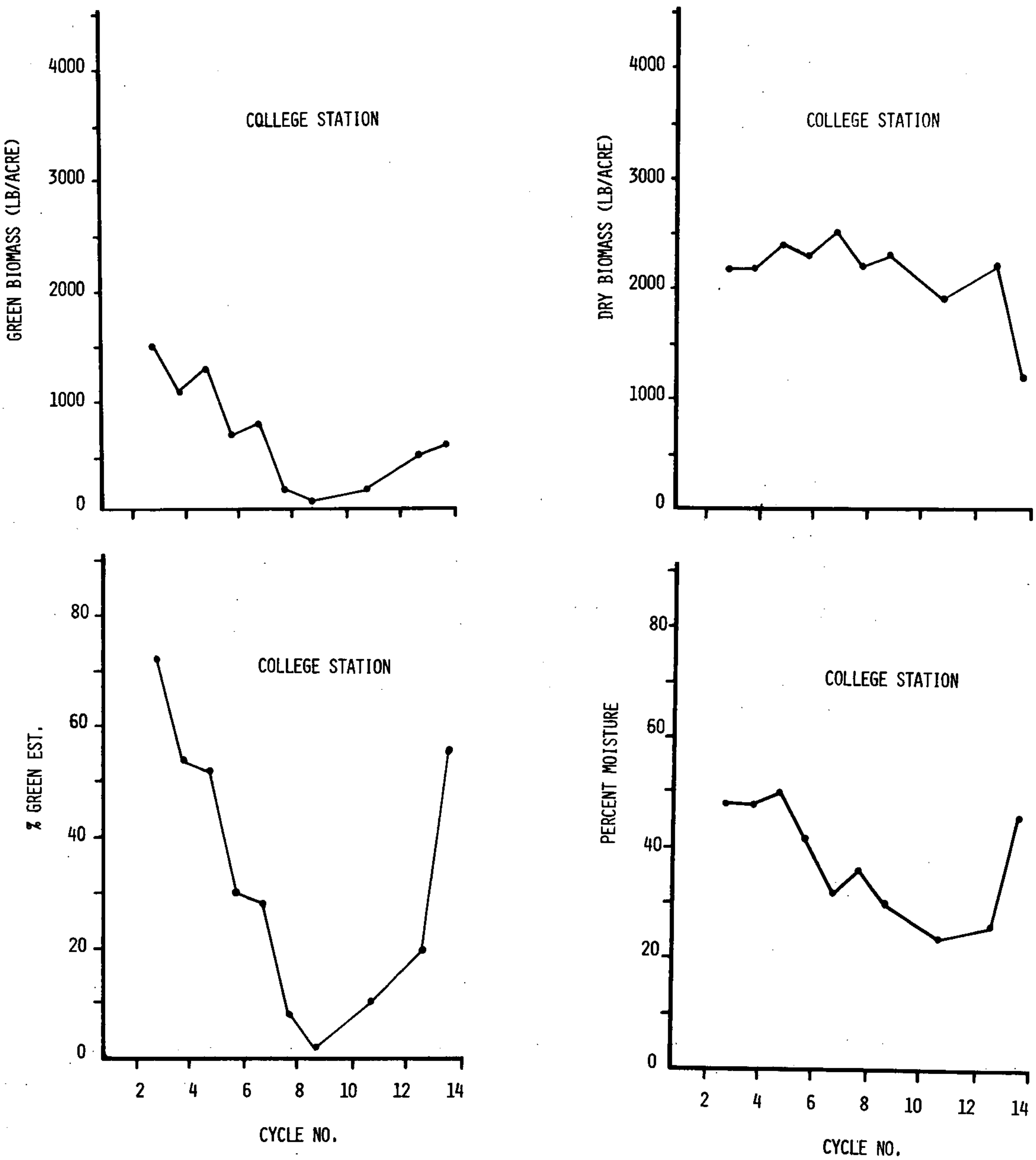


Figure 4-3. Temporal measurements of green biomass, dry biomass, percent green estimates, and percent moisture at the College Station test site.

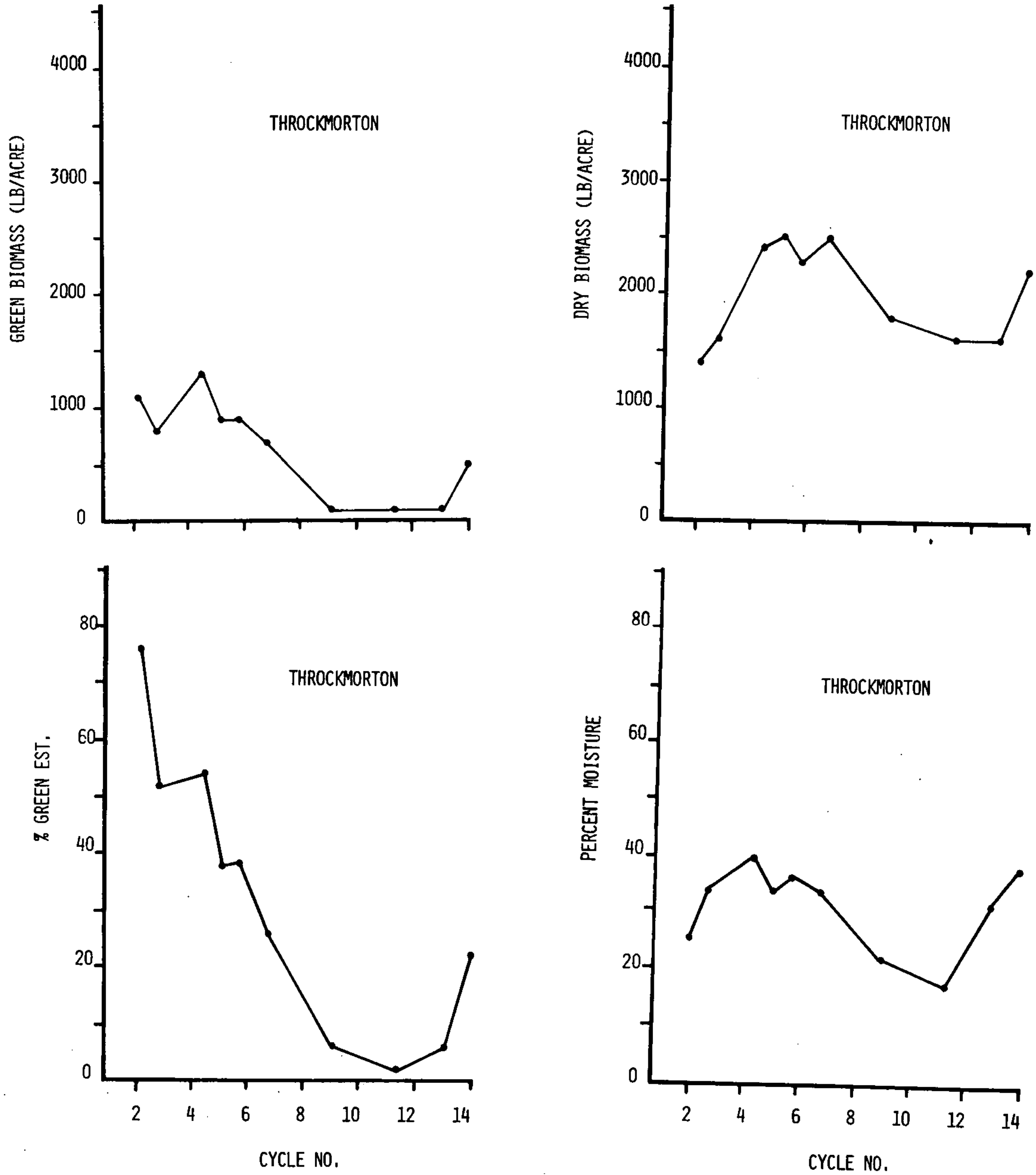


Figure 4-4. Temporal measurements of green biomass, dry biomass, percent green estimates, and percent moisture at the Throckmorton test site.

Moisture content of the herbage at the College Station test site varied from about 50% in late summer to 35% in mid-autumn to less than 30% by the end of autumn, and at the Throckmorton test site it changed from 25% to 35% to 20%, respectively. Since the amount of moisture in the vegetation is greatly influenced by the quantity of green plant material, the graphs of these two vegetation condition indices are similar. Because these two parameters were determined independently and as the graphs reveal similar trends in vegetation condition, the contention that the percentage green estimate sampling technique used is capable of monitoring real change is supported.

Other ground observations being recorded to aid in interpreting satellite data and in understanding vegetation changes reveal the phenology of the dominant species, changes in apparent species dominance, and visual determinations of overall vegetation condition. These data and ground photographs, which document these conditions for future reference, will be utilized in intensive individual test site analyses in a later phase of the project.

4.1.4 Environmental Conditions

Weather parameters being monitored and recorded at the test sites include temperature and precipitation. Vegetation changes occurring at the test sites are reflected in the weather data that has been collected, particularly precipitation data.

4.1.5 Summary of Ground Observations

Green biomass, dry biomass, and percentage moisture content of the vegetation were shown to have decreased from late summer to winter dormancy. The magnitude and rapidity of decline varied at each test site but regional differences were also observed.

Data for the northern test sites are not as complete as that for the central and southern test sites due to the earlier onset of dormancy. However, the Great Plains Corridor test site data presented reveal that vegetation conditions and temporal changes in vegetation condition have been measured and monitored during the autumnal phase of this investigation.

Data collected at three of the southern test sites, College Station, Sonora, and Throckmorton, (Figs. 4-1 and 4-2) toward the end of this reporting period provide good evidence that the initial stages of the vernal phase (vernal advancement) are being documented.

4.2 Imagery

As outlined in the Data Handling Plan, ERTS-1 standing order product data are received by the Vegetation Systems Laboratory and logged and filed by appropriate test site. MSS bands 4,5,6, and 7 are received as standing order products. Evaluation of the image quality with respect to the test site, in terms of cloud cover, image noise and site location, are performed on a routine basis for all products received. For those satellite passes having a favorable evaluation and for which digital products are ordered, an order is also placed for the color composite print.

4.2.1 Single Band Black & White Positive Transparencies

During the early phases of the investigation an evaluation was made of the information content of the single band imagery for manual interpretation. Although Band 4 generally shows a weak contrast it has good utility for locating cities, highways, airfields, etc. and is useful in this respect for locating test sites with respect to these features.

Band 5 appears to contain the greatest information for a single band. Woodland, grassland and cropland types are often distinguished on the Band 5 imagery. Since most landscapes within the Great Plains Corridor are covered to some extent with vegetation, lakes and small water areas are discernable as a tonal contrast on Band 5. Band 5 appears to be the most useful for discerning vegetation types and the exact location of test sites.

Bands 6 and 7 show weak contrast for vegetated areas but are useful for locating test sites because rivers and small lakes are well contrasted on these bands. In general the contrast in information apparent on the four MSS test bands is sufficiently great to warrant continued receipt of all bands for the purposes of this project.

A limited attempt has been made to use the black and white positive transparency for making diazachrome prints from the four MSS bands. When overlayed and properly registered the color enhanced product of this technique can be used to demonstrate a facsimile of the color composite imagery. It is also possible to use this process in developing a change detection procedure. Further development of these techniques may be used to illustrate temporal vegetation changes of gross magnitude.

4.2.2 Color Composites

Prior to the receipt of the first color composite imagery from NASA/Goddard, the Western Aerial Photography Laboratory, ASCS-USDA, was contracted to produce color composites from ERTS-1 imagery for three dates at the College Station test site. The purpose for this evaluation was to compare the information contents of color composites made from MSS Bands 4,5,6, and Bands 4,5,7. Positive transparencies (9" X 9") and positive prints (24" X 24") were produced of each of the two band combinations for ERTS-1 overpasses on August 30, Oct. 23, and Dec. 16, 1972 (Obs. I.D. nos. 1038-16303, 1092-16305, and 1146-16311, respectively). The quality of the color composite reproduction was excellent and provided a valuable imagery series for determining manual interpretation capabilities in regard to changes that can be detected in the autumnal phase.

Late in the reporting period the project began receiving color composites from NASA/Goddard. Although the color balance and exposure control of these imagery do not compare with those produced by the Western Aerial Photography Laboratory, ASCS-USDA, they have proven to be a valuable data set for observing and demonstrating the seasonal vegetation changes that are apparent in the Great Plains Corridor through the autumnal phase.

4.2.3 Manual Interpretation Capabilities

A first look evaluation of the single band black & white transparencies for MSS Bands 4,5,6 and 7 revealed an outstanding difference in information content in the separate bands. As expected high reflecting solid surface scenes such as highways, urban areas, etc. are well contrasted in Band 4. Changes in vegetation and vegetation differences are best contrasted in Band 5. As indicated above, this band is the most useful single band for locating test sites and making general observations about data quality. Bands 6 and 7 contrast water bodies and should be very useful in the detection and monitoring of these scenes.

The multiband color composite imagery provide an invaluable kind of data for manual interpretation. A systematic approach was taken to assess manual interpretation capabilities from the three dates of imagery that contain the College Station test site. Figure 4-5 is a black and white reproduction from a color composite paper print showing the approximate geographical

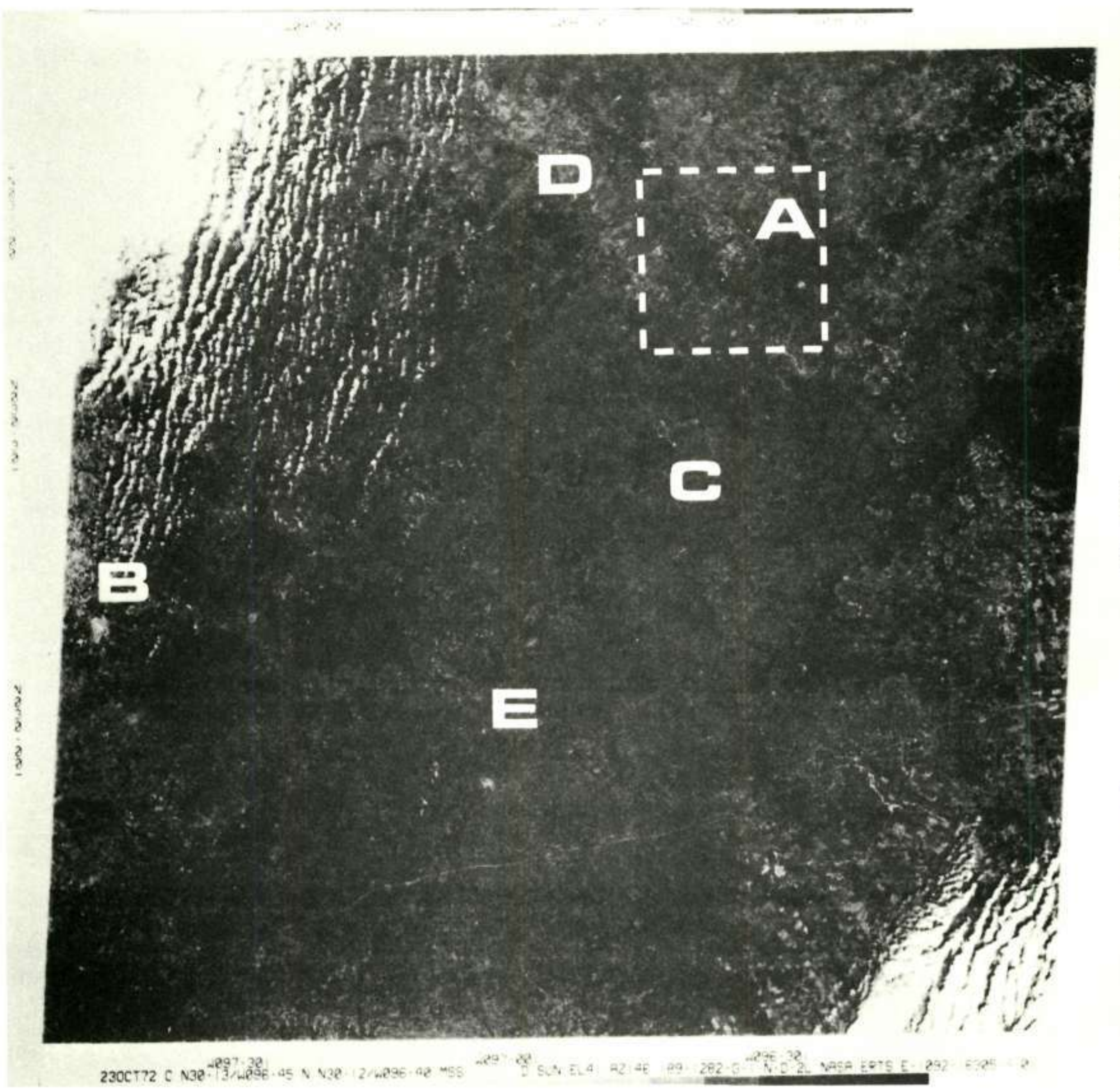


Figure 4-5. Prominent landmarks observable on ERTS-1 image 1092-16305, as reproduced from a color composite print, include: A) College Station, Texas (GPC test site No. 1), B) Austin, Texas, C) Sommerville Lake, D) Brazos River, and E) Colorado River and associated bottomlands.

location covered by these imagery. The following landmarks are readily apparent on the color composite series: College Station and the Great Plains Corridor test sites for this location (A) are located within the northeast quarter of this image. Interstate 45 between Madisonville and Huntsville Texas appears in the extreme Northeast corner. Interstate 10, between Houston and San Antonio, Texas, occurs across the bottom of the scene. Bergstrom Air Force Base and the eastern part of Austin, Texas (B) are apparent at the western edge of the image. Sommerville Lake (C) occurs in the center of the image. Agriculturally rich bottomlands of the Brazos (D) and Colorado (E) Rivers transect the image from northwest to southeast.

Point information, such as Bergstrom Air Force Base, the "Old Bryan Air Force Base", the Texas International Speedway (located between College Station and Navasota, Texas) and numerous small communities encompassed by this scene, are readily observable on all dates of imagery. The water course of the Brazos and Colorado Rivers are well defined and prominent sand bars at the bends of the rivers are easily detected. Interstate highways, and multi-lane roads are very obvious. However, farm-to-market roads and some two-lane state highways are only apparent in areas with a high vegetation contrast.

Vegetation systems are readily apparent on both of the three-band, color-composite images produced for each date. Although there are readily apparent differences in tonal values for different vegetation types between Bands 4,5,6 and Bands 4,5,7, manual interpretation capabilities are about equal for the two types of color-composites. Woodlands, grasslands, and croplands are readily contrasted on the August 30, 1972 color composite for scenes including College Station, Texas. Geological formations are outlined by the natural vegetation. For example, Coastal Bend formations are very evident across the scene from southwest to north-east. In the northwest corner of the scene the highly developed agricultural areas of the Black Land Prairie soils are observed. To the southeast of this area are woodlands much of which have undergone land use conversion and are in dryland crops or tame pastures. Further to the south and east a zone of prairie soils is relatively free of woodland types. The southeast corner of the scene is dominated by highly developed cultivated agriculture of the Gulf Coast Prairie.

Water bodies as well as clouds and cloud shadows are apparent on the color composites. On partly cloudy days care must be taken to distinguish small cloud shadows from water bodies. Water bodies of two to three acres are readily distinguishable on the color composite imagery.

4.2.4 Time Dependent Parameters Observed

ERTS-1 MSS imagery (color composite) obtained from the Western Aerial Photography Laboratory, ASCS-USDA for August, October, and December, 1972 were used to evaluate manual interpretation of time dependent parameters. Color balance for the three dates of imagery are very good, a factor which is probably essential for proper interpretation of time dependent parameter changes such as changes in the vegetative scene.

At the time of the August 30, 1972 overflight (Obs. I.D. no. 1038-16303), natural vegetation (i.e. woodlands and grasslands) and cropland areas show a high degree of plant vigor, probably due to the very desirable summer moisture in this area. During the early part of August, forest and woodlands appear as deep dark red areas, while grasslands range from brilliant red to various tones of gray with a very light red cast.

In the dryland farming areas approximately 75% of the crops have been harvested and the unplowed fields are highly reflective. In the irrigated agricultural areas, such as the Brazos River bottom, more than 90% of the landscape is occupied by the vigorously growing cultivated crops.

At the time of the October 23, 1972 overpass (Obs. I.D. no. 1092-16305), much of the rangeland had browned to the point that the woodland types are highly contrasted. Maximum differentiation is noted at this time among vegetation systems associated with geological formations and soil types. In dryland crop areas some winter crops, such as annual forages for livestock grazing, can be recognized. In the irrigated crop areas more than 75% of the fields are unplanted and very few of the fields appear to have been tilled following harvest. In areas where crops are readily apparent it is not possible to manually determine from the single date of imagery whether these croplands are occupied by unharvested crops or by newly planted winter crops.

Several hard freezes preceeded the December 16 overpass (Obs. I.D. no. 1146-16311), killing the tops of susceptable herbaceous vegetation and the foilage of deciduous trees in all except the Coastal Plains area, which is apparent in the southeast part of the scene. General rains had also preceeded this overpass providing a wet surface for all areas. Light colored sandy soil and darker fine textured soils contrast throughout the region and could be easily mapped. The reflectance difference between plowed and unplowed fields, attributed to the relatively smooth surface of unplowed soils, makes it possible to easily identify those fields which have been plowed prior to the December overpass. All winter crops (oats, spinach, ryegrass, etc.) are easily observed.

Of special interest are the pine dominated and deciduous woodlands that occur east of College Station and in an isolated area near Bastrop, Texas (Obs. I.D. no. 1146-16311). Due to the loss of foilage on the deciduous trees these areas are only subtly outlined and darker tones indicate generally high radiation absorption in all bands. However, on areas dominated by pine (or other evergreen species) the typical woodland red tones are apparent. Thus, it is apparent that the reflectance change in the red and IR bands were sufficiently changed by the killing frost to cause a striking differentiation among the deciduous and evergreen woodlands.

Because of heavy rains preceeding the December 16 overpass (Obs. I.D. no. 1146-16311), flooding was occuring on several of the small streams, such as the Navasota and San Jacinto Rivers. These flooded areas are readily discernible on the color composite imagery. This indicates that it would be very feasible to map the extent of flooding for large streams and rivers.

4.3 Digital Data Processing

Processing of ERTS-1 MSS data is accomplished primarily by digital computer analyses. Distinct stages of these analyses are being performed upon receipt of the digital ERTS MSS data, at periodic intervals, and as a continuing process to enhance the knowledge derived from the satellite data.

In this ERTS-1 study concurrent ground measurements are available and the data from network sites are processed in terms of their composite subsites. Specific digital computer analyses include statistical estimation of spectral signature means and covariances and computation of phenological indicator parameters. For the network sites various statistical analyses will be conducted to determine the relationship between phenological indications and satellite measurements. Computer generated summary reports are prepared as a result of these analyses.

Software packages are being developed to provide fundamental analysis capability in the areas of signature estimation, ground data analysis and statistical correlation. Additional software has been provided to perform data management functions and assist in the evaluation of the atmospheric and illumination problems.

4.3.1 Test Site Processing

The primary unit of satellite data analysis is embodied in site processing. Upon receipt of the digital CCT from GSFC the data sets are logged. Site processing is initiated when data from an approximate 20 mi. X 20 mi. square, centered on the test site coordinates, is extracted from the CCT and stored on high speed disc storage for future access.

Initially, it was planned that test site data would be accessed from the computer compatable magnetic tapes by extrapolation to tape coordinates from the center-of-cell geographic coordinates which are available from the tape header label. Computer software programs were written to perform this extrapolation and the procedure tested. Errors in site location were as large as ± 5 miles and too great for the types of analyses desired. Application of models for correcting errors in satellite data alignment due to earth rotation and satellite motion failed to reduce the site location error significantly. At this point procedures were adapted to accomodate the site location errors and to provide a precise location of satellite data.

The software developed for site location was modified to provide computer generated grey-scale image printouts of a 20 mi. X 20 mi. area around the calculated site center tape coordinates (Fig. 3-8). Computer generated grey-scale image printouts are produced by assignment of alphameric symbols of varying inking densities to each numerical data count. This assignment is made by examining count frequency distributions from the area to be displayed. Data are assigned to symbols with various densities so that approximately 12.5% of the data is assigned to each of eight grey scale levels. This assignment is optimum in terms of displaying information from a single ERTS-1 MSS band. It also provides the basis for major category classification of the scene. For example, in high contrasting scenes such as a woodland-grassland areas, the dominant deciduous woodlands are consistantly assigned a grey-scale value "X". These woodland areas could be readily mapped from the single band grey-scale printout with a high degree of accuracy. Grey-scale printouts (20 mi. X 20 mi.) have proven to be adequate for locating dominant terrain and cultural features and referencing site locations included previously in the enlarged areas. The actual test site tape coordinates are noted from the 20 mi. X 20 mi. grey-scaled areas and used for precise site location in second step site processing.

To complete site processing, the Vegetation Systems Laboratory personnel locate the test sites on grey-scale maps and furnish the Data Analysis Laboratory with the tape record coordinates for the site. These tape record coordinates are utilized to extract 4 mi. X 4 mi. areas from the data set in disc storage and means and covariances are calculated for four quadrants of the test area and for the total area (Fig. 4-6). Grey-scale computer images of the small site areas are also produced for each of the MSS bands.

Difficulty was originally encountered in interpreting the satellite calibrations and data reduction procedures. The following calibrations criteria have been determined from NASA/GFSC and NASA/JSC publications and are currently used for data calibration:

MSS Band	Range Acquisition Mode		Calibration Maximum (RMAX)	
	Compressed	Uncompressed	Gain #1	Gain #2
4	128	64	8.3	24.8
5	128	64	6.7	20.0
6	128	64	17.6	17.6
7	64	64	15.3	15.3

$$\text{Radiance} = \frac{\text{Count Value X RMAX}}{\text{Range}}$$

RESULTS BY QUADRANT

NORTHWEST QUADRANT

SITE DESIGNATOR:	GP 1-02	CELLS	1889 TO 2008
IMAGE IDENTIFIER:	1092-16305	LINES	532 TO 613
DATE ACQUIRED:	23OCT72	TOTAL POINTS	9840

CORRECTED FOR SUN ELEVATION 41 DEGREES

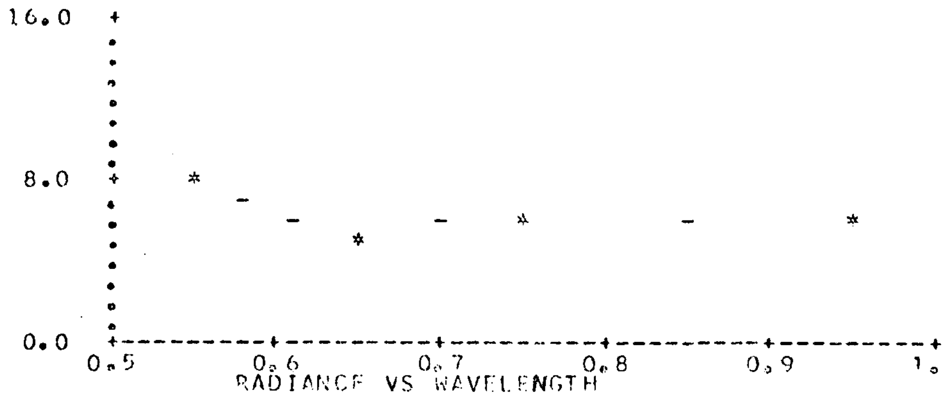
RADIANCE(MWATTS/SQCM-STR-MICROMETER)

	MEAN	STANDARD DEVIATION	WAVELENGTH (MICROMETERS)
BAND 4	7.73	0.60	.5 - .6
BAND 5	5.47	0.93	.6 - .7
BAND 6	6.29	1.10	.7 - .8
BAND 7	5.86	1.33	.8 -1.1

NORMALIZED COVARIANCES

	BAND 4	BAND 5	BAND 6	BAND 7
BAND 4	1.000	0.743	0.258	0.081
BAND 5	0.743	1.000	-0.126	-0.347
BAND 6	0.258	-0.126	1.000	0.915
BAND 7	0.081	-0.347	0.915	1.000

BAND RATIO PARAMETER 0.034
TRANSFORMED PARAMETER 0.731



PREPARED BY:TEXAS A&M UNIVERSITY, REMOTE SENSING CENTER
DATA ANALYSIS LABORATORY 19JUN73

Figure 4-6. Example of mean radiance and normalized covariance values for NW quadrant of a 4 mile X 4 mile sub-site at College Station, Texas.

In subsequent versions of the software package, irregular subdivision of the test sites (masking) will be used for calculating mean and coveriance by subsite areas. These values will be computer stored in high speed files for further processing with ground measurements in the statistical analysis phases. As a result of site processing an investigation summary report is prepared.

4.3.2 Atmospheric and Illumination Conditions

The problem of changing atmospheric and illumination conditions has been recognized since the beginning of the ERTS project. These changing conditions generally affect the absolute variations of the spectral signatures recorded from different times and locations, and will in general have some unspecified effect on the results derived from these signatures. Currently a data analysis project is underway to determine the amount of variation introduced as a result of these changes. This project is also investigating methods and models which will be useful in reducing these effects upon the results of the phenology study. The atmospheric/ illumination study is in the early stages of formulation and analysis but it is expected to develop initially along several directions.

Analyses are being conducted to gain experience with the satellite data to correlate with observed albedo changes in wavelength and strength. Initial studies were conducted by examination of between-band probability density functions of the sensor data values from multiple date and multiple site sources. A (20 mi. X 20 mi.) scene was selected for the College Station, Texas area for three satellite overpass dates (Aug., Oct., and Dec. Obs. I.D. nos. 1038-16303, 1092-16305, 1146-16311, respectively). Two dimensional frequency counts were made of two band data value pairs for each date. A frequency threshold was selected (700 points) and all data pairs having a higher rate than this threshold were plotted on a two-dimensional cluster plot (Fig. 4-7).

In examining the aggregate of superimposed clusters from multiple dates, two characteristics are noted. Changes in scene characteristic signatures apparent in the shapes of the clusters are noted especially between the October and the December data. Between the August and October data sets the relationship is relatively consistant at the level of significance of the display. However, the dominant trend apparent in

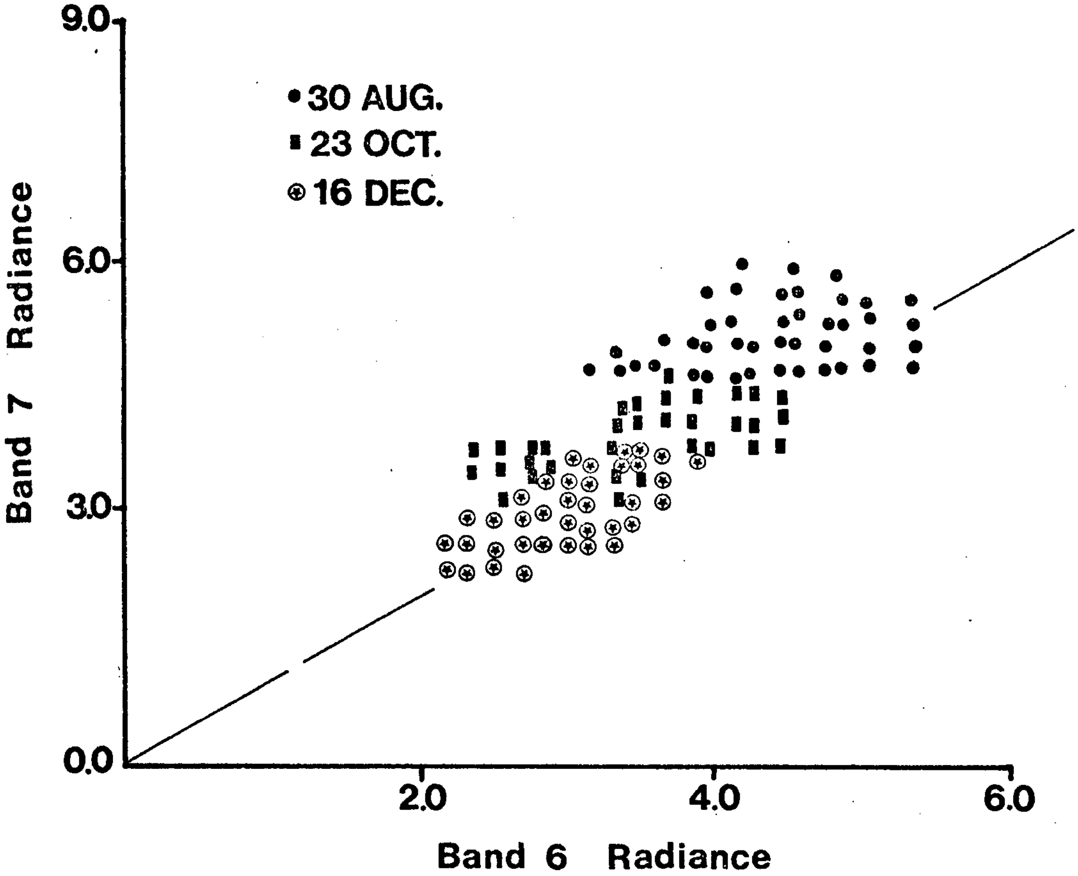


Figure 4-7. Two band distribution of multi-date MSS data from Test Site No. 1 at College Station, Texas.

the data is a general decrease in scene data values over time and the average variation lies along a line of slope β=1.0. This result immediately suggests scene illumination variations (as might be expected) and emphasizes the magnitude of their effect, which dominates the data relationships.

In Solar Radiation (N. Roberson, Ed. 1966) the mathematical relationship of the intensity of solar radiation falling upon a horizontal plane is presented as a function of the solar constant I_o, and the solar elevation γ. The relationship reflects atmospheric effects, and is developed solely from geometric considerations. This relationship,

$$I_H = I_o \sin\gamma$$

was used to apply corrections to satellite data for variations due to the changes in source illumination intensity as a function of solar elevation angles. These illumination corrections appear to be largely successful in removing bias from the data sets apparent as a function of time. Spectral signatures of test areas are subsequently more closely aligned with expected data variation.

In parallel with these solar illumination studies an activity is being initiated to obtain multi-temporal, spectral signatures from terrain areas generally expected to vary the least, such as urban areas and cultural features. A test site from the downtown Bryan, Texas area was selected for initial study. Multiple date spectral signatures were computed for the three dates. The temporal variation is readily apparent (Fig. 4-8). Applying the sun angle corrections described above, the sun angle correction puts all of the signatures within a sample standard deviation (Fig. 4-9). These results are encouraging, in that a significant amount of variation appears to be removed by application of the sun angle correction which is derived independently from atmospheric considerations.

Atmospheric studies are continuing to determine the extent of atmospheric attenuation and spectral dispersion through the identification of atmospheric models and by comparison of data from ground targets of relatively consistant spectral signature over time. These studies are being conducted in conjunction with vegetation studies to determine suitable parameters which are less sensitive to illumination and atmospheric conditions and which also have significant relationships

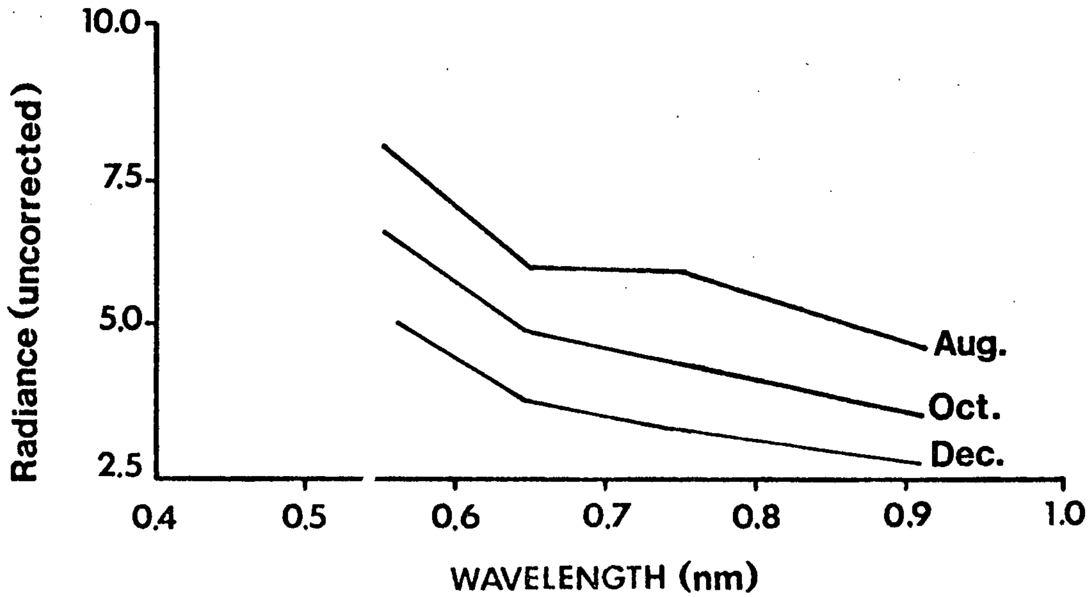


Figure 4-8. Uncorrected ERTS-1 MSS radiance values for a 12 X 12 pixel scene in downtown Bryan, Texas.

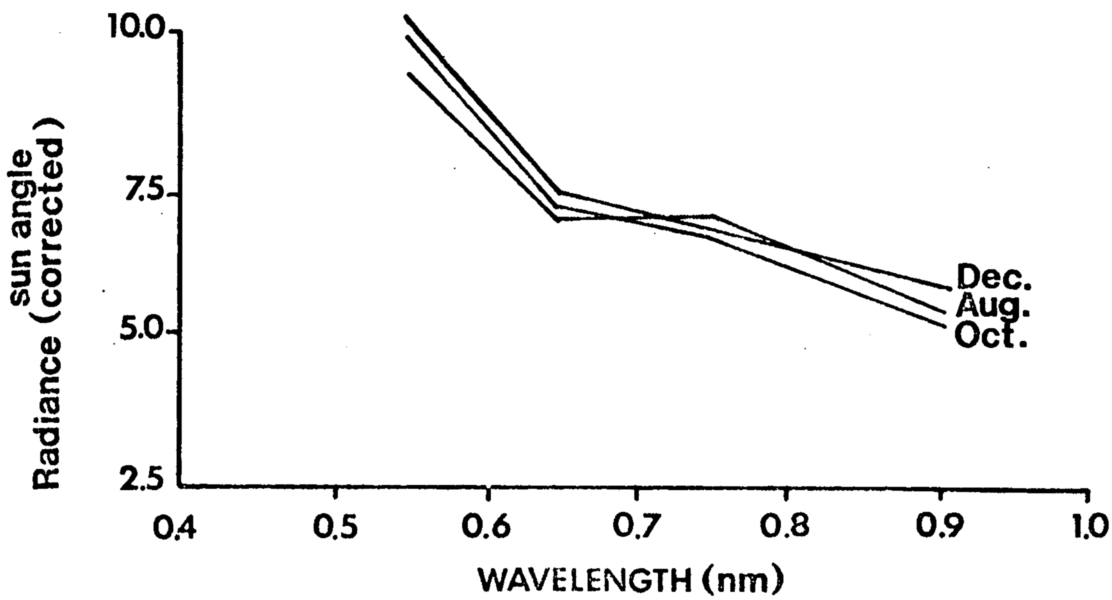


Figure 4-9. ERTS-1 MSS radiance values corrected for sun angle effect.

with the vegetative parameters of interest. It appears however at this time that scene heterogeneity is the major contribution to data variance, and that variance produced as a result of atmospheric variation from some nominal value is small in comparison. Direct application of ERTS data to the problems addressed in this study is not dependent upon precise atmospheric correction and it appears from the data considered, that sun angle correction will provide adequate reduction of temporal data variation.

4.3.3 Data Results

In Table 4-2 is listed the sun angle corrected MSS data values calculated for several Great Plains Corridor test sites during Autumnal Phase investigations. Additional data sets for the Autumnal Phase are currently being processed.

Table 4-2. Autumnal Phase MSS Data (corrected for sun elevation angle).

Name	Location Latitude	Date	Sun	MSS Band 4	5	6	7
GP1-Ø	30°33'N	30Aug.	55	9.78	7.29	7.25	5.73
X		30Aug.	55	8.45	5.82	7.18	6.45
Y		30Aug.	55	7.73	5.03	6.59	6.19
Z		30Aug.	55	9.73	5.21	8.87	8.44
Ø		23Oct.	41	10.09	7.33	6.81	5.38
X				8.00	5.62	6.49	6.05
Y				7.38	4.85	6.14	5.85
Z				7.79	5.49	6.62	6.14
Ø		16Dec.	30	10.2	7.44	6.78	5.72
X				8.36	5.90	6.82	7.18
Y				8.62	6.02	6.78	6.84
Z				8.08	5.72	6.04	5.96
GP2	30°18'N	20Sept.	50	8.47	6.19	7.14	6.41
GP3	33°15'N	08Oct.	44	7.96	5.64	7.05	6.34
		13Nov.	33	8.06	5.74	6.55	6.00
		30Nov.	30	8.28	5.96	6.58	5.88
		23Jan.	29	9.25	7.52	8.04	6.46
GP5	38°55'N	21Sept.	45	7.43	7.30	6.84	6.69
GP7	43°50'N	06Sept.	46	8.79	8.01	7.16	6.99
GP9	26°30'N	06Oct.	49	8.19	5.34	7.98	7.21
GP10	35°14'N	25Oct.	37	8.71	6.71	6.36	5.48

4.4 Data Analysis Summary

During the period of this report, preliminary evaluations were made of the ground observations and ERTS-1 satellite data obtained during the autumnal phase of the 1972 growing season. These evaluations strongly indicate that the ERTS-1 data and supporting ground data are adequate to successfully complete all phases of this investigation. The following sections summarize the more important aspects of the initial analyses.

4.4.1 Data Quality

Ground observations at the ten Great Plains Corridor test sites appear to be adequate for establishing the phenophase dependent information necessary for ERTS-1 data comparisons. These data are used to create a permanent file on the conditions existing at the time of satellite overpass. Biomass data and terrestrial photography both show the seasonal change and existing condition of vegetation. Since the range of the network test sites covers the major vegetation types of the extensive area encompassed by the Great Plains, the ground data being collected as a result of this investigation promises to become a unique data set for comparison with ERTS-1 measured parameters.

During the 1972 autumnal phase, good quality ERTS-1 MSS data was obtained from all Great Plains Corridor test sites. Cloud cover at the time of satellite overpass was a major problem. However, a survey of the data received from the time of satellite launch through January, 1973, indicates that the GPC test sites were cloud free at the time of satellite overpass more than 50% of the time. Through the first ten cycles two or more GPC test sites were cloud free during each ERTS-1 cycle.

ERTS-1 data quality appears to be excellent and well suited for the purpose of the current investigation. Successful removal of the solar angle effects should enhance the usefulness of radiance value estimates and provide for their use without normalization. Although further investigation of atmospheric effects is anticipated, the use of cloud-free ERTS-1 digital data appear to be possible for rural scenes without the necessity of elaborate corrections for differential band to band atmospheric attenuation.

Preliminary statistical evaluation of MSS digital data from two locations suggest that the coefficient of variation (CV) for MSS Band 5 mean reflectance is useful in determining the homogeneity of a natural vegetation scene. CV's range from about 5% for uniform grassland to more than 20% for woodland-grassland areas with a highly variable ground cover. The relatively low CV values for a uniform scene appears also to indicate a desirable signal to noise ratio, enhancing the potential usefulness of the data for quantitative "signature" analysis.

4.4.2 Theoretical Vegetation Index Model

The vernal advancement (green wave effect) and its seasonal retrogradation occur as a function of local weather conditions and other environmental parameters favorable to plant growth. Although it seems probable that these phenological phenomena can be qualitatively interpreted from ERTS-1 MSS color composite imagery, it is desirable to document the seasonal vegetation changes quantitatively. Therefore, it was important to develop a theoretical model for using ERTS-1 data to measure the relative "greenness" of natural vegetation scenes.

It is well established that the foliage of green plants differentially absorb and consequently, differentially reflect energy in the visible (0.5 - 0.7μ) and near infrared (0.7 - 1.1μ) regions of the spectra measured by ERTS-1. Since the red band (MSS Band 5) energy is strongly absorbed and the near-infrared band (MSS Bands 6 and 7) energy somewhat more reflected by dense green vegetation, a ratio of the red to near-infrared reflectance should provide a useful index of the greenness of a vegetation scene. This fundamental relationship suggests a hypothetically useful concept for monitoring natural vegetation changes.

Although a simple ratio of Band 5/Band 7 reflectance could be used as a measure of relative greenness, location-to-location, cycle-to-cycle, and location-within-cycle deviations would likely occur as a large source of error. Thus, the difference in Band 7 and Band 5 reflectance values, normalized over the sum of these values, is used as an index value and is called the "vegetation index".

$$\text{Vegetation Index (R)} = \frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}} \qquad (1)$$

To avoid working with negative ratio values and the possibility that the variance of the ratio would be proportional to the mean values, a square-root transformation is applied. The resulting "transformed vegetation index" is then

$$\text{Transformed Vegetation Index} = \sqrt{R + 0.5} \qquad (2)$$

when R is the vegetation index (1). Figure 4-10 shows the relationship of the original ratio (i.e., vegetation index) to the transformed vegetation index values (2) over the range of values obtained throughout the autumnal phase. The "transformed vegetation index" values will theoretically increase as the difference between Band 7 and Band 5 increases due to increased absorption of Band 5 energy by green plant material.

4.4.3 Ratio Analyses

As a tentative evaluation of the validity of the ratio analysis approach, autumnal phase ERTS-1 MSS data from College Station and Throckmorton, Texas were used to calculate a limited number of band to band ratios. Although someother band to band ratios appeared to have some promise, the "transformed vegetation index" described above was calculated for all existing ERTS-1 data for the selected sites.

At College Station four subsites were compared at three dates: August 30, October 23, and December 16, 1972 (Fig. 4-11). At each of three subsites, designated X, Y, and Z, MSS data from 4 mile X 4 mile scenes were used to calculate the mean radiance for Bands 5 and 7

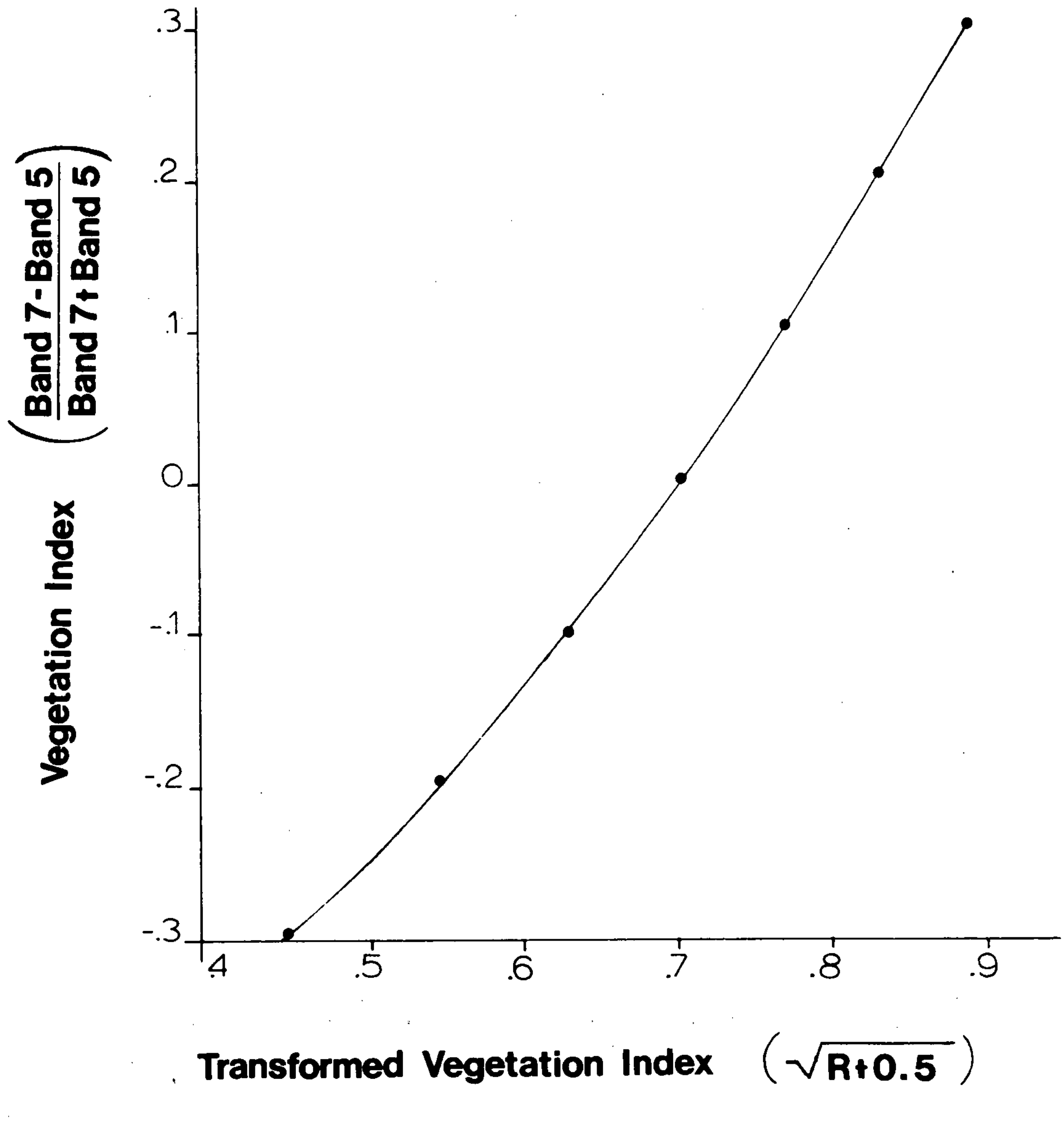


Figure 4-10. Relationship of vegetation index to square-root transformations of the vegetation index.

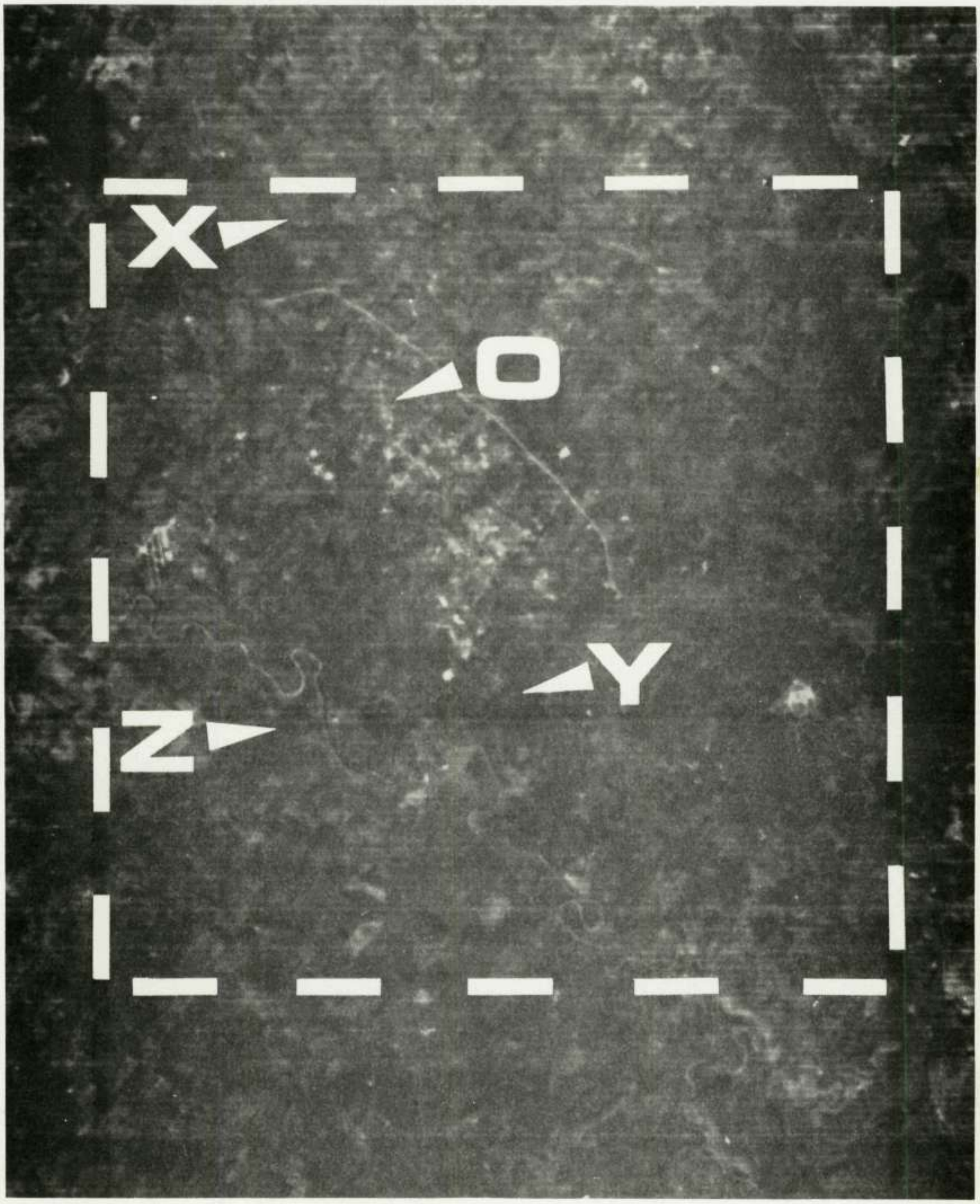


Figure 4-11. Photo enlargement of ERTS-1 image 1092-16305 (Fig. 4-5) showing sub-sites at Test Site No. 1: O) Downtown Bryan, Texas, X) north rangeland site, Y) south rangeland site, Z) Brazos River bottom site.

for each date. Sites X, Y, and Z can be designated mixed pasture and dryland farming, mixed woodland-grassland, and irrigated cropland, respectively. Site 0 is an urban scene (12 X 12 pixel) from downtown Bryan, Texas, which has little vegetation or bare soil. Asphalt, concrete and crowded buildings are the predominant features of Site 0. Mean radiance values were used for calculating the transformed vegetation index values shown in Figure 4-12.

At Sites X and Y the scenes were dominated by natural vegetation and the index value changes were small. The changes were, however, consistent with estimates of greenness. The increased index value at Site X in December is probably the result of winter pasture included in the 4 mile X 4 mile scene. The dramatic shift between August 30 and October 23 at Site Z results from the harvest of irrigated crops from the Brazos River Valley. Ratio values obtained from the urban (Site 0) scene were very low compared to rural scenes dominated by vegetation.

Further evaluation of the transformed vegetation index was made using data from the ERTS-1 Throckmorton test site. Index values were calculated from mean radiance values for each of four quadrants of a 4 mile

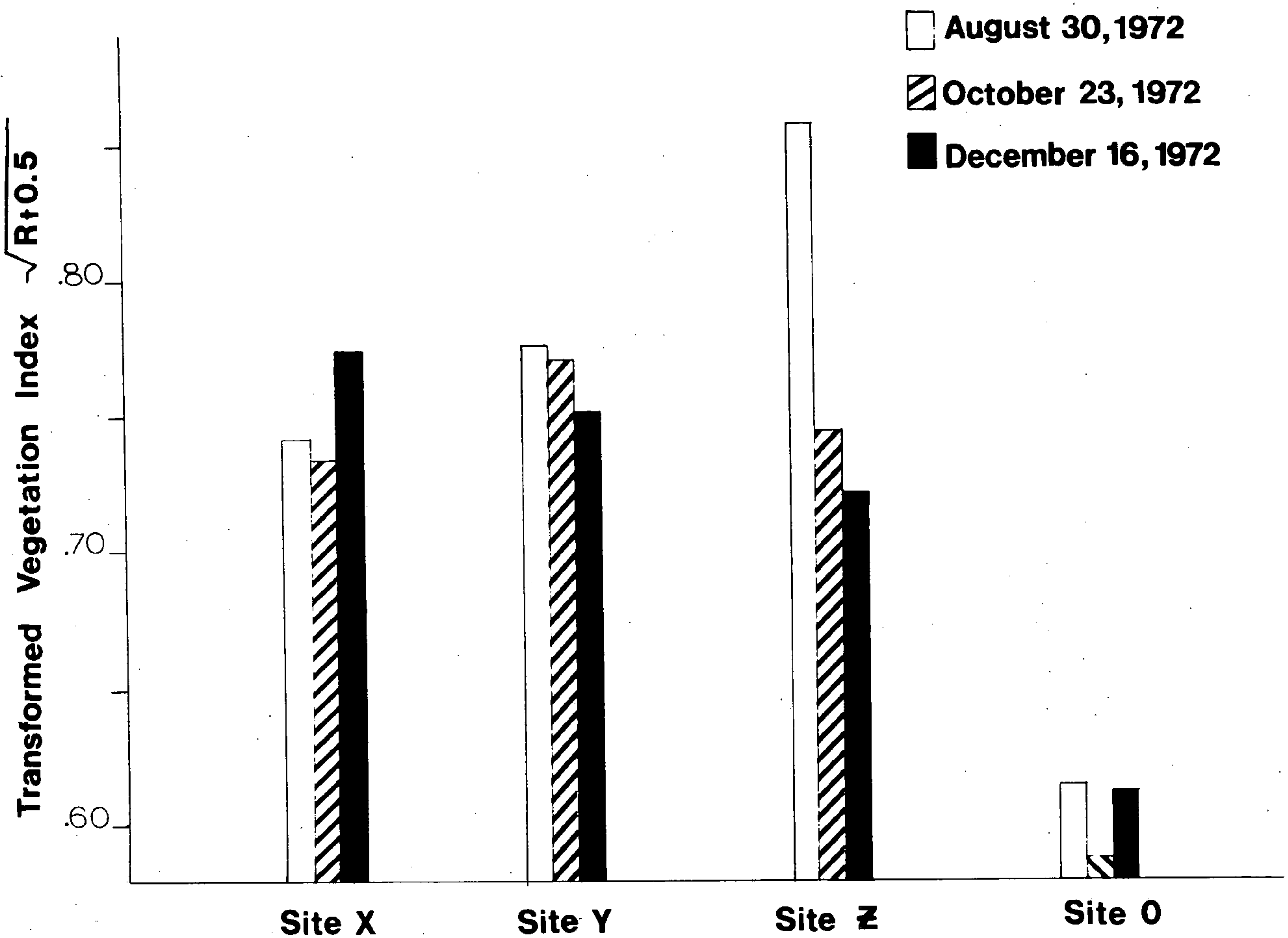


Figure 4-12. Transformed vegetation index values from four sub-sites at College Station.

X 4 mile scene that is mostly native grassland. Transformed vegetation index values are compared with standing dry biomass, green biomass, and percent green estimates taken at four dates during the 1972 autumnal phase (Fig. 4-13).

These data show an excellent relationship between the index values and the gradual "brownout" of grassland vegetation during the fall of 1972. There is an obvious decline in percent green biomass following the first killing frost that occurred about Julian day 336. Although no ERTS-1 data are available for Julian day 355, it is expected that the index values would also reflect the sharp drop in green biomass.

Analysis of variance indicate that the differences among transformed vegetation index values were highly significant (ρ=.001) and that the differences among all dates are statistically significant. A least squares, multiple regression analysis indicates that 99% of the variation in the transformed vegetation index is accounted for by the mean percent green estimate and standing dry biomass measured at the time of the ERTS-1 overpass. These preliminary analyses for the Throckmorton site suggest that changes in the order of 200 Kg/ha green biomass or 4 percent green estimate

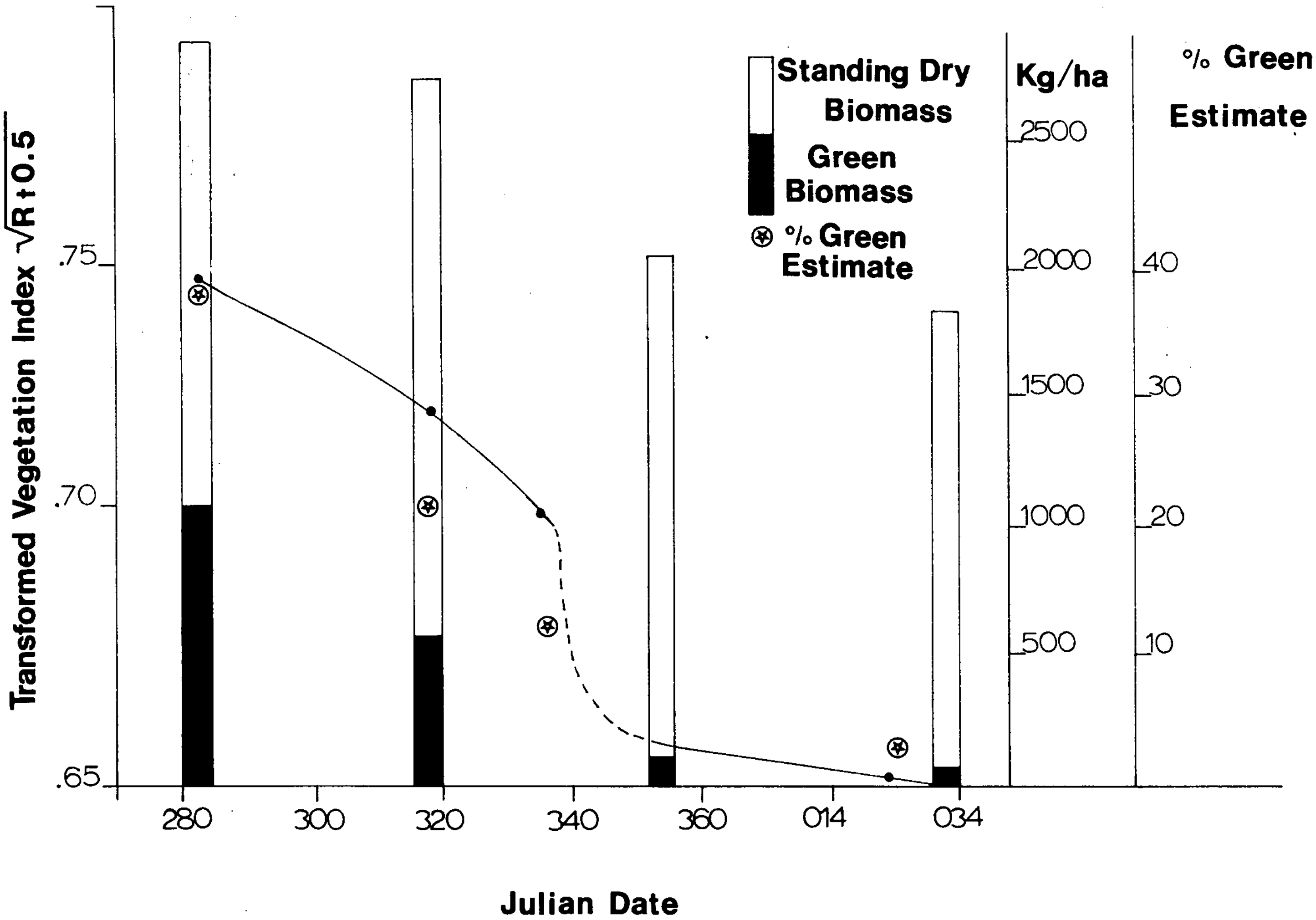


Figure 4-13. Transformed vegetation index values compared to autumnal phase biomass data from the Throckmorton test site.

may be detectable from ERTS-1 data for sites having a uniform vegetation cover.

Further analyses are needed to verify the degree of accuracy obtainable using ratio analysis for detecting changes in vegetation cover and condition. However, the preliminary analyses of the ERTS-1 and ground data suggest that the vegetation index is a practical approach and has potential for providing a quantitative estimate of the condition of natural vegetation.

It is recognized that numerous factors may affect band to band reflectance shifts, including amount and kind of soil, surface soil moisture content, height and vigor of vegetation, and water and pigment content of plant materials. These and other factors will be investigated in an attempt to assertain how the component reflectance values of a vegetated scene integrate to give a scene reflectance value. This endeavor will be aided by a cooperative effort with NASA/JSC using the Field Signature Acquisition System, currently under contract development with Lockheed Electronics, Inc.

5.0 Program Projection

During the period of the first Type II report an effective test site network has been established within the Great Plains Corridor and has functioned well during the autumnal phase of the growing season. This same effective network is currently being employed to monitor the vernal advancement. It is anticipated that the following tasks will be completed during the period of the next Type II report.

5.1 Ground Data Collection

Ground data (i.e., terrestrial photography, biomass data, etc.) will be collected in conjunction with each ERTS-1 overpass at each of ten test sites. Specific vegetation measurements will be computer stored, summarized and plotted against time to aid in visual illustration of the vernal advancement through the Great Plains Corridor. Statistical summaries of the spring and summer data will be completed and further evaluation made with respect to attaining the study objectives.

Specific investigations will be conducted to evaluate the factors affecting the reflectance patterns from rangeland scenes. A cooperative effort with

NASA/JSC, using the Field Signature Acquisition System, will provide fundamental information on the integration of component reflectance in establishing scene signatures. An effort will be undertaken to specifically characterize the influences contributing to reflectance pattern changes.

5.2 Test Site Characterization

Although significant progress has been made toward identifying terrestrial features at the individual sites within the test site network, emphasis will be given during the 1973 growing season to mapping and characterizing the land use within a 10 mile by 10 mile area centered on the test site. This effort will employ NASA-obtained high-flight imagery, existing large-scale black and white photographs, RSC obtained color-IR photographs and ground survey data to document the kind and quality of land use in areas adjacent to test sites. All test sites will be characterized in terms of soils, vegetation, climate and management history. These data will provide baseline information for evaluating differences in spectral characteristics and changes in reflectance patterns.

5.3 Data Analysis

Data will be received and analyzed as projected in the data handling plan. Additional developments will be completed to isolate and analyze ERTS-1 data for ultimate subsites.

Data cataloged for each of the test sites will be summarized and presented in a comprehensive computer printed report. This report will summarize the calculated data and vegetation measurements from throughout the Corridor and present this information graphically as a function of time and latitude. Regression, correlations and variance analyses will be initiated in conjunction with the summary effort.

Continuing data analyses will be performed to enhance investigators understanding of the phenological processes and their relationships to other regional variables, as well as understanding the actual ERTS measurement processes. Such analyses will serve to indicate confidence bounds on the data and the reliability of ERTS data for purposes of the investigation.

5.4 Field Signature Acquisition System

During the period of this report a cooperative effort was established with NASA/JSC to obtain field signatures of rangeland species using the Field Signature Acquisition System (FSAS). Grass reflectance characteristics of rangeland vegetation scenes will be obtained at ERTS-1 test site locations near College Station during the 1973 growing season. The measurements will serve to evaluate the temporal reflectance changes for rangeland vegetatation.

A second test site will be used to collect fundamental information about the reflectance characteristics of natural vegetation and will include: 1) a simulated grazing effect and 2) a study on the integration of reflectance components for a grassland community. Field plots at the two locations have been established, and initial data collected. Periodic measurements will be made during the 1973 growing season to characterize the phenophase-dependent vegetation changes.

6.0 CONCLUSION

6.1 Discussion of Project

The project objectives established at the outset for this initial six-month phase have been attained and the program is progressing according to schedule with only minor deviations. The emphasis has been on implementing and evaluating the test site network and the data handling system . The second six-month phase will concentrate on obtaining detailed test site characterizations, computer processing of all available ERTS MSS data for each site, and plotting of the vernal advancement throughout the Great Plains Corridor.

The revised project schedule recently received from Goddard Space Flight Center extends the originally proposed eighteen-month study through November 1974 (26 months). This schedule permits operation of the project through two growing seasons, which should improve the technical results, however the problem of stretching the original budget over this extended time period is expected to pose difficulties. Adjustments are being made in an effort to meet this situation, but the full effect of the extension cannot be determined at this time.

6.2 Atmospheric Effects

The objectives of this project require utilization of the time-dependent parameters of the natural vegetation systems. Thus, ERTS-1 data must be compared for widely varying latitudes on different orbits and over an extended period of time. Because of this situation, possible variations of the data due to time-dependent factors other than vegetation changes must be known . The atmosphere is believed to be one of the significant contributing factors.

The effect of seasonal variations in the sun angle have been isolated in the ERTS data, and a method of correcting for this effect has been incorporated in the data analysis program. However, the effect of possible spectral-dependent, time-dependent changes in the atmosphere have not been isolated. Studies at NASA/JSC indicate pronounced atmospheric effects in urban regions where aerosol contents are high, but that the effect is minor in rural regions . Since all Great Plains Corridor sites are some distance from major urban areas, atmospheric scatter due to aerosols is not anticipated to cause significant effects in the MSS measurements of the test sites .

C-2

Each test site is relatively large compared to an ERTS-1 resolution cell, therefore, an area integration is performed to obtain the average spectral reflectance characteristics of each scene. It has been observed that the ERTS-1 MSS data have appreciable cell-to-cell variations, even within relatively homogeneous sites. These variations are such that the spectral dependence of the atmosphere will be masked, hence, atmospheric effects are considered to be secondary perturbations. Thus, it appears that atmospheric-dependent error resulting from comparing orbit-to-orbit sun-angle corrected ERTS-1 data should be minor for the Great Plains Corridor test sites.

6.3 Related Activities

The ERTS-1 study at Texas A&M University has stimulated considerable interest among local, state, and federal agencies concerned with natural resources and the environment. A variety of new inquiries have emerged as a result of the Great Plains Corridor project and associated activities within the Remote Sensing Center. The Center, under separate funding, is also participating in the ERTS Satellite Phenology Experiment (MMC 159) and maintains an ERTS-1 Browse File for NOAA. In addition, the Center is developing several remote sensing application areas under NASA Grant NGL 44-001-001, which includes extensive use of ERTS-1 data.

The state of Texas has begun a vigorous program throughout the several state agencies to implement applicable remote sensing techniques and synoptic data to assist governmental functions. The Center is represented on the Governor's Remote Sensing Task Force formed to achieve these objectives, and it appears that ERTS-1 data will play a significant role in this activity, especially relative to land use studies. Cloud-free ERTS-1 data are available for almost the entire state for several cycles.

The USDA is conducting a pilot project in Texas which is part of a boll weevil and bollworm eradication program. The work requires current agricultural land use information over a large region on a timely basis within each growing season. The information must include crop plant distribution and developmental stages. ERTS data, complimented by aerial photography, appears to be ideally suited to this need and Texas A&M University is cooperating to develop the required information product.

A cooperative program has been initiated with the Soil Conservation Service, USDA, which will evaluate potential remote sensing applications for land resource management. The feasibility and cost effectiveness of certain land inventories would be determined using NASA-obtained aerial photography and ERTS-1 imagery for Brazos County, Texas. A phased program will undertake three primary tasks: 1) updating an existing soil survey for Brazos County, 2) conducting a "Conservation Needs Inventory" and 3) surveying the status and trend of wildlife habitat on a county-wide basis. (SCS project description by Dr. Haas)

Additional studies under NASA Grant NGL 44-001-001 include use of ERTS-1 data for studies of dredging activities in Galveston Bay; sediment transport in Corpus Christi Bay; and water quality in fresh water bodies. The ERTS-1 data have made possible the study of natural phenomena on a scale not previously manageable.

6.4 New Technology Statement

In accordance with the New Technology clause of contract NAS 4-21857, it is noted that no developments during this report period are considered applicable to this reporting requirement.

TEXAS A&M UNIVERSITY
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College of Agriculture
College of Engineering
College of Geosciences
College of Science

TECHNICAL MEMORANDUM RSC-71

GROUND DATA COLLECTION AT THE ERTS-1 GREAT PLAINS CORRIDOR TEST SITES

BY

D. W. DEERING

APRIL 1973

VEGETATION SYSTEMS LABORATORY

Technical Memorandum RSC-71

GROUND DATA COLLECTION FOR THE ERTS-1 GREAT PLAINS CORRIDOR RANGELAND STUDY

by

D. W. Deering
Remote Sensing Center
Texas A&M University

INTRODUCTION

At each of ten established rangeland study sites within the Great Plains Corridor region (Figure 1), ground data is being collected to record temporal vegetation and climatic changes. These data are being used for evaluating the ability of the ERTS-1 satellite to measure and monitor these changes. Of particular interest is whether the ERTS-1 multispectral scanner (MSS) system is capable of detecting the onset and advance of spring from south to north through the Great Plains Corridor.

The ground truth data collection for the ERTS-1 project is performed by highly skilled field personnel experienced in sampling rangeland vegetation. The cooperating research stations and research personnel (Figure 2) are also providing background information

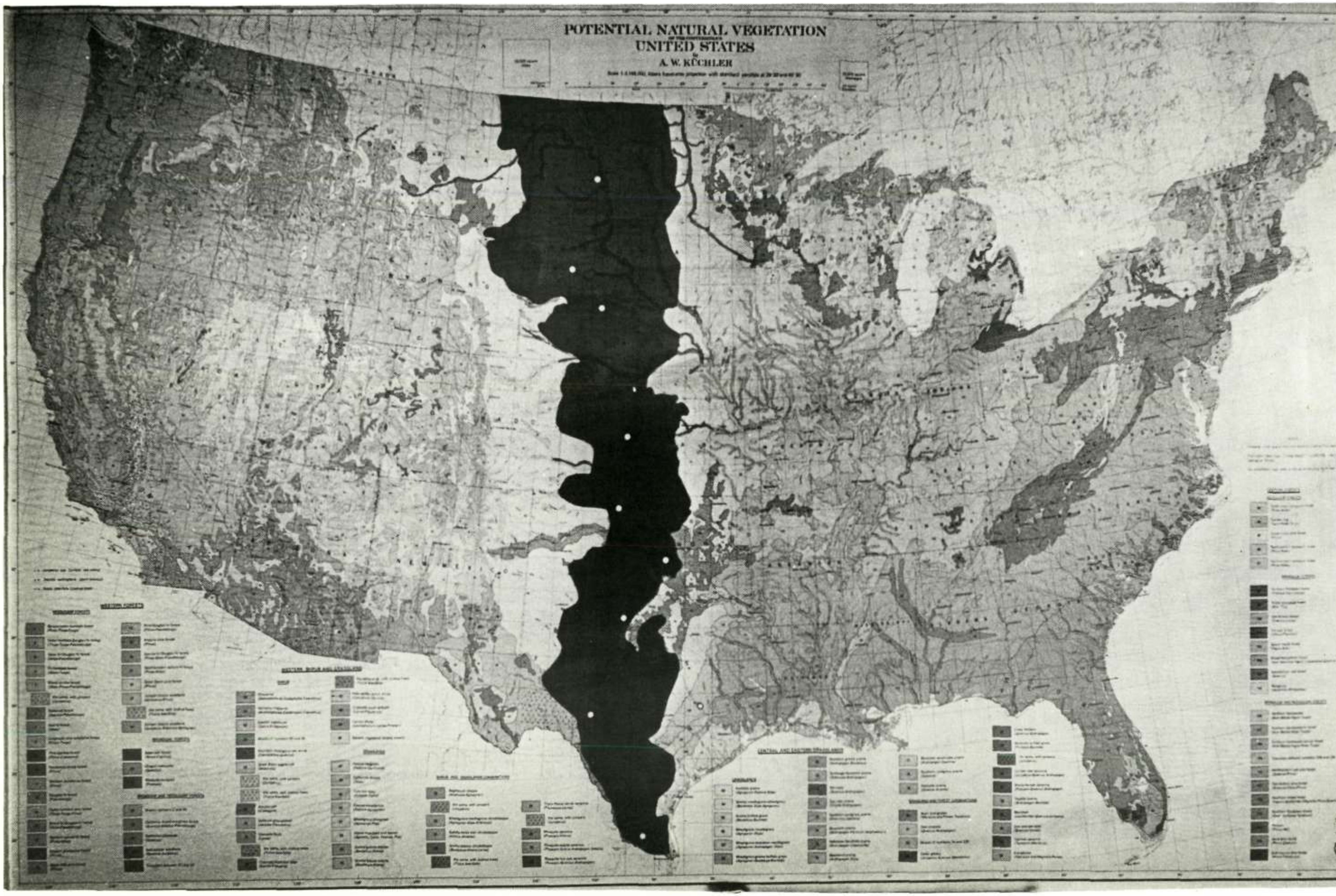

Figure 1. Great Plains Corridor and test site network.

Figure 2. Personnel and research stations associated with the ERTS-1 Great Plains Corridor Studies.

Mr. D. W. Deering, Remote Sensing Center, College Station, Texas.

Mr. C. Gonzalez, Remote Sensing Laboratory, Agricultural Research Service, USDA, Weslaco, Texas.

Dr. L. B. Merrill, Texas Range Station, Sonora, Texas.

Dr. M. M. Kothmann, Texas Experimental Ranch, Throckmorton, Texas.

Mr. B. Blanchard, Southern Great Plains Branch, Agricultural Research Service, USDA, Chickasha, Oklahoma.

Dr. E. H. McIlvain, Southern Great Plains Field Station, Agricultural Research Service, USDA, Woodward, Oklahoma.

Dr. J. L. Launchbaugh, Fort Hays Branch Station, Hays, Kansas.

Dr. P. Seevers, Department of Agronomy, Lincoln, Nebraska.

Dr. R. P. Gibbens, Animal Science Department, Range Field Station, Cottonwood, South Dakota.

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concerning the climate, soils, vegetation and grazing management for their test site areas.

SAMPLING SITES

In the summer of 1972 a minimum of five sampling sites were selected at each of the ten study sites by the Great Plains Corridor cooperators with the assistance of Vegetation Systems Laboratory personnel of Texas A&M University's Remote Sensing Center. Seven of the study sites have five sampling sites. Of the remaining three the College Station and Hays study sites have ten sampling sites each and the Throckmorton study site has eleven. The individual sampling sites were selected as being representative of the overall study area.

The sampling sites are sampled by the cooperators at each time of the satellite overpass ± 3 days, except during the dormant seasons. The sampling procedure involves taking photographs at each site, clipping a one square meter (or similar) plot on each site, and recording other vegetation and climatic conditions.

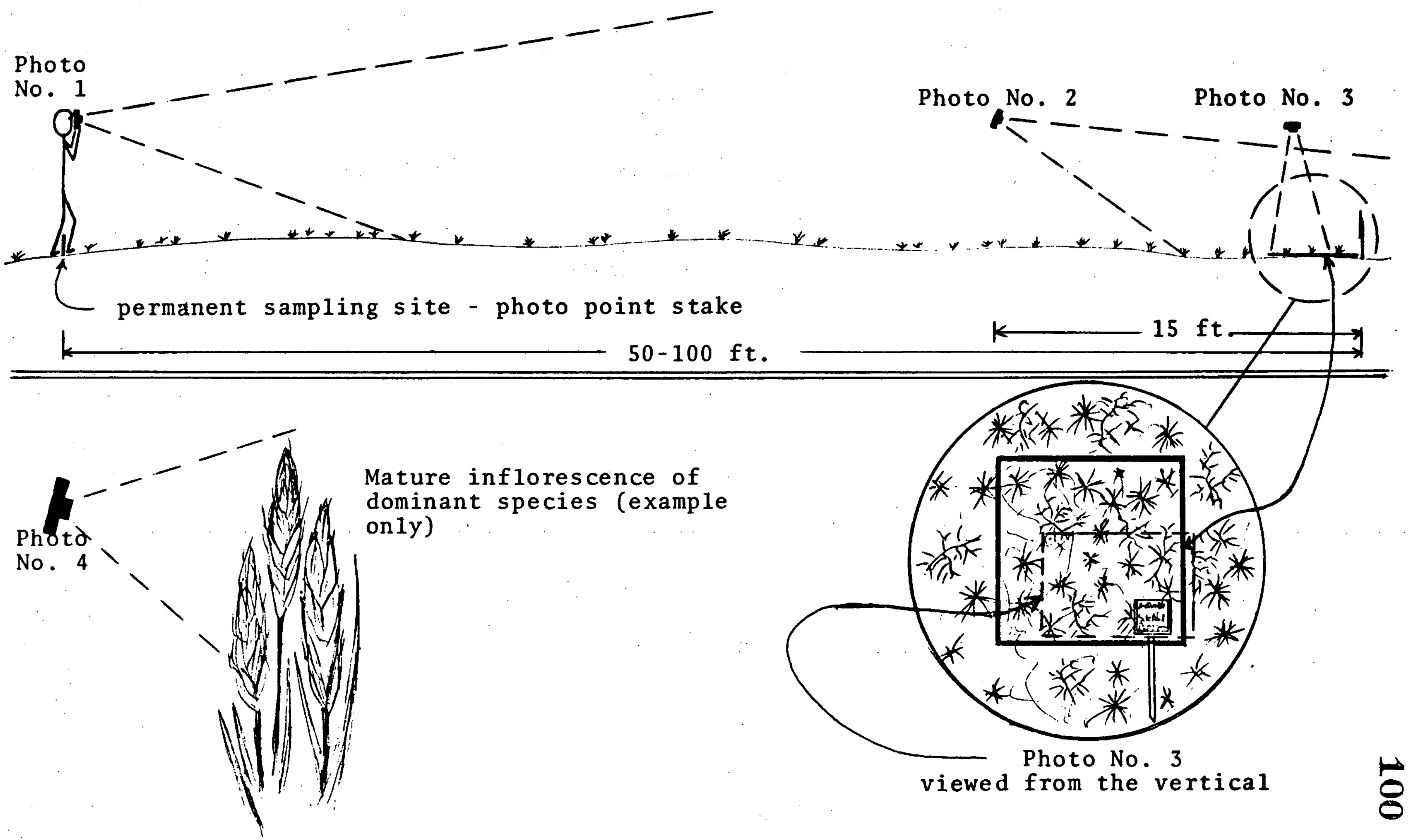
PHOTOGRAPHY

Permanent photograph points, which establish the sampling sites, are marked with wooden or metal stakes driven in the ground at each sampling site. These photo point stakes are located on the sampling site such that when the photographs of the site are taken, while standing at this marker, the camera will be pointed in a northerly direction. This minimizes lighting problems that result from photographing the same scene or area at different times of the day or the various sampling dates and during the different seasons of the year. Work scheduling problems sometimes necessitates sampling at different times of the day. Offensive back-lighting, resulting in poor quality photographs, would be the result if the photographs were taken in other than the polar direction.

The photographs are taken with a 35mm format camera with a 50 or 55mm lens. Ektachrome-X color slide film is used, and all processing is handled through the use of film mailers and sent to the same Kodak processing plant. Four photographs are taken at each sampling site. The relative locations of these photo points are diagramatically presented in Figure 3.

Prior to taking the first photograph, a plot label and 1 m^2 plot frame are placed within the

Figure 3. DIAGRAM SHOWING PHOTOGRAPHS TO BE TAKEN AT EACH SITE



sampling site area established by the permanent photo point. It is located approximately 50 to 100 ft. or more to the north of the permanent photo point stake in an area that is representative of the vegetation of the site.

The first photograph at each sampling site is taken while standing at the permanent photo point stake (Figures 3 and 4). This is an oblique general aspect shot of the site that is re-photographed at each sampling. Color 3 1/2" X 5" prints carried in the field enable precise relocation of the same scene at each sampling interval. This photo provides a permanent record of the general condition of the vegetation at the time of sampling.

The camera shutter speed and f-stop settings used when taking this aspect photograph are recorded on the data collection form (Figure 8) at each of the sampling sites. This provides an aid to understanding exposure problems that sometimes arise and helps in recommending adjustments that can be made for future sampling.

The second photograph taken at each sampling site is located along an imaginary line between the plot and the permanent photo point stake. The photo is

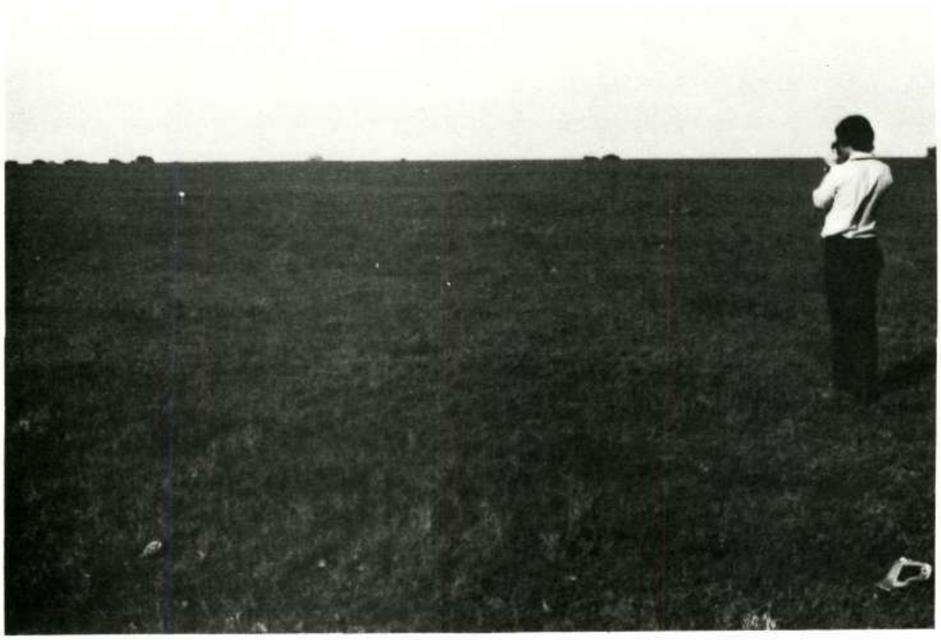


Figure 4. Photo point No. 1 - taking the oblique "permanent photo point" aspect shot.

Figure 5. Photo point No. 2 - taking an oblique photo about 15 ft. from the 1 m^2 clipping plot.

a paced distance of 15 feet from the 1 m^2 plot frame (Figure 3 and 5). This photo is centered on the plot and, consequently, provides a good view of the entire plot that is to be clipped. It reveals the condition of the vegetation in the plot and adjacent area. Estimates of vegetation height, species composition, and homogeneity can be made from this photo.

The third photograph is a veritcal photograph of a "typical" portion of the 1 m^2 plot (Figures 3 and 6). This photo provides a record for estimating the amount of vegetative cover, percentage green vegetation vs. brown vegetation, bare ground, litter, species composition, and phenological stage of dominant species.

The subject included in the fourth photograph taken at each sampling site is a photograph of some aspect of the vegetation that dominates the visual aspect of the site at the time of sampling (Figure 7). Selection of this photo is left to the discretion of the photographer. For example, a dense stand of a grass or forb species with a fully mature infloresence may cause the vegetation over the landscape to look dry or dormant, when the leaves and stems are actually still green and succulent. A close-up of the infloresence of this species might be a good choice for this fourth

Figure 6. Photo point No. 3—taking a vertical shot of a portion of the biomass clipping plot.

Figure 7. Photo point No. 4—taking a close-up of a grass species that dominates the visual aspect of the sampling site.

photograph (Figure 3).

VEGETATION MEASURES AND OBSERVATIONS

After all of the photographs have been taken at a sampling site, the percentage of green vegetation in the 1 m^2 plot is estimated (i.e., dry weight basis) and recorded on the data collection form (Figures 8 and 9). This value is the percentage of the total standing vegetation in the plot that is green matter, and when coupled with the dry biomass clipping weight provides an estimate of the quantity of green vegetation on the site.

Other vegetation field determinations are then made including condition of the vegetation (qualitative), current apparent intensity of utilization of the herbage on the site by livestock, and plant species currently dominating the visual aspect on the site and its (their) existing phenological stage. These determinations are entered on the data collection form (Figure 8).

The aboveground standing biomass contained within the 1 m^2 plot is clipped near the ground (to about 1/2 inch of the soil surface) and placed in a paper bag (Figure 10). This bag is then labeled by

ERTS-1 OVERPASS CORRELATED GROUND TRUTH DATA

Test Site:______________________________Sampling Date:______________________________

Number of days since last measurable precipitation:______________________________

Precipitation since last sampling:________Sample Plot Size:______________________

Maximum and minimum temperatures since last sampling: Max.________Min.________

	Site 1	Site 2	Site 3	Site 4	Site 5
1. Condition[1] of Veg.: a. at time of satellite overpass					
b. at time of sampling					
2. Date Grazing Initiated					
3. Current Utilization[5]					
4. Species dominating the visual aspect a.					
b.					
c.					
5. Phenological stage[4] of dominant species a.					
b.					
c.					
6. Field estimate[2] of % green vegetation					
7. Above ground biomass[3] a. Fresh wt.					
b. Dry wt.					
8. Camera settings[6] for aspect photos	ss- ;f-	ss- ;f-	ss- ;f-	ss- ;f-	ss- ;f-
9. Remarks (use back side if necessary)					

[1] V = Vigorous, H = Healthy, Un = Unhealthy, D = Dry
[2] % of standing vegetation that is green matter; a dry-wt. percentage estimate.
[3] sample plot-clipped vegetation weight in grams.
[4] 1-Immature Vegetative, 2-Mature Vegetative, 3-Early Bloom, 4-Full Bloom, 5-Immature Seed, 6-Mature Seed, 7-Seed Shatter, 8-Dormant.
[5] 0 = None, L = Light, M = Moderate, H = Heavy
[6] SS-shutter speed; f-aperture setting

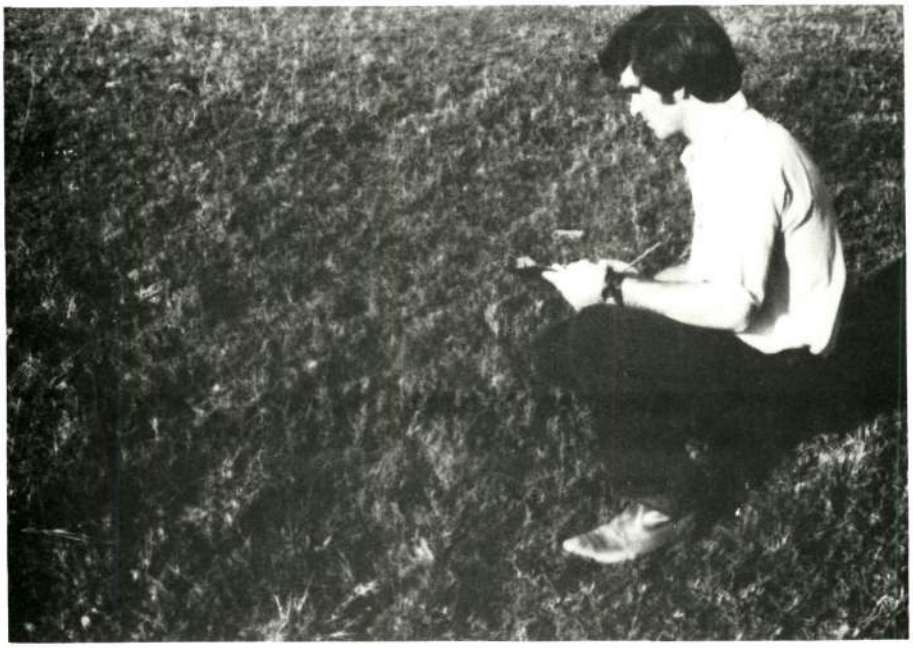


Figure 9. Percentage green vegetation within the 1 m^2 plot is determined and recorded on the data collection form.

Figure 10. Aboveground standing biomass contained within the 1 m^2 plot is clipped near the ground and sealed in a bag.

site number and date and placed in a larger plastic bag, which will also accommodate the other biomass samples. The plastic bag acts as a "seal" to retard the loss of moisture from the vegetation samples until they can be taken to the lab and weighed. The biomass samples are dried in an oven at 65 to 70° C for 24 hours and re-weighed. These "fresh" and "dry" biomass weights are also recorded on the data collection form (Figure 8).

The biomass clipping data furnish an estimate of the total amount of herbage on the site, the amount of green vegetation on the site (when combined with the percentage green estimate), and the water content of the vegetation. All of these factors and their many implications (i.e., amount of ground cover, vegetation height and density, soil moisture, etc.) are expected to be very important site spectral signature determinants.

OTHER SIGNIFICANT DATA

Other "on site" data that is obtained at the time of each satellite overpass and sampling include the amount of precipitation since the last sampling, the number of days since the last measurable precipitation, and the maximum and minimum temperatures since the last sampling.

Information on the date that grazing was initiated on a site indicates the length of time that a site has been grazed. When related to previously supplied grazing treatment information these data enable a fuller understanding of the measured temporal change in vegetation biomass.

All study site photographs and sampling data are sent to the Vegetation Systems Laboratory of the Remote Sensing Center for interpretation, analysis, and archiving.

SUMMARY

The following is a step-by-step summary for the collection of ERTS-1 overpass correlated ground truth data. Steps 1-11 are repeated at each of the five sampling sites.

1. Locate the permanent photograph point (sampling site) stake.
2. Place the 1 m^2 (or similar) clipping plot frame in an area that is representative of the vegetation of the site and is within the sampling area established by the permanent photo point (approximately 50 to 100 ft. or more to the north of the

camera's location).

3. Affix the appropriate site and date labels to the aluminum plot marker stake and position the stake at the center of the far side (north) of the plot frame.
4. Return to the permanent photo point stake and take one oblique photo of the pre-selected scene that includes the clipping plot. Record on the data form the camera f-stop and shutter speed settings used.
5. Walk directly toward the plot frame. At approximately 15 ft. south of the plot take another photo, centering on the obliquely viewed plot.
6. Go to the clipping plot, pull up the aluminum marker and lay it down so that the label tag is within the plot frame and will be seen in the lower right or left hand corner of a photograph taken from the vertical. It should be taken at a 4-5 ft. height from the side of the plot that will provide the best detail of the vegetation in the plot under the existing light conditions.

7. The contents of the fourth photographs at the site is left up to the discretion of the photographer. Preferably, it will be a shot of some component of the vegetation that dominates the visual aspect.
8. After all four photographs have been taken, estimate the percentage of the standing vegetation the plot that is green matter (projected to a dry weight basis) and record the value in Item 6 on the data collection form.
9. Complete items 1,3,4, and 5 on the data collection form.
10. Clip the standing vegetation in the plot to within about 1/2 to 1 inch of the soil surface and place this sample in a paper sack.
11. Label the paper sack according to site and date and place it in the large plastic bag supplied by the VSL.
12. After all 5 sites have been sampled, return to headquarters and weigh each of the biomass samples.

13. Place the samples in a drying oven and dry the samples at 65 to 70^{o} C for 24 hours and then re-weigh them. If air dry weights are used indicate this on the data collection form.
14. Mail the film in the film mailer supplied by the VSL.
15. Complete item 2 and the blanks at the top of the data collection form, attach the record stub from the film mailer to the form, and return the form in an envelope supplied by the VSL.
16. Repeat this procedure at the time of the next scheduled satellite overpass.