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

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October 1973
Type II Report for Period April 1973-September 1973

Prepared For:
Goddard Space Flight Center
Greenbelt, Maryland 20771

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

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by

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16. Abstract

The Great Plains Corridor rangeland project being conducted at Texas A&M University utilizes natural vegetation systems as phenological indicators of seasonal development and climatic effects upon regional growth conditions. A method has been developed for quantitative measurement of vegetation conditions over broad regions using ERTS-1 MSS data. Radiance values recorded in ERTS-1 spectral bands 5 and 7, corrected for sun angle, are used to compute a band ratio parameter which is shown to be correlated with green biomass and vegetation moisture content. This Type II report details the progress being made toward determining factors associated with the transformed vegetation index (TVI) and limitations on the method. During the first year of ERTS-1 operation (cycles 1-20), an average of 50% usable ERTS-1 data was obtained for the ten Great Plains Corridor test sites.

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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

The Great Plains of the central United States produces over forty percent of the nation's beef and much of the country's grain. The beef industry in six Great Plains Corridor states is a $23 billion operation, which is extremely vulnerable to adverse seasonal or climatic conditions. Stability of the beef and agricultural industry in the Great Plains Corridor is contingent upon decisions made by the 400,000 farmers and ranchers in this region. These private operators need timely information on regional range forage conditions and crop production levels upon which to base their management decisions. This ERTS-1 study of rangelands in the Great Plains has established the potential for using ERTS-type data to provide quantitative regional vegetation condition information required to support these agricultural operations.

The Great Plains Corridor rangeland project being conducted at Texas A&M University utilizes natural vegetation systems as phenological indicators of seasonal development and climatic effects upon regional growth conditions. The basic task is that of monitoring

the vernal advancement and retrogradation of vegetation (green wave effect) throughout the uniform Mixed Prairie Grassland Association extending from south Texas into Canada, a distance of over 2,000 miles.

The study employs a network of ten test sites at established range research stations in the six states extending northward from south Texas into North Dakota. Ground observations recorded every eighteen days at each site include green biomass, phenology of dominant species, moisture content of vegetation, weather information, etc. ERTS-1 MSS data have been acquired for all sites for a full season. Over fifty percent of the total ERTS-1 data obtained over the test sites were sufficiently cloud-free to provide usable spectral reflectance measurements.

The ERTS-1 MSS data are computer processed for selected areas of each site. Spectral reflectance data are analyzed for each available date for each site. The measurements are corrected for seasonal sun angle differences to permit temporal comparisons. Radiance values recorded in ERTS-1 spectral bands 5 and 7 are used to compute a Band Ratio Parameter which is shown to be correlated with aboveground green biomass and vegetation moisture content.

ERTS-1 color composite imagery is used to delineate the areal extent of vegetation condition differences.

This research program has established a method for obtaining a quantitative measurement of vegetation conditions over broad regions using ERTS-1 MSS data. It is anticipated that this capability will be further developed to provide regional rangeland vegetation condition and growing condition information needed in rangeland management and agri-business activities in the Great Plains.

This Type II report details the progress of the project for the second six months of operation. This period has yielded significant findings relative to the project objectives based upon analysis of ERTS-1 MSS and ground-based data for the 1972 autumnal phase and the 1973 spring phase. The results of these analyses are presented, and their significance relative to establishing the feasibility of an operational system is discussed.

The related applications activities using ERTS-1 data initiated as cooperative projects with state and federal agencies, have been expanded using funds from NASA Grant NGL 44-001-001. The projects are also outlined in this report.

2.0 PROGRAM 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.

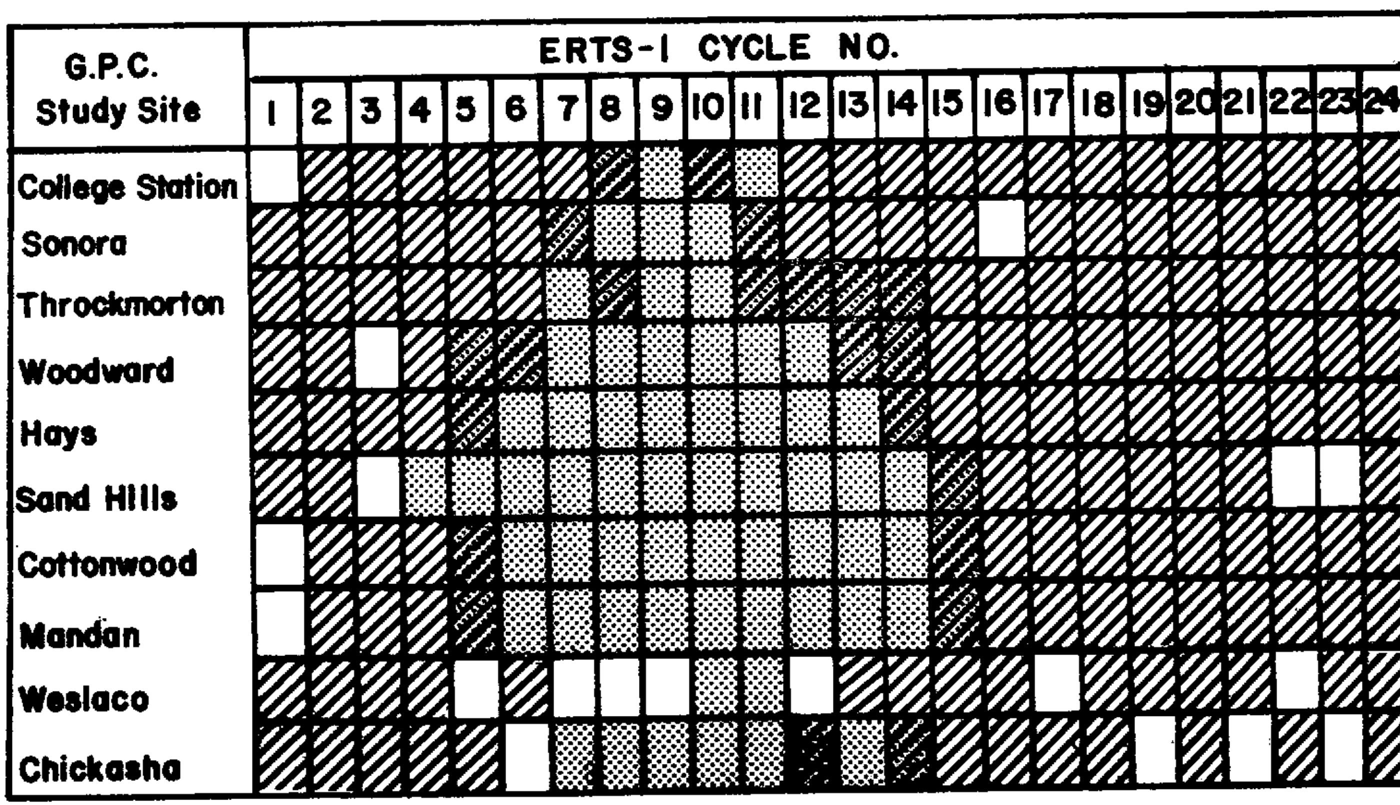
Ground observations at ten test sites within the Great Plains Corridor provide the primary validation data for this ERTS-1 investigation. ERTS-1 data products are routinely received, logged, processed and summarized for comparison with ground data and other important information. The test sites are being characterized in regard to soils and vegetation resources and land use. These activities are summarized for the reporting period in the following sections.

2.1 Ground Observations

The Great Plains Corridor test site network, described in RSC Progress Report 1978-1, functioned very efficiently during the spring and summer of 1973.

During the period covered by this report, March 28, 1973 through September 27, 1973 (ERTS-1 cycles 14-24), six of the ten test sites collected ground truth data as required for all eleven cycles (Fig. 2-1). Occasional manpower shortages and other factors prevented sampling on all dates at four of the test sites. However, the maximum number not sampled at any test site for this period was only three, and these were spaced at regular intervals. The ground data collected during the current and previous reporting periods provide an excellent data set for evaluating ERTS-1 data during the first 14 months of satellite operation (cycles 1-24).

Figure 2-1. Ground Data Collected at Great Plains Corridor 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.

2.2 Remote Sensing Data

2.2.1 ERTS-1 Data

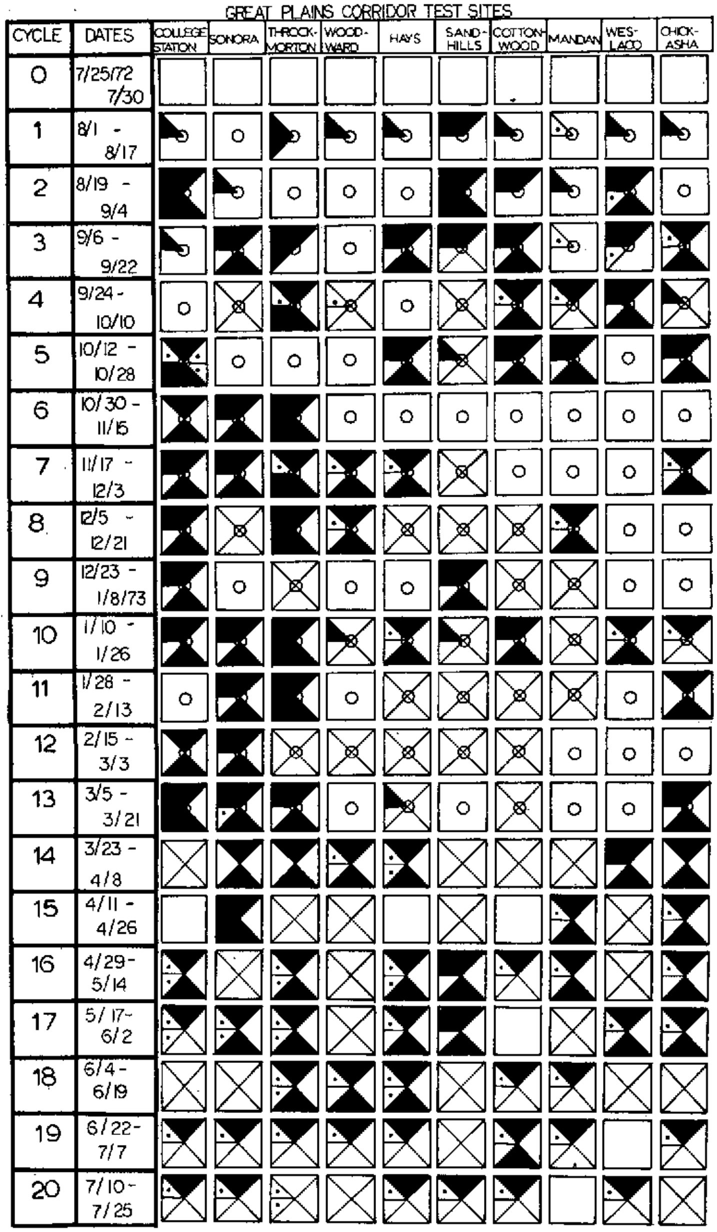
The ERTS-1 imagery and tape receipts and orders "quick-look" chart (Fig. 2-2) presents the status of the ERTS data inventory and data requests at the end of this reporting period.

By September 27, 1973 the following ERTS-1 data products for the Great Plains Corridor test sites had been received from NASA/GSFC: 221 sets of four black-and-white standing order images, 97 color composite paper prints, 19 color composite transparencies, and 74 sets of computer compatible tapes.

Four retrospective data requests have been placed since the last reporting period. These were sent on August 2, August 6, August 28, and September 17, 1973. These bring the total of the retrospective data requests to 18 by the end of this reporting period.

Based on the evaluations of high quality color balanced color composite ERTS-1 images produced by the Western Aerial Photography Laboratory, ASCS-USDA, and reported in RSC Progress Report 1978-1, additional color products have been ordered. These will enable intensive interpretations for feature and change detection for selected sites and dates.

Figure 2-2. ERTS-1 IMAGERY AND TAPE RECEIPTS AND ORDERS



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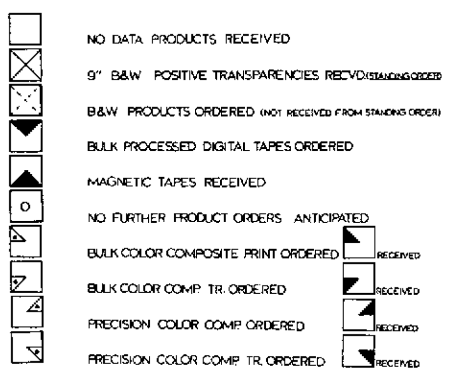

The first year (cycles 1-20) of ERTS-1 resulted in very good cloud free coverage for the Great Plains Corridor. An average of 50% of the ERTS-1 overpass cycles provided usable MSS data for the Corridor test sites (Fig. 2-3). The Throckmorton, Texas test site had the highest percentage of usable ERTS-1 data with 70%. The Chickasha, Okla. and Hays, Kans. sites each had 65% usable data. The Sonora, Texas; Mandan, N. Dak.; and College Station, Texas test sites had 60%, 55%, respectively. Weslaco, Texas; Sand Hills, Nebr.; and Cottonwood, S. Dak. all had 35%. The Woodward, Okla. test site had the lowest percentage of cloud free data with 30%.

Overlap of adjacent ERTS-1 coverage swaths sometimes enables the acquisition of satellite data for a particular test site when during a given coverage cycle, the test site is cloud covered on the scheduled overpass date. If the test site lies within the overlap area on the preceeding or following day, and cloud free conditions exist over the test site, then ERTS-1 test site data can be obtained for that cycle.

In the Great Plains Corridor this sidelap double coverage has been very valuable for several of the test sites. Image sidelap ranges from about 24%

G.P.C. Test Site	ERTS-1 Cycle																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
College Station		░			■		■	■	■				■			■	■		░	■
Sonora			■			■	■			■	■	■	■	■	■		■		■	■
Throckmorton	░		■	■		■	■	■		■	■		■	■		■	■	░	■	
Woodward							■	■		■				■				■	■	
Hays	■		■		■		■	■		■			■	■		■	■	■	■	■
Sand Hills		■	■						░	■						■	■			■
Cottonwood		■			■			■		■							■		■	■
Mandan			░	■	■			■			■	■			■	■	■		■	■
Weslaco	■			■						■			■	■			■			■
Chickasha			■	░	■		■			■	■		■	■	■	░	■		■	░

Figure 2-3. ERTS-1 imagery received for which 100% cloud-free conditions[1] existed (solid black) over the test sites during cycles 1 through 20[2]. Stippled blocks indicate cycles that were not cloud-free but most of the site data is usable[3].

[1]Determined from the imagery
[2]Entire images not necessarily cloud-free
[3]Usually small cumulus clouds dotting the area with much clear area

at the south end of the Corridor to about 43% at the north end. Eighteen percent of the usable data reported in figure 2-3 was available due to this sidelap characteristic. In addition, cloud free coverage on two consecutive dates was obtained for 15% of these data as a result of the image sidelap.

In the first year of ERTS-1, however, sidelap double coverage has not been consistent for some of the test sites. For example, at the Throckmorton, Texas test site double coverage due to image sidelap was possible during the first eleven ERTS-1 cycles (Fig. 2-4). In late February or early March, 1973 the satellite's orbit had drifted to the west such that the primary test site area fell outside of the sidelap double coverage area. At that time the orbit apparently became more stable also, as evidenced in figure 2-4.

While the orbit shift decreased the chances for good ERTS-1 coverage at the Throckmorton and Woodward test sites it correspondingly increased the chances at the College Station, Sonora, Chickasha, and Mandan test sites. Coverage of the other four sites was essentially unchanged.

2.2.2 ERTS-1 Digital Processing

Processing of ERTS-1 MSS data is accomplished

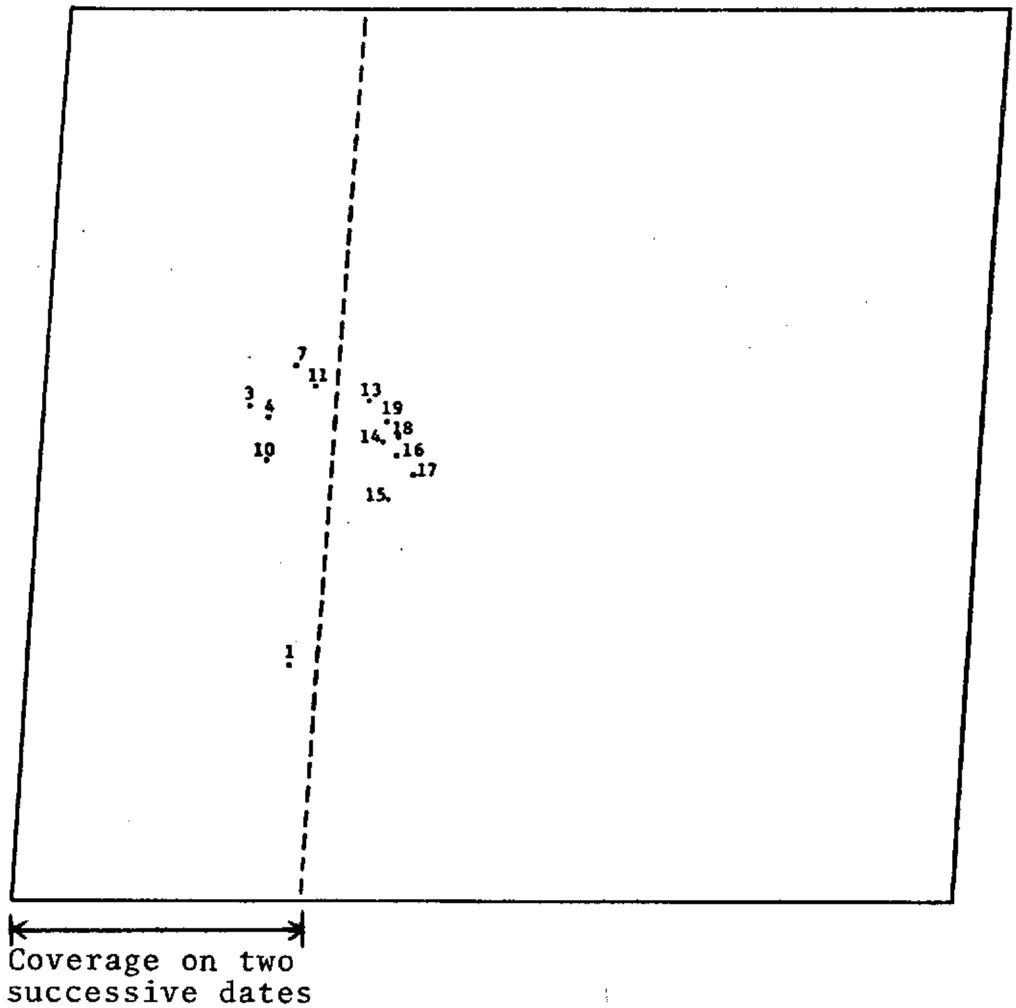

Figure 2-4. Position of the Throckmorton test site within ERTS-1 images for 13 cycles.

by digital computer analyses. Distinct stages of these analyses are being performed as is specified in the data handling plan. Table 2-1 summarizes routine site processing activity to date. The summary appears in three categories. The first category includes those tapes which have been received from NDPC and processing has not been initiated, the second category includes those tapes for which the first level of site processing has been accomplished and are awaiting the second level of site processing. The third category includes all those tapes for which site processing reports have been generated providing estimations of the system mean spectral signature and TVI vegetation parameters. The project totals as these categories indicate 25 data sets received/not processed, 19 data sets processed to the first level of site processing, and 60 data sets where site processing has been completed.

2.2.3 Dynamic Color Display

The increased use of computers for processing, enhancement and presentation of imagery and spatial relationships has created a need for flexible, high-speed interactive interface between computer data files, and the human investigator. This interface has traditionally taken the form of monochromatic CRT display

Table 2-1. Summary of digital data processed for ten Great Plains Corridor test sites.

Site	Data Received but Not Processed	SITE PROCESSED	
		Move/Map	Report
1	6	0	8
2	3	1	12
3	3	1	13
4	0	1	3
5	2	4	6
6	3	4	3
7	4	0	4
8	2	1	2
9	2	2	3
10	0	5	6
Total	25	19	60

or line printer grey-scale mapping as is used in this project. Recently the development of a digital color image display system has been completed at the Remote Sensing Center as a part of activities conducted under NASA Grant NGL 44-001-001. This display system uses a standard color television receiver as the display device to insure a low cost display terminal, and allows for simplified expension in multiterminal applications (Fig. 2-5).

In addition to the simple display of computer generated or enhanced imagery, the color display system has provisions for operator interaction either via the display control panel or over the computer interface. Using the controls available, the operator can select the color coding of the imagery, expand selected portions of the screen, or extract data from refresh storage for numerical readout display. The display has been designed as a stand-alone unit so that refresh and operation interaction may be continued, once data has been transferred, without interfering with other computing functions.

2.2.4 Aerial Photographic Data

Since the previous semi-annual reporting period, one major mission has been flown by NASA/JSC

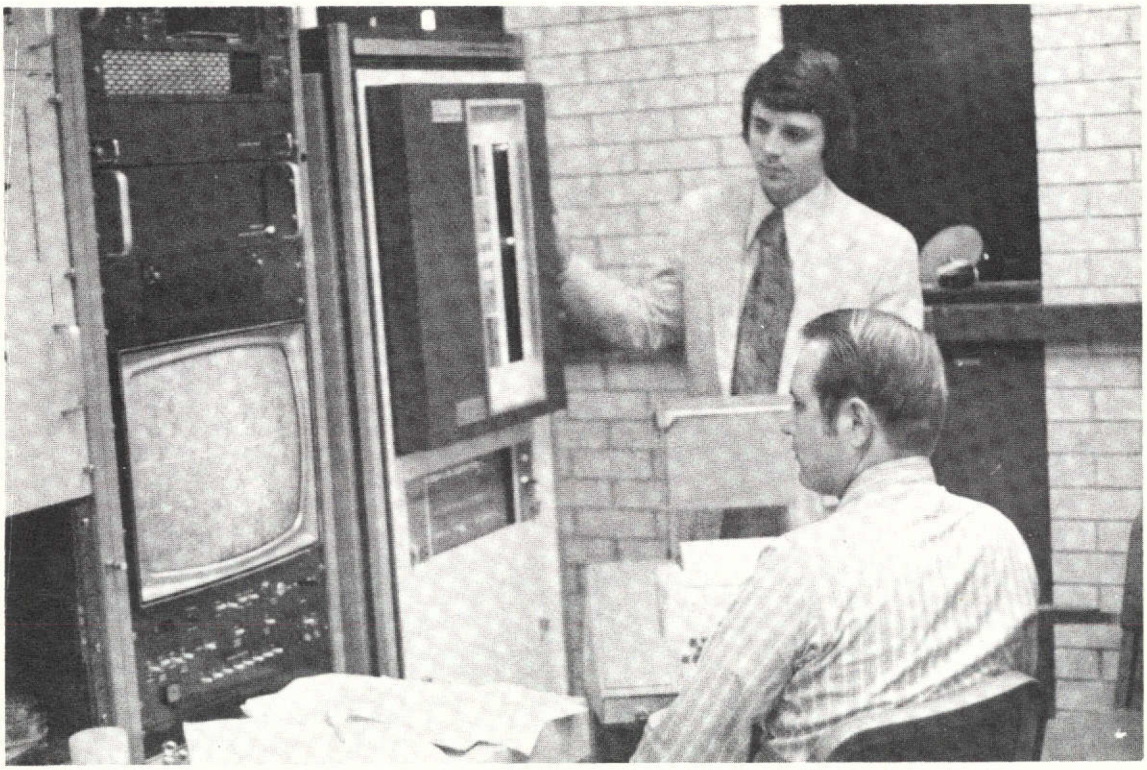

Figure 2-5. Analysis of ERTS-1 data using the Dynamic Color CRT Display.

to acquire aerial photography of the Great Plains Corridor test sites. NASA Mission 248 was flown in late July and early August, 1973. By the end of this reporting period only one partial shipment of this data had been received. Consequently, an evaluation of the quality of data acquired on this mission will be reported at a later date.

The previous aerial photography containing the Corridor test sites has proven invaluable for test site characterization. Seasonal photography is necessary for multistage evaluations of test site vegetation conditions, and this type of photography has not been received for the Corridor sites as requested.

In support of more intensive sampling being done at the Throckmorton and College Station test sites, large scale aerial photography has been obtained by the Remote Sensing Center through the Texas Forest Service of the Texas A&M University system. In conjunction with satellite overpass and intensive ground sampling, the Throckmorton test site was flown in April, May, and July, 1973, and another flight is scheduled for October, 1973. The College Station test site was flown in March, April, May, and July, 1973.

2.3 Test Site Characterization

The ten Great Plains Corridor test sites are being mapped and characterized in terms of soils, vegetation, climate, and management history. Each site is being characterized within a 10km X 10km area centered on the test site. This effort employs NASA-obtained high-flight aerial photography, existing large scale black-and-white photographs, RSC obtained color-IR aerial photographs, and ground survey data to locate and document the kind and quality of land resource uses in the test site area. These data will provide baseline information for evaluating differences in spectral characteristics and changes in reflectance patterns.

2.3.1 Classification System

A Resource and Land Use Inventory classification system has been developed (Appendix A). This classification scheme was developed because the different schemes proposed in the literature had terminology incompatibility and the same term is often used differently in several systems. The classification scheme described incorporates the use of soil surveys and vegetation resource and land use information as independent parameters for identifying land parcels within the test site.

Soil surveys and other available soils information have been obtained for all sites. The following six sites have had soils information coded and are ready for transfer to computer storage: College Station, Mandan, Sand Hills, Sonora, Weslaco, and Woodward.

The soil data at each site is analyzed according to the series descriptions and classification in the Soil Taxonomy of the National Cooperative Soil Survey. Based on this information, the various soils are combined into suitable units for use with the computer generated grey-scale map. These soil data are transfered to acetate for use as overlays in the test site characterization.

In developing the soil and vegetation resources and land use data that would be useful for this investigation, it was necessary to develop a scale that could be used with several scales of aerial photography. Since the soil survey maps and aerial photography varied from 1:15,000 to 1:62,5000, a scale of 1:30,000 was selected as being best for consolidating the map units. At this scale (1:30,000), the soil information can be easily transfered to several different scales. A Kail Reflecting Projector is used to change the scale of the 1:30,000 map to 1:135,000, or to 1:7,000 scale without intermediate steps.

2.3.2 Characterization Technique

The following procedures are being used in the characterization of the sites and the development of computer compatible data:

1) Determine the frame or frames of photography to be used in making the characterization of the sites. All sites have 1:60,000 or 1:120,000 color-IR positive transparencies available for use in the characterization.

2) Secure 7.5 minute series topographic maps of the sites. These topography maps are with acetate overlays to record the resource and land use data at a scale of 1:24,000. This scale will be usable with the computer generated grey-scale maps of Band 5 MSS data.

3) Determine the area to be characterized. The test sites are located on the color-IR positive transparencies and the topographic map of the area. A 10km X 10km or 7km X 7km area is centered on the site and outlined on the acetate which is secured to the topographic map.

4) Characterize the site according to resource and land use. The 10km X 10km areas are characterized with the use of the color-IR positive transparencies of the site and recorded on the acetate overlay on the 7.5 minute topographic map for the site. The information

is characterized according to the guidelined for coding resource and land use data in Appendix A. The soil information is assigned number codes for each site individually. All resource and land use data within the 10km X 10km area are recorded on data sheets for the ten test sites.

5) <u>Transfer the resources and land use data to the computer generated grey-scale map</u>. Band 5 MSS grey maps are used for the delineation of the resource, land use and soil types information. Within the 10km X 10km area, the center 7km X 7km area is "extracted" and the computer generated grey-scale maps are then blocked off into subareas corresponding to specific resource and land uses within this area. The 7km X 7km area is stored in the computer centered on the test site. The border area within the 10km X 10km area and surrounding the 7km X 7km area allows better interpretation of edge areas of the 7km X 7km area. It also provides the capability for easily expanding to computer process the greater area.

6) <u>Store the resource and land use information in the computer</u>. The 7km X 7km areas that have been recorded on the grey-scale map are stored in the computer as a "mask" for each test site. This data will provide baseline information for evaluating differences in

spectral characteristics and changes in reflectance patterns from different soil types, vegetation types, or land use patterns.

3.0 ANALYSIS ACTIVITIES

Significant progress was made during the reporting period in receipt and analysis of ground observations and ERTS-1 MSS data. Changes in green biomass measured at the ten test sites provide a basis for indicating progression of the vernal advancement northward through the Great Plains Corridor. The following section describes the analysis of ground observations and ERTS-1 MSS data with respect to monitoring the vernal advancement.

3.1 Ground Observations

Procedures and type of data being collected in conjunction with satellite overpass at the ten Great Plains Corridor project test sites are detailed in RSC Progress Report 1978-1. For the 1973 growing season, cooperators at each of the test sites were requested to begin collecting ground data corresponding with the ERTS-1 overpass immediately preceeding the expected date of spring green up. They were then instructed to sample in conjunction with satellite overpass immediately following the first spring flush of vegetation growth. Figure 3-1 reveals the chronolgical order of the onset of spring at each test site.

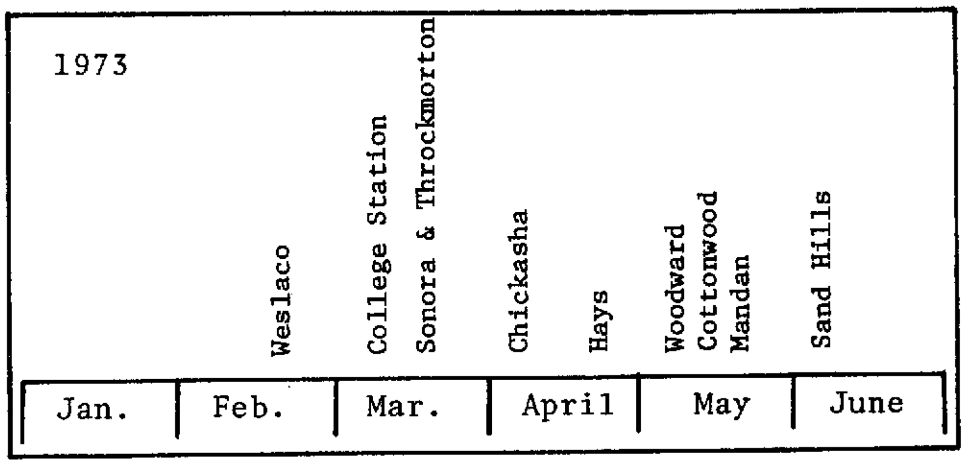

Figure 3-1. Time of occurrence at initial spring greenup at ten Great Plains Corridor test sites in 1973.

With respect to the advance of spring (vernal advancement) northward through the Great Plains Corridor, only two test sites, Woodward and Sand Hills, appear to be out of place. Both of these sites are dominated by sandy soils supporting primarily warm-season vegetation, whereas, the other eight G.P.C. sites are dominated by clayey or loamy soils supporting a mixture of warm and cool season species. Since sandy soils warm-up much more slowly than clayey or loamy soils due to poorer heat conductivity through the porous sandy soil mass, it is to be expected that these sites would experience a delayed greenup in the spring. In addition, the "absence" of cool season species, which respond more rapidly than warm season species with the onset of spring, is partly responsible for the delayed greenup at these sites. It should be noted also that the more southerly Woodward site greened up approximately one month before the northern Sand Hills site.

Among the more important vegetation parameters being measured at the G.P.C. test sites are green biomass, dry (total) biomass, and moisture content of the vegetation.

3.1.1 Green Biomass

Green biomass is probably the most sensitive parameter for detecting significant changes in vegetation condition. 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.

Green biomass (Fig. 3-2) measured at the four Texas sites during the time of maximum green biomass

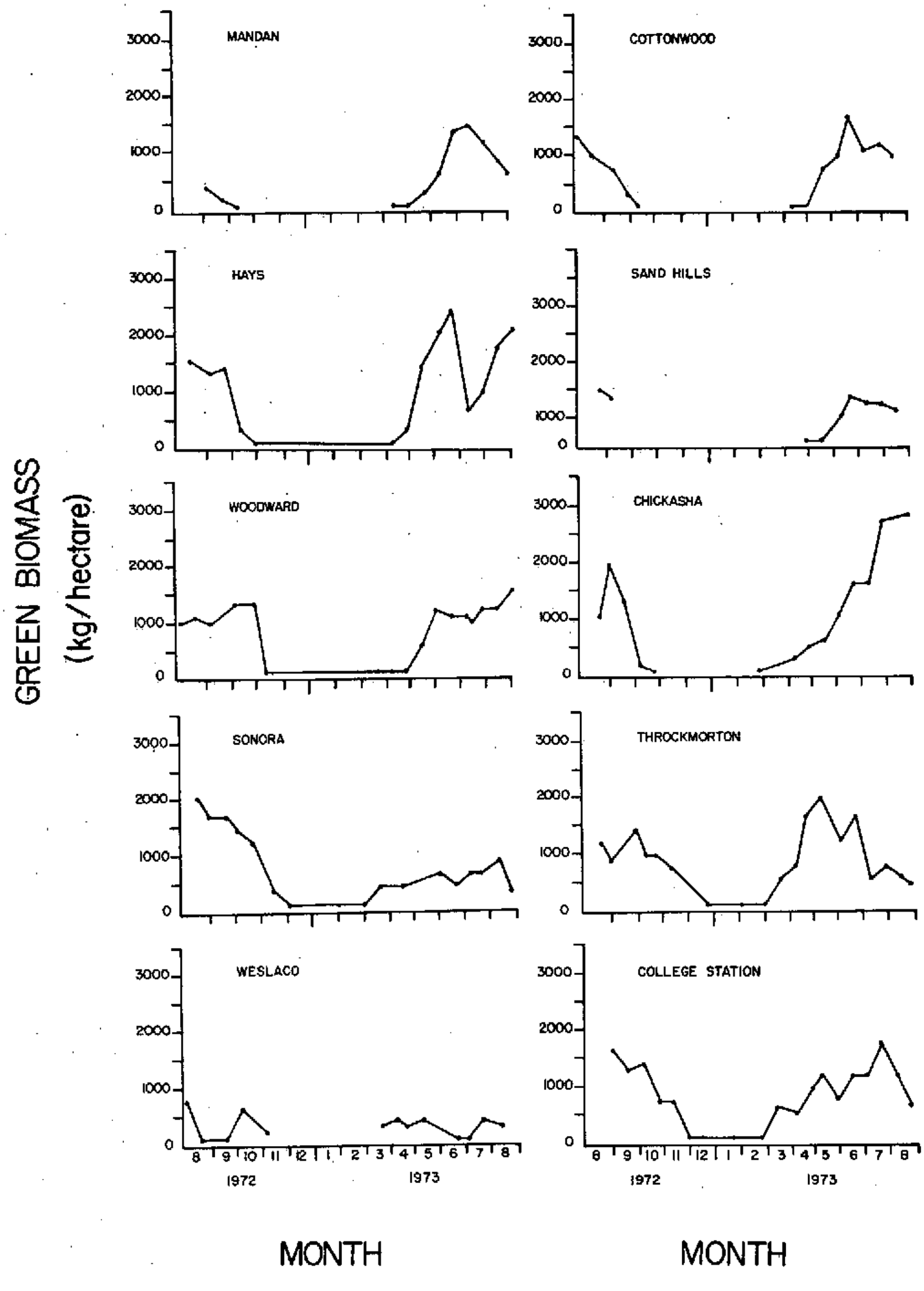

Figure 3-2. Green biomass at ten Great Plains Corridor test sites as measured for the first 13 months of ERTS-1 coverage.

averaged about 1350 kg/hectare. For the Oklahoma and Kansas sites the average maximum was 2350 kg/hectare, and the three northern sites averaged 1350 kg/hectare at their maximum.

In late April and early May, 1973 green biomass for the Texas sites was relatively high, averaging 940 kg/hectare. The Oklahoma and Kansas sites were just beginning to green-up and averaged 390 kg/hectare. The northern sites had only 100 kg/hectare, and this was due primarily to the growth cool season species.

In late May and early June the average green biomass for the Texas sites was somewhat lower (840 kg/hectare) due to drier conditions at the Throckmorton and Weslaco sites. The Oklahoma and Kansas sites were in good condition at this time averaging 1460 kg/hectare, and the northern sites had begun to greenup quite well with an average of 730 kg/hectare.

More favorable growing conditions in early July caused an increase in the average green biomass for the Texas sites (1230 kg/hectare). The Oklahoma and Kansas sites averaged 1680 kg/hectare at this time, an increase of 220 kg/hectare over the early June period, even though the Kansas site showed a large reduction due to drought. The northern sites continue to show an increase in green biomass with an average of 1120 kg/hectare.

All of the southern (Texas) and northern sites were experiencing summer drought by late August and, consequently showed a significant decline in green biomass (Fig. 3-2). The southern sites averaged only 440 kg/hectare, and the northern sites had dropped to 780 kg/hectare. All of the central Great Plains sites (Oklahoma and Kansas) had good moisture in July and August and continued to produce new green matter. Green biomass measurements showed an average of 2200 kg/hectare at these three sites.

It is evident from these data that ground measurements were adequate for measuring temporal changes in vegetation condition within the Great Plains Corridor. The advance of spring northward, drought duration, and extent of green biomass reduction were monitored by the test site network.

3.1.2 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 3-3 shows the variations in dry biomass for the ten test sites for the first 13 months of ERTS-1 coverage. This time period corresponds with ERTS-1 cycles 1 through 22.

During the 1973 spring and summer period reported herein, the maximum dry biomass ranged from 3680 kg/hectare at the Chickasha test site to 560 kg/hectare at Weslaco. Minimum dry biomass ranged from 1980 kg/hectare at the Mandan test site to 180 kg/hectares at Weslaco.

Grazing treatment can cause a considerable influence on fluctuations in measured dry biomass. For example, green biomass at the Chickasha test site continued to increase from late April to late May due to the increase in percentage of the vegetation that was green matter. However, dry biomass decreased from late April to mid-May, since cattle were continuously grazing the pastures during this period. Following the mid-May sampling,

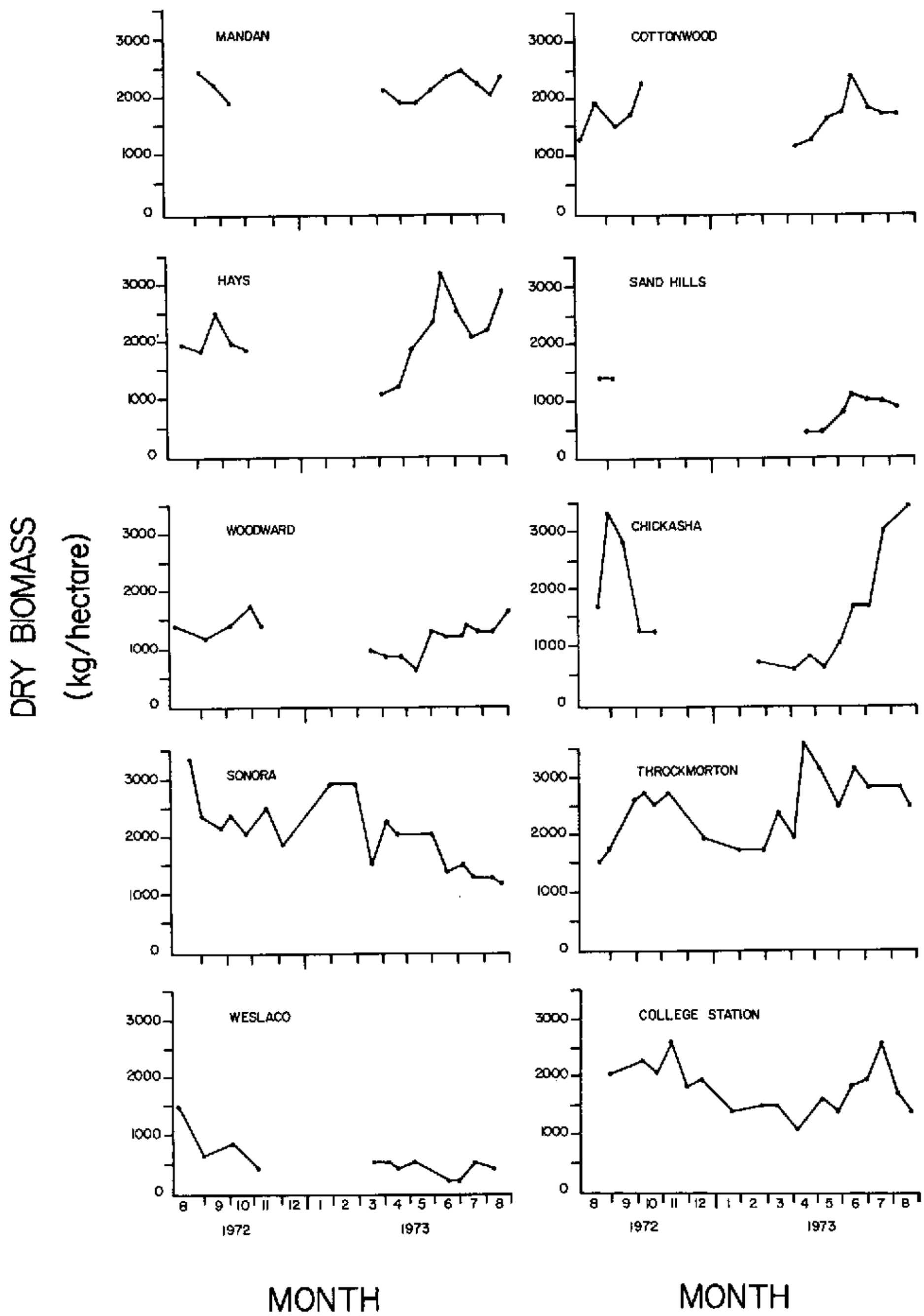

Figure 3-3. Dry biomass (total standing herbage expressed on a dry weight basis) at ten Great Plains Corridor test sites as measured for the first 13 months of ERTS-1 coverage.

five inches of rain stimulated growth such that by the late May sampling dry biomass had increased about 40%. The percentage of the vegetation that was green matter was essentially unchanged on the two May dates.

3.1.3 Vegetation Moisture Content and Precipitation

Moisture content of the vegetation is being measured at the ten Great Plains Corridor test sites at the time of each sampling, since moisture stress is expected to influence the spectral reflectance properties of plants. Moisture content of vegetation ranged from almost no moisture at Sonora (Feb. 3, 1973) to 75% moisture at College Station (April 25, 1973).

Moisture content of the vegetation is generally indicative of growing conditions, with higher moisture contents indicating better growing conditions. Since the amount of moisture in the vegetation is greatly influenced by the quantity of green plant material, the graphs of these two humidity and cool temperature can cause the moisture content to be relatively high, irrespective of the quantity of green plant material present. For example, at the Throckmorton test site, green biomass decreased approximately 20% between August 9, 1973 and August 24, 1973 (Fig. 3-2), while the moisture content increased (Fig. 3-4). This discrepancy can be at least

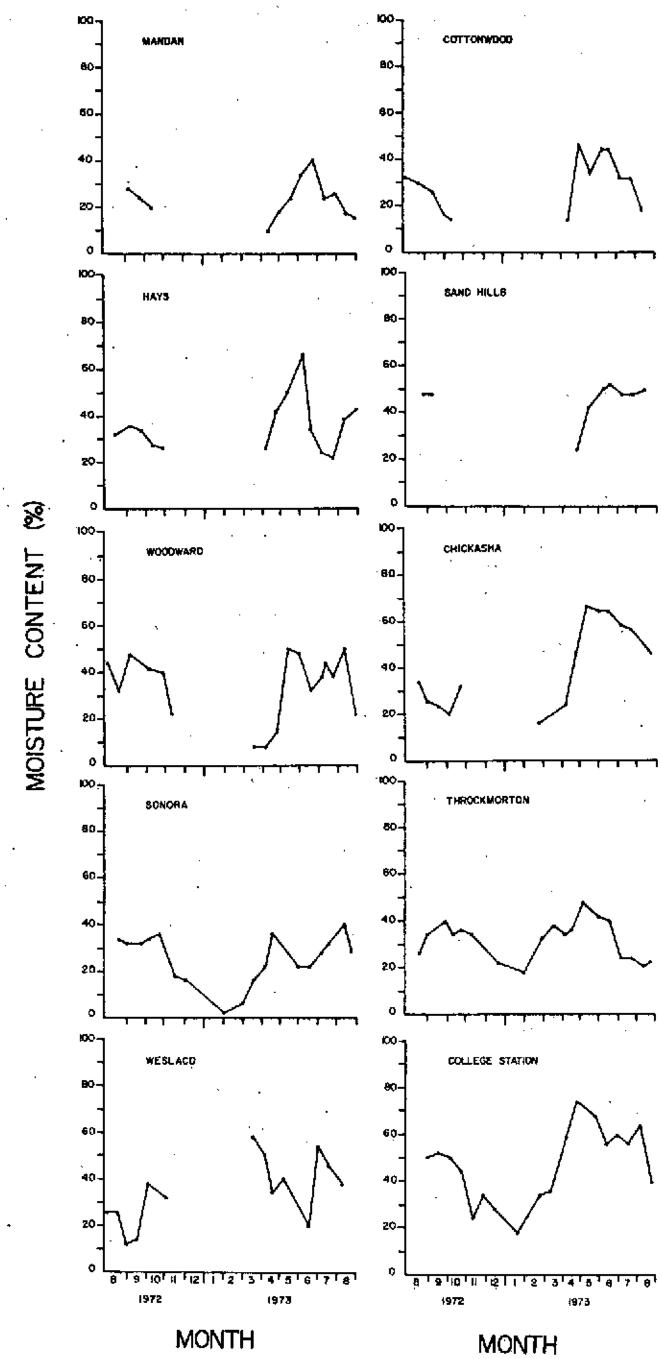

Figure 3-4. Percentage moisture content of the vegetation at ten Great Plains Corridor test sites as measured for the first 13 months of ERTS-1 coverage.

partially attributed to the 1.5 inch rainfall that fell between the two sample dates.

The relationship between rainfall and moisture content of the vegetation at the Throckmorton test site during the early part of the growing season (February to May) can be seen in figure 3-5.

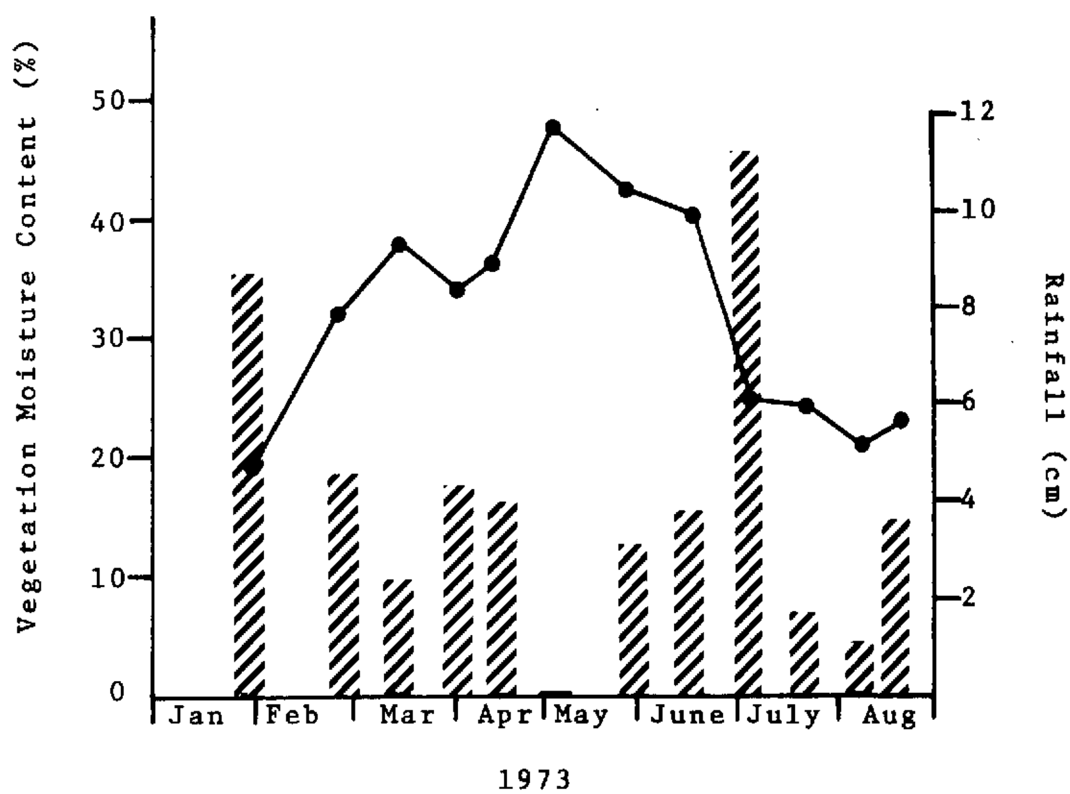

Figure 3-5. Vegetation moisture content and rainfall accumulation between sample dates at the Throckmorton test site for the vernal phase in 1973.

There appears to be a time lag in the active incorporation of precipitation moisture into plant tissue, and is related to the time required to initiate new growth. Temperature is also important in this "time lag" and in determining the amount of moisture lost to evaporation and transpiration. It should also be noted that a lack of appreciable precipitation is generally followed by a reduction in moisture content of the vegetation (Fig. 3-5).

These anticipated occurrences have been effectively monitored by the test site network in the Great Plains Corridor. Other ground observations and weather information are being used to aid in understanding changes in vegetation measured on the ground and by ERTS-1.

3.2 Manual Interpretation Capabilities

ERTS-1 image products (MSS bands 4,5,6, and 7) have provided excellent utility in precise locations of G.P.C. test sites. Additionally, they are routinely used to assess cloud cover and data quality prior to placing retrospective orders for color composites and MSS digital tapes. Manual interpretation capabilities from the color composite imagery (Bands 4,5,7) has been shown to be dependent upon image color balance. To aid in evaluating manual interpretation capabilities from ERTS-1 MSS color composite imagery, a series of carefully color balanced imagery were obtained from the Western Aerial Photography Laboratory, ASCS,USDA.

3.2.1 Identification of Rangeland Features

Many important rangeland features are readily interpreted from the MSS color composite imagery. Typically, the woodland-grassland complex in central Texas is best discriminated on fall 1972 imagery (Obs. I.D. No. 1128-16311). The Blackland Prairie, much of which is now cultivated, is readily discernible from adjacent natural vegetation types on this image. In the vacinity of College Station, Texas, winter annual grass pastures are easily identified on dormant season imagery (Obs. I.D. No. 1164-16410). Spring growth was initiated prior to the March 16, 1973 image at this location (Obs. I.D. No. 1236-16314) and vigorous growth of cool season native vegetation is dominant in the scene. By May 9, 1973 (Obs. I.D. No. 1290-16312), the extraordinarily vigorous growth of both warm and cool season vegetation differentiates the naturally vegetated areas in a brilliant red; however, many important features are not discernible at this season.

Due to an early spring drought in the vicinity and west of the Sonora test site, it is possible to observe in one image (Obs. I.D. No. 1275-16484) the complete array of vegetation conditions, from dormant to vigorous, healthy native rangeland (following the vernal advancement). The spectacular contrast provides evidence that regional drought on rangelands can be manually interpreted and mapped from MSS color composite imagery.

In north central Texas, rangelands are easily identified from adjacent croplands. A temporal image sequence (Obs. I.D. Nos. 1058-16410, 1184-16414, 1238-16421, and 1292-16420) illustrates the potential of color composite imagery for rangeland inventories. Favorable local weather in the vicinity of Throckmorton, Texas, during the early fall of 1972 produced observably good growing conditions (Obs. I.D. No. 1058-16410). In January, only the most freeze resistant vegetation, primarily winter wheat, appeared as healthy vegetation. However, tonal contrast shows the areas heavily infested by mesquite, an important noxious rangeland weed (Obs. I.D. No. 1184-16414). On this date areas infested with Juniperus spp. are also uniquely identified. The tonal contrast for rangeland heavily infested with mesquite improved through March (Obs. I.D. No. 1238-16421) and provides the capability for mapping mesquite areas throughout the region. In April, following vernal progression past the test site area, rangeland condition is generally recognizable from the color tones associated with vegetation growth (Obs. I.D. No. 1256-16421). Areas having greater residual biomass and supporting warm season vegetation are more highly reflective and appear lighter than comparable rangeland in poor condition.

Approximately one week prior to the March 18, 1973 image (Obs. I.D. No. 1238-16421) a section (640 acres) of rangeland was burned on property operated by rancher Bob Brown. The burned area appeared as a block square on the March image and remained obvious through April 5, 1973 (Obs. I.D. No. 1256-16421). Further observations of this documented area are anticipated throughout the 1973 growing season.

Landscapes and terrain features are frequently best delineated on dormant season MSS imagery. In the vicinity of the Woodward test site, land forms and soil associations are readily apparent on the December 1, 1972 image (Obs. I.D. No. 1131-16465). However, land use patterns are typically more apparent in the spring or early summer (Obs. I.D. No. 1329-16463). In this June 17, 1973 image a definite land use contrast is apparent for the same landscapes at the Texas-Oklahoma boundary. A much greater area is retained in rangeland in Texas than in Oklahoma, where dryland cropping is abundant.

Other observations include extensive flooding along rivers in Kansas in April (Obs. I.D. No. 1257-16464); early season dormancy at Cottonwood, South Dakota following killing frost in October (Obs. I.D. No. 1081-17062); extensive management effects on natural vegetation at the Wichita Mountain National Wildlife Range in Oklahoma (Obs. I.D. No. 1256-16415); and retrogradation of natural vegetation following vernal advancement at the Weslaco test site in the spring of 1973 (Obs. I.D. Nos. 1254-16325 and 1308-16323).

3.2.2 Detection of Rangeland Fertilization Response

Observations were made of fertilizer treatments at the Hays, Kansas, test site during the 1973 growing season. On May 2, 1973, a 32 acre pasture containing sampling subsite No. 1 was fertilized with 56kg N/hectare (ammonium nitrate). The adjoining 32 acre pasture (subsite no. 2) was left untreated as a control. The next adjoining 32 acre pasture (not monitored) was also fertilized at the same rate, and the fourth adjoining 33 acre pasture (subsite no. 3) was also left as a control plot.

The control pastures were stocked with 9 head of yearling steers on May 1, while the fertilized pastures were stocked with 15 head of yearling steers. All pastures were grazed until October 1, 1973. Grazing history and herbage production were similar for all four pastures.

Table 3-1 reveals that the two adjoining pastures being monitored (sampling subsites 1 and 2) had approximately the same quantity of green biomass and a similar amount of dry biomass on April 25, 1973 just prior to fertilization. On May 14, 1973 the ground observer noted significantly more green vegetation on the fertilized pasture. The table shows that by May 14 the control pasture had a 620% increase in green biomass due to normal spring greenup, whereas the fertilized pasture had a 760% increase. By June 5 the fertilized plot showed a 30% greater green biomass and total dry biomass than the unfertilized pasture. However, by June 18 the 70% heavier grazing by cattle for 50 days on the fertilized pasture had obviously affected the herbage. Consequently, the fertilized pasture showed a 20% lower green biomass and a 5% lower total dry biomass than the control.

Table 3-1. Herbage yield on two adjoining pastures at the Hays test site prior to and following fertilization. The control pasture is subsite 1 and the fertilized pasture is subsite 2.

Date (1973)	Green Biomass (kg/hectare)		Total Dry Biomass (kg/hectare)	
	Control	Fertilized	Control	Fertilized
April 25	220	250	1120	830
May 14	1610	2130	2010	2370
June 5	2580	3700	2770	3900
June 18	3000	2510	3750	3590

Pre fertilization black-and-white and color composite ERTS-1 images (e.g. Obs. I.D. No. 1257-16462, April 6, 1973) do not show differences between the four treatment pastures. Although the Hays pastures are very small (32 acres each), differences between the fertilized and unfertilized pastures can be detected under magnification on ERTS-1 MSS black-and-white imagery (Ob. I.D. No. 1294-16515) acquired on May 13, 1973 - only eleven days after the fertilizer was applied. Band 5 shows the fertilized pastures to be somewhat darker than the control pastures. These differences were not visually detectable on Bands 4,6, and 7.

May 31, 1973 (Ob. I.D. No. 1312-16514) produces a better differentiation between treatments on the Band 5 image. Again black-and-white Band 4,6, and 7 images do not show obvious differences. The color composite transparency (Bands 4,5,7) shows the fertilized pastures as a very rich deep red and the control pastures as a reddish purple color.

On June 18, 1973 (Ob. I.D. No. 1329-16454) the color composite transparency shows good differentiation between treatments, but the richness of the colors is reduced. The fertilized pastures are light red and the control pastures are light purplish red. None of the black-and-white images reveal treatment differences.

On all dates the color composite prints did not show treatment differences as well as the color composite transparencies.

3.3 Digital Data

Digital data analyses during this reporting period have been primarily concentrated on the routine preparation of site processing reports of 7km X 7km areas containing the G.P.C. test sites. These site processing reports include means and covariances for all four bands of the MSS reflectance data contained within the 7km X 7km site areas. These data are corrected for seasonal sun elevation angle changes and "transformed vegetation index" values are calculated. The nature of these corrections and calculations are described and data processed during this reporting period are detailed below.

3.3.1 TVI and Processed MSS Data

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 and mapped from ERTS-1 MSS color composite imagery, it is desirable to document the seasonal vegetation changes quantitatively.

It is well established that the foliage of green plants differentially absorb and 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 useful concept for monitoring natural vegetation changes. It was initially presented in RSC Progress Report 1978-1.

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".

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

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" or TVI is then

$$TVI = \sqrt{R + 0.5}$$

when R is the vegetation index. The TVI values will theoretically increase as the difference between Band 7 and Band 5 increases due to increased absorption of Band 5 energy and increased reflectance of Band 7 energy by green plant material.

Corrected mean MSS data and corresponding calculated TVI values for the test sites and dates processed during this reporting period are presented in Table 3-2.

3.3.2 Atmospheric Corrections

Investigation of the effects of atmospheric variation on the quality of the spectral data measured by the ERTS MSS system is continuing. Scenes expected to remain generally constant in their spectral response are being monitored. Specific analyses have been conducted on data obtained from downtown Bryan. The results of the initial spectral analyses were presented in RSC Progress Report 1978-1. Table 3-2 shows the data processed since that time. Site GP1 is the downtown Bryan

Table 3-2. ERTS-1 MSS Data Processed March - September, 1973 (corrected for sun elevation angle)

Name	Location	Date	MSS Band				
			4	5	6	7	TVI
GP1-Ø	30°33'N	11/28/72	10.12	7.33	6.92	5.69	0.612
X			8.43	5.99	7.34	7.07	0.763
Y			8.04	5.48	6.49	6.20	0.749
Z			8.65	6.42	6.97	6.56	0.715
Ø		3/16/73	10.61	8.06	7.8 0	6.31	0.615
X			7.40	4.67	7.47	7.25	0.846
Y			7.62	4.96	6.95	6.59	0.801
Z			7.71	5.55	6.90	6.28	0.749
Ø		5/8/73	9.27	6.91	8.17	3.98	0.481
X			6.95	4.24	8.24	4.63	0.737
Y			6.77	4.11	7.96	4.12	0.707
Z			7.41	5.49	7.32	3.45	0.521
GP2	30°18'N	11/13/72	8.31	5.88	6.55	6.42	0.737
		11/30/72	9.15	6.62	6.94	6.51	0.701
		12/1/72	9.06	6.67	6.80	6.36	0.690
		1/23/73	9.78	7.37	6.75	5.98	0.629
		3/1/73	8.66	6.54	5.94	5.35	0.632
		3/18/73	8.64	7.90	7.56	6.73	0.648
		4/5/73	9.29	7.04	7.35	6.71	0.690
		4/24/73	8.16	6.16	6.42	5.90	0.692
		5/29/73	9.19	7.45	7.42	6.71	0.669
GP3	33°15'N	12/19/72	9.49	7.46	7.07	6.10	0.632
		2/10/73	9.46	7.55	6.90	6.06	0.625
		3/18/73	7.71	7.25	7.52	6.69	0.678
		4/15/73	8.60	6.36	7.66	7.17	0.748
		5/11/73	8.01	5.23	7.56	6.76	0.793
		5/29/73	7.90	5.70	7.48	6.88	0.770
GP4	36°37'N	12/1/72	9.13	6.80	6.24	5.37	0.619
		12/19/72	17.85	13.92	10.93	7.62	0.455
		4/6/73	9.01	7.41	7.23	6.45	0.656
GP5	38°55'N	10/26/72	9.88	7.99	7.83	6.77	0.646
		12/2/72	9.74	7.43	5.63	5.88	0.619
		3/20/73	9.78	8.09	7.57	6.81	0.643
		4/6/73	10.04	8.42	8.03	7.02	0.640
		6/17/73	8.95	7.07	8.42	7.59	0.731

Table 3-2. (continued)

Name	Location	Date	MSS Band 4	5	6	7	TVI
GP6-1	42°39'N	9/4/72	8.52	6.63	6.01	6.40	0.694
2			8.59	6.79	6.98	7.00	0.718
3			7.90	5.96	5.83	6.42	0.733
4			7.60	5.74	6.02	6.34	0.741
GP6-1		5/15/73	9.68	8.10	7.74	6.75	0.640
2			10.13	8.72	8.26	7.19	0.635
3			9.84	8.44	7.86	6.81	0.627
GP6-2		6/1/73	9.77	8.07	7.90	6.74	0.640
			9.83	8.12	7.85	6.75	0.638
GP7	43°50'N	9/14/72	10.14	8.18	7.95	7.29	0.665
		10/12/72	9.88	7.99	7.00	5.85	0.588
		1/10/73	38.90	30.91	22.35	18.81	0.506
GP8	46°45'N	10/12/72	9.28	7.16	6.88	6.10	0.648
		12/5/72	52.64	41.55	33.26	24.47	0.491
GP9	26°30'N	1/22/73	8.75	6.60	6.19	5.39	0.632
		4/3/73	8.63	6.15	8.54	8.06	0.796
GP10	35°14'N	9/19/72	7.78	6.59	6.70	5.78	0.659
		11/30/72	8.52	6.67	6.31	5.54	0.639
		2/10/73	8.05	6.53	6.22	5.85	0.667
		4/5/73	7.58	6.27	7.16	6.78	0.734

site. With the exception of the May data, all signature curves fall within a standard deviation of individual data sets. The May (Obs. I.D. No. 1289-16254) data set appears to be erroneous for some undetermined reason; possibly due to standing water due to rains the previous afternoon.

These investigations seem to reconfirm the contention that for sites within the Great Plains Corridor, the currently used sun angle correction is sufficient to obtain meaningful data from ERTS-1 under clear sky conditions.

3.4 Analysis Summary

Green biomass determinations appear to be sensitive to changes in the condition of vegetation within the Great Plains Corridor region. The northward progressing vernal advancement (green wave) has been monitored by the ground measurements and regional and seasonal drought has been documented.

Spring advanced northward by G.P.C. sites in latitudinal succession except for the Woodward and Sand Hills sites, which are dominated by sandy soils. These two experienced a delayed greenup, presumably due to the additional time required for these soils to warm up and the predominance of warm season vegetation.

At most of the test sites initial greenup lasted from one to two months followed by one or two short periods of drought, then a re-greenup period, which dropped off abruptly in late August. Moderate seasonal drought conditions were evident in the reduction of green biomass and vegetation moisture content, and to some extent in dry biomass. The magnitude and rapidity of decline varied at each test site, but regional differences were observed and documented.

3.4.1 Relationships of TVI to Ground Data Measurements

An investigation was initiated to use the transformed vegetation index (TVI) in relating unmarked ERTS-1 MSS digital data to ground data measurements. Twenty-nine data sets available near the end of the reporting period were analyzed statistically to determine the relationship of TVI to green biomass, percent green estimate, moisture content, and dry biomass. These data sets were primarily from the five southern test sites and represent data collected from August 1972 to June 1973.

The initial step-down multiple regression analysis using all twenty-nine data sets indicated that dry biomass, percent green estimate, moisture content and the interactions of dry biomass, percent green estimate, moisture content and the interactions of dry biomass with moisture content accounted for 60% of the variation in TVI. In a second analysis the green biomass and moisture content parameters and their interaction accounted for approximately 55% of the variation in TVI; however, green biomass alone could not be significantly related to TVI at all locations.

Further analyses related the above independent parameters to TVI at selected locations having sufficient data sets for regression analysis. Of the five locations utilized in this analysis, green biomass was best related to TVI at Throckmorton, a relatively uniform grassland area, and least related at College Station, a heterogeneous woodland-grassland area. At Sonora, a shrubland-grassland, the relationship was intermediate. These data suggested that the value of the TVI as an indicator of "range feed condition" at this stage of ERTS-1 digital data processing could best be evaluated at the more uniform grassland site at Throckmorton.

The initial regression analysis of ground data from Throckmorton with TVI calculated from MSS digital data indicates that vegetation moisture content and percent green estimate, along with their interaction, accounts for 99% of the variation of TVI for eight sampling dates. The green biomass parameter alone accounts for 89% of the variation in TVI at this location. When the interaction (% moisture X green biomass) is added to the regression of green biomass with TVI, the accountable variation increases to 93%. The regression equation for TVI is as follows:

$$Y = 0.627 + .025\, X_1 - .0003\, X_1 X_2$$

where

$\hat{Y}$ = Transformed Vegetation Index

X_1 = green biomass as kg/hectare

X_2 = moisture content (percent)

Figure 3-6 shows the relationship of TVI and green biomass measured for eight dates at the Throckmorton test site.

Further investigation was made to assess the relationship of the independent parameters to TVI at Throckmorton. A scatter diagram (Figure 3-7) shows that TVI was underestimated at very low green biomass levels and somewhat overestimated at two measurement dates. Another scatter diagram (Figure 3-8) shows that vegetation moisture content had little effect on TVI until the moisture content exceeded 13%.

The percent green estimate parameter is also well correlated with TVI values at the Throckmorton test site (Figure 3-9). Although dry biomass was eliminated from the original multiple regression equation, the Throckmorton data indicates that there is a significant influence of standing dry biomass accumulated above approximately 1700 kg/hectare (Figure 3-10). It is possible that this affinity may indicate a more direct relationship with height of standing biomass than yield. Further analyses with larger data sets are needed for more locations before accurate generalizations can be made as to the major factors effecting variation in TVI.

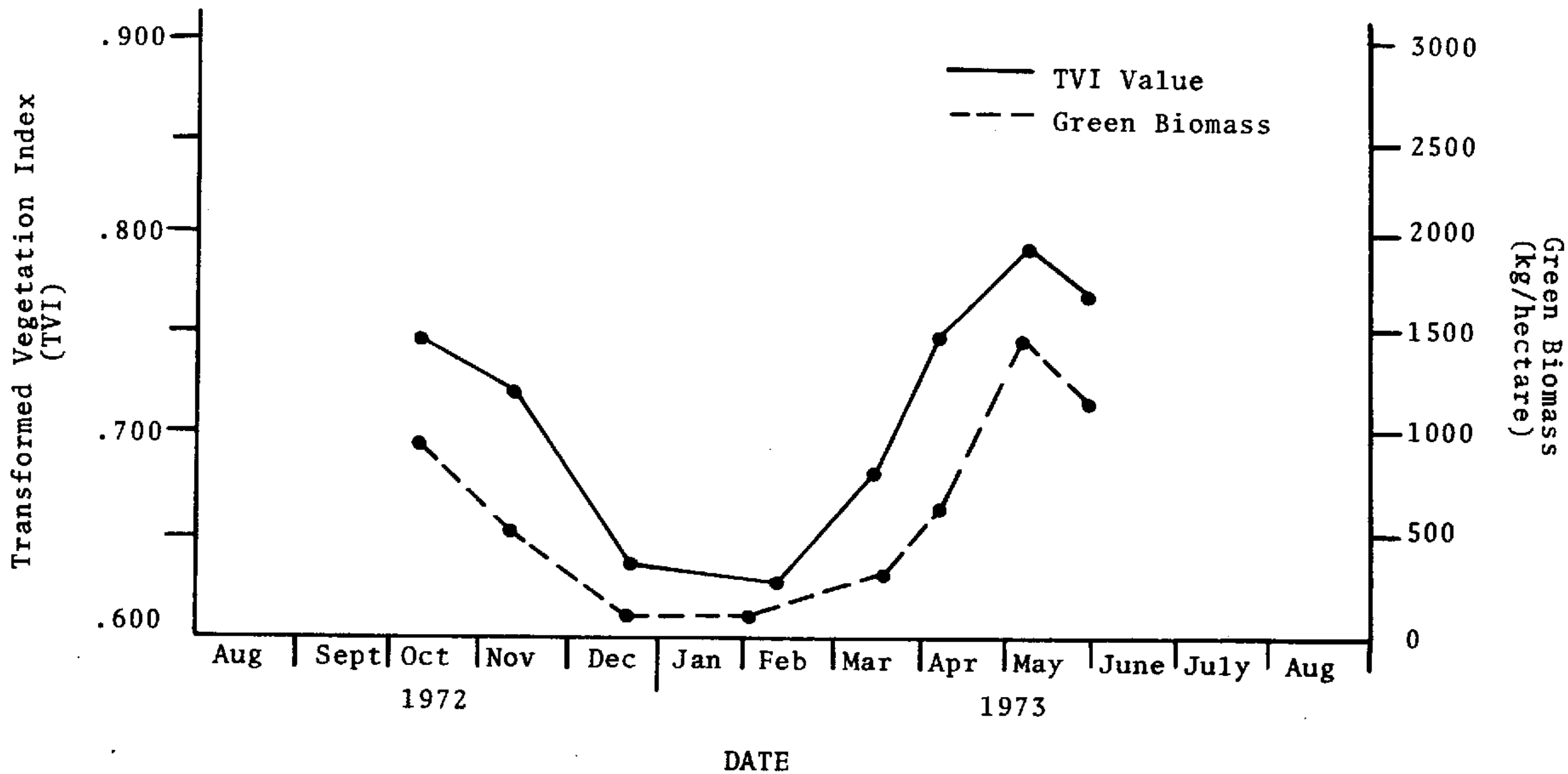

Figure 3-6. Graph showing relationship of transformed vegetation index and and green biomass measure for eight dates at the Throckmorton test site.

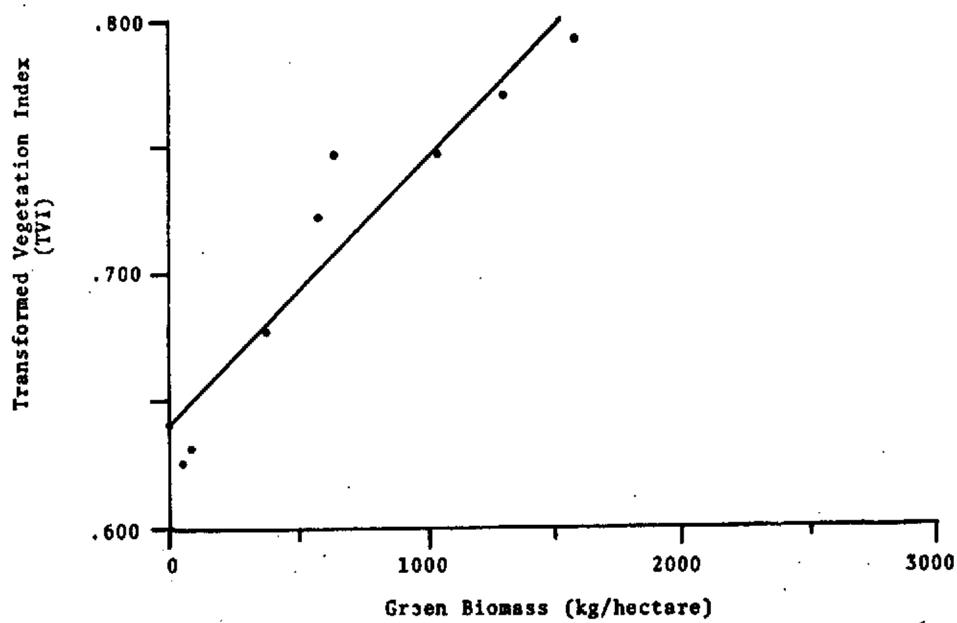

Figure 3-7. Scatter diagram showing the relationship of TVI to green biomass measured at the Throckmorton test site.

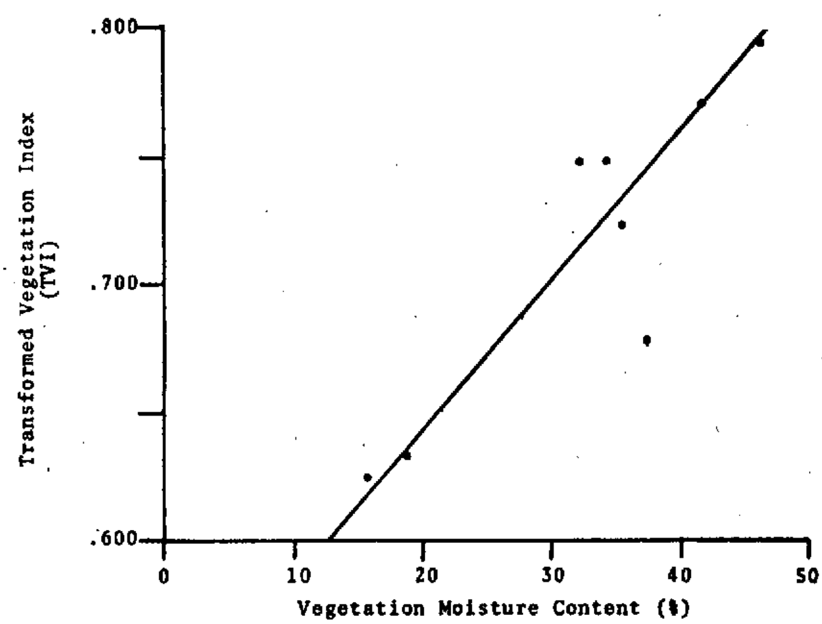

Figure 3-8. Scatter diagram showing the relationship of TVI to vegetation moisture content measured at the Throckmorton test site.

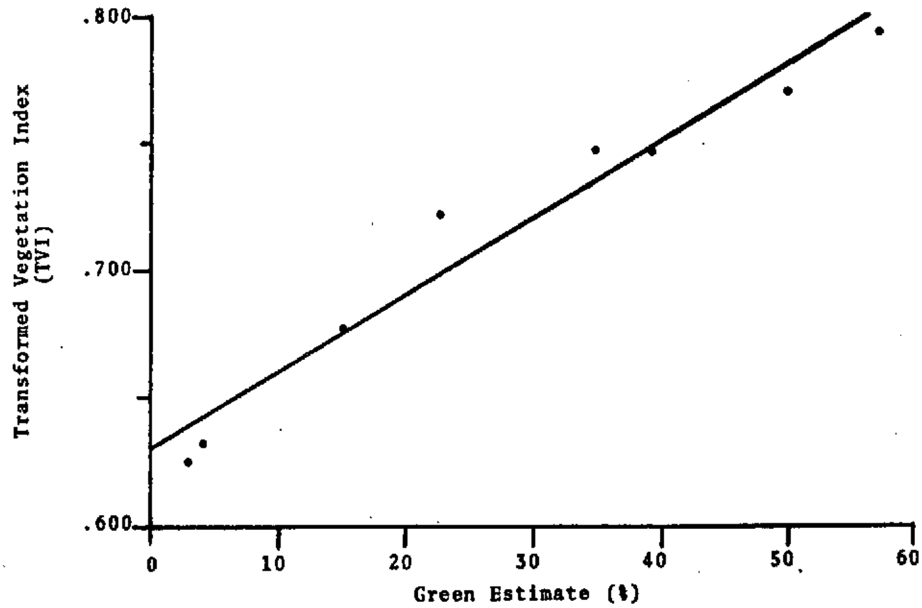

Figure 3-9. Scatter diagram showing the relationship of TVI to percent green estimate measured at the Throckmorton test site.

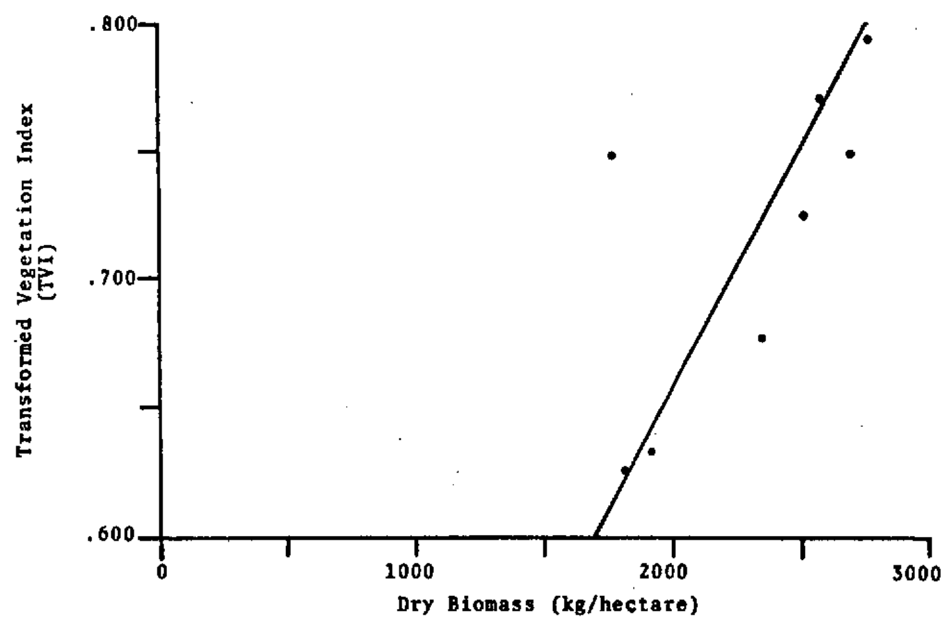

Figure 3-10. Scatter diagram showing the relationsip of TVI to dry biomass measured at the Throckmorton test site.

Minimum TVI values occur in the dormant season and appear to be relatively stable at about 0.63 for grassland vegetation that is dormant. Lower values have been observed for sites other than rangelands (i.e. urban areas, and cropland areas) and on snow covered rangeland (i.e. Cottonwood test site, Obs. I.D. No. 1171-17065).

Analyses completed during the reporting period are adequate to indicate that the transformed vegetation index (TVI) values are well correlated with ground measurements made on uniform grassland vegetation. The fact that the relationship is poor for heterogeneous woodland-grassland types indicates the necessity for concentrating further analysis on ultimate subsite data. It is expected that the "masking" procedure will eliminate extraneous influences currently not accounted for within the 7 km X 7km areas used in calculating TVI data.

No attempt has been made to determine the environmental influences on the TVI parameter; however, it is anticipated that weather data available from all locations (e.g. Throckmorton data, Table 3-3) will be important in reducing the variance in TVI and constructing a useful model for using the TVI data product.

Table 3-3. Weather data corresponding with available ERTS data at the Throckmorton test site beginning September 1, 1972.

Satellite Coverage Date	Precipitation (inches)			Temperature (F°)					
	Since Previous Coverage Date	Last Ppt. Prior to ERTS Coverage Date		Date of ERTS Coverage			Since Previous Coverage Date		
		No. Days	Inches on Last Day	Mean	Max.	Min.	Mean	Max.	Min.
10-8-72	5.45	16	0.89	71	89	53	73	94	42
11-13-72	6.40	1	0.23	46	54	38	58	95	38
12-19-72	1.86	7	0.90	54	67	40	42	76	13
2-10-73	4.18	3	0.83	35	50	20	41	78	11
3-18-73	1.91	8	0.67	60	74	46	50	76	26
4-5-73	1.74	2	0.40	49	64	34	55	74	34
5-11-73	1.31	22	0.50	80	92	68	58	92	28
5-29-73	0.70	6	0.70	68	84	52	71	98	48

The TVI parameter appears to be most adequate for monitoring the vernal progression and retrogradation of vegetation within the Great Plains Corridor and has good potential for measuring green biomass in increments useful for regional applications. Additional analyses are necessary to ascertain the limits of the procedure and major factors influencing TVI measurements.

4.0 PROGRAM PROJECTION

4.1 Ground Data Collection

During the period of this second Type II report, ground data was collected during the early stages of spring through mid-summer. The Great Plains Corridor test site network will continue to collect this ground data in 1973 until after killing frost in the fall. At the Throckmorton and College Station test sites, these data will be obtained throughout the winter dormant period when significant changes in vegetation are expected to occur.

It is anticipated that all ten test sites will continue to collect ground truth data at least during the spring and early summer of 1974. Intensive sampling of the Throckmorton and College Station test sites will be continued during the 1974 growing season.

Ground information necessary for test site characterizations at the ten G.P.C. sites will be collected. This will permit masking procedures to be fully developed for extracting ERTS-1 data for specific areas within each of the test sites.

4.2 Test Site Characterization

Significant progress has been made in characterizing the test sites in terms of soils, vegetation, climate, and management history. Emphasis is being given to completing the characterization of a 10km X 10km area centered on the test site by mid-winter. A "mask" will be developed for each test site showing the interaction of the soils, vegetation, and land use for a 7km X 7km grey map area centered on the test site. The computer compatible masks will then be used to generate site processing reports for selected areas.

This characterization of the soils, vegetation, and land use will be published as a technical report upon the completion of the characterizations of all test sites. These data will provide baseline information for evaluating differences in spectral characteristics and changes in reflectance patterns from different soil types, vegetation types, or land use patterns.

4.3 Data Analysis

Data will be received and analyzed as outlined in the Data Handling Plan, including routine updating of ground observation summaries and routine processing of CCT's. Two activities, however, will be emphasized. One involves the extraction and analysis of "masked" (ultimate subsite) test site areas. The second involves statistical correlation of ground data and weather information with ERTS-1 MSS test site data through multiple regression and other analyses.

In addition the Dynamic Color Display described in Section 2.2.3 will be utilized to display ERTS-1 MSS CCT data and transformed data for selected test site areas to determine its capabilities for enhancing ERTS data interpretability.

4.4 Field Signature Acquisition System Study

During the period of this report a cooperative effort was established with NASA/JSC to obtain field signatures of rangeland species using the NASA/JSC Field Signature Acquisition System (FSAS). The primary FSAS sensor used during this study is a visible infrared interferometer spectrometer capable of measuring spectral signatures in the 450 nm to 2500 nm range. Grass reflectance characteristics of rangeland vegetation scenes were obtained at test site locations near College Station during the 1973 growing season. These measurements will serve to evaluate the temporal reflectance changes of rangeland vegetation.

The primary objective of this endeavor is to obtain fundamental information about the reflectance characteristics of natural vegetation. Two studies are underway to obtain information on: 1) the effect of simulated grazing conditions on the spectral reflectance, and 2) the integration of the reflectance of components of a grassland community into an overall reflectance of that community. Field plots were established and initial data collected. Periodic measurements were made during the 1973 growing season to characterize phenophase dependent vegetation changes.

Major phases of data reduction have been completed producing spectral reflectance curves valid in the region from 450 nm to 2500 nm. These curves provide an accurate spectral "data bank" of rangeland characteristics for the College Station area and simulated grazing condition of that range. Also, spectral reflectance characteristics of components of that grassland community are included. The precision of the reflectance curves is ±5% reflectance units.

The reduced spectra have been reformatted into bands simulating a multispectral sensor such as the ERTS-1 sensor. Two methods of analysis will be employed. One involves calculating the Transformed Vegetation Index (TVI) to determine the effects of smimulated grazing on this parameter. The other involves using a nonsupervised classification routine to operate on the simulated ERTS data. Results of these routines are correlated with data concerning the range sites in order to determine the uniqueness of site classification by remote sensing. To date, reduced spectra have been reformatted into ERTS bands. TVI calculations and computer classification have not been completed.

5.0 CONCLUSION

A basic hypothesis of the Great Plains Corridor project is that natural vegetation systems can be employed as "phenological indicators" of seasonal and climatic effects and that ERTS-1 measurements of naturally vegetated areas are adequate to provide a new information source for regional agriculture. The results of analyses of ERTS-1 data received to date indicate that MSS data provide the potential for quantitative description of vegetation conditions, substantiating the basic hypothesis.

The most significant development supporting the regional application of ERTS data is the development of a band ratio parameter calculated from MSS bands 5 and 7. One parameter, the Transformed Vegetation Index (TVI), utilizes the radiance difference measured for the two bands normalized over their sum. Comparison of the ERTS-derived TVI with ground data shows a quantitative relationship of this parameter with green biomass and vegetation moisture content.

Procedures have been developed for efficient handling of digital MSS data. These procedures are consistent with requirements for timely, broad regional application of ERTS information. The data are corrected for seasonal variations in solar declination. The computer processing techniques are readily adaptable to monitoring broad regions on a sampling basis.

The study has shown that ERTS-1 data acquisition in the Great Plains Corridor is adequately reliable for regional application. During the first year of operation (cycles 1-20), an average of 50% usable ERTS-1 data was obtained for the ten G.P.C. test sites. This is judged to be more than adequate for monitoring from an extended test site network.

5.1 Scheduled Activities

All aspects of the investigation are currently on schedule and continuance of routine data handling is anticipated during the next reporting period. Procedures developed for the analysis of ultimate subsite data will be initiated upon completion of test site characterization. Emphasis will be given to statistical analysis of ground observations and ERTS-1 data accumulated during the 1973 growing season. Investigations will be made into factors affecting ERTS-1 measurements and the resulting information employed in developing models for the use of ERTS-1 parameters in the Great Plains region.

5.2 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.

Specific application-oriented projects have been initiated as cooperative efforts with state and federal agencies. Each of these projects employs ERTS-1 data for evaluation of utility and cost-effectiveness for specific applications. Among these projects are:

Land Resource Management - A cooperative project among USDA Soil Conservation Service (SCS), Texas Agricultural Experiment Station, and Remote Sensing Center personnel was initiated to evaluate remote sensing to assist in land resource management. The feasibility and cost effectiveness of applying remote sensing techniques to aid in land resource inventory tasks performed by the SCS including: 1) updating soil surveys, 2) conducting "Conservation Needs Inventory", and 3) other types of inventories associated with land resource management are being determined. NASA/JSC obtained aerial photography of Brazos County during May 1973 in support of this project. Additional flights are scheduled for late 1973 and mid-1974. SCS personnel from the Temple, Texas office have been assigned to the project to participate in a training program and the collection of ground data.

Cotton Insects - This is a cooperative project between USDA Agricultural Research Service (ARS) and Remote Sensing personnel to obtain synoptic information needed in the state-side effort to control the advance of the bollworm and boll weevil in Texas. Control of cotton insects is a matter of enormous economic is significance in Texas. The ARS is conducting a pilot project of Frio County, Texas to determine insect population dynamics and effective eradication methods. It has been determined that timely agricultural land use data are extremely important for effective use of the inventory and control techniques. Airborne and ERTS-1 data have been acquired for Frio County. The ERTS-1 data are being computer processed to isolate and identify crop types, location, and acreages.

Coastal Dredging - This is a cooperative project among U.S. Coprs of Engineers, Civil Engineering Department, and Remote Sensing Center personnel to quantify the impact of dredging activities in Galveston Bay. The project was initiated as a ground-based study for the Corps of Engineers. The Center has offered to acquire and analyze remote sensing data as a compliment to the ongoing effort so as to determine the utility and cost effectiveness of remote sensing techniques in this application. ERTS-1 data have been acquired and several overflights by the Texas A&M University photoequipped aircraft have been conducted.

5.3 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.

APPENDIX A

I

RESOURCE AND LAND USE INVENTORY

Great Plains Corridor Project

"Guidelines for Coding Resource
and Land Use Data"

prepared by
Vegetation Systems Laboratory
Remote Sensing Center
Texas A&M University

October, 1973

II

Guidelines for Coding Resource and Land Use Data[1]

LOCATION AND DATA RECORD

Test Site - Name of test site.

Map derived - ERTS image number.

Band - MSS band grey-scale map used.

Date Acquired - Date that image was acquired by ERTS.

Area Reference - Upper left corner of area to be coded on grey-scale map. Recorded by lines and cell numbers.

Sub Area - Breakdown of each resource and land use area. Numbered consecutively beginning from left to right and proceeding top to bottom.

Coordinates:

Lines - Numbers on left side of grey-scale map.

Cells - Numbers on top of grey-scale map.

Soil Resource:

A coded numbering system assigned the soil series for each of the ten sites. This will be a separate system for each site.

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[1] See attached data recording sheet, Exhibit 1.

Vegetation Resource:

Type. Vegetation type is given a letter designation as follows:

Code letter	Vegetation Resource
C	Cropland
P	Pastureland
R	Rangeland
F	Forested lands
W	Non-forested wetlands
N	Other (non-agricultural)

Subtype. Subtype provides a subordinate description of each principal type presented above. Each subtype is assigned a numerical code in the following manner:

Type	Code No.	Subtype
Cropland (C)	1	row crops
	2	broadcast crops
	3	fallow
	4	orchards

Type	Code No.	Subtype
Pastureland (P)	1	warm season, sod-forming forages
	2	warm season, bunchgrass forages
	3	cool season, sod-forming forages
	4	cool season, bunchgrass forages
	5	mixed forages
Rangeland (R)[3]	1	open grassland
	2	grass-shrubland
	3	shrubland
	4	savannah
	5	wooded grassland
	6	woodland
Forestland (F)[3]	1	deciduous forest
	2	evergreen forest
	3	mixed forest

Water Resource:

Type. Water resource types are assigned coded numbers as shown on the following page.

[3] See attached sheet, Physiogromic Descriptions for Natural Vegetation Types, Exhibit 2.

Code No.	Type
1	Ponds < 40 surface acres
2	Lakes
3	Reservoirs
4	Rivers
5	Intermittent streams
6	Coastal waters

Size. This category applies to ponds only. Each pond is subdivided into size classes and given a coded number as below:

Code No.	Size Class
1	Ponds < 10 surface acres
2	Ponds 10-20 surface acres
3	Ponds 30-40 surface acres

Land Use:

Various functional land uses are coded with letters as shown on the following page.

Code	Land Use
C	Cropping
Cb	Cropping, broadcast crops
Cf	Cropping, fallow
Co	Cropping, orchards
Cr	Cropping, row crops
F	Forestry
Fc	Forestry, commercial
Fcg	Forestry, commercial, grazed
Fcu	Forestry, commercial, ungrazed
Fn	Forestry, non-commercial
Fng	Forestry, non-commercial, grazed
Fnu	Forestry, non-commercial, ungrazed
G	Grazing
Gn	Grazing, native grassland
Gt	Grazing, tame pasture
H	Hayland
I	Industrial
R	Recreation
T	Transportation
U	Urban and built-up lands
Z	Other (farmsteads, rural home, trailer park, rural business buildings)

Special Features:

This column allows data to include site information not appearing on the Location and Data Record. Included are areas that are to be omitted from the grey-scale map.

Exhibit 1

Great Plains Corridor Project

________________Test Site

Map derived from Image I.D. No.__________Band___________

Date Acquired____________________________

Area Reference___________________________

Sub Area	Coordinates		Soil	Resource Vegetation		Water Resource		Land Use	Special Features
	Lines	Cells		Type	Subtype	Type	Size		

Exhibit 2

Physiognomic Descriptions for Natural Vegetation Types

1. Open Grassland - herbs (grasses, forbs and grass-like plants) dominant; woody vegetation lacking or nearly so (<5 percent canopy area).

2. Grass-shrubland - herbs dominant; woody plants generally < 2.5m tall with >5<15 percent canopy area.

3. Shrubland - woody plants <2.5m tall dominant (>15 percent canopy area); herbs abundant to lacking; occasional woody plants >2.5m (<5 percent canopy area).

4. Savannah - woody plants >5.0m scattered throughout (<10 percent canopy area) with continuous cover of herbs.

5. Wooded Grassland - woody plants mostly 2.5-7.5m tall dominant (>10<30 percent canopy area); herb abundant with occasional thickets of woody plants < 2m.

6. Woodland - trees mostly 5 to 7.5m tall (>30 percent canopy area), mostly deciduous; herbs relatively abundant to sparse.

7. Forest (F) - deciduous or evergreen trees mostly > 7.5m tall (>30 percent canopy area), with or without woody understory; herbs mostly in natural or cleared openings.

Unpublished physiognomic descriptions originally developed by D. W. Deering and R. H. Haas.

The REMOTE SENSING CENTER was established by authority of the Board of Directors of the Texas A&M University System on February 27, 1968. The CENTER is a consortium of four colleges of the University; Agriculture, Engineering, Geosciences, and Science. This unique organization concentrates on the development and utilization of remote sensing techniques and technology for a broad range of applications to the betterment of mankind.