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**MONITORING VEGETATION CONDITIONS FROM
LANDSAT FOR USE IN RANGE MANAGEMENT**

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ABSTRACT

A summary of the LANDSAT Great Plains Corridor projects and the principal results are presented. Emphasis is given to the use of satellite acquired phenological data for range management and agri-business activities. A convenient method of reducing LANDSAT MSS data to provide quantitative estimates of green biomass on rangelands in the Great Plains is explained. Suggestions for the use of this approach for evaluating range feed conditions are presented. A LANDSAT Follow-on project has been initiated which will employ the green biomass estimation method in a quasi-operational monitoring of range readiness and range feed conditions on a regional scale.

INTRODUCTION

The Great Plains Corridor project conducted by Texas A&M University as part of the NASA LANDSAT investigations has yielded results of considerable significance to rangeland management and agri-business activities employing

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phenology data. The objective of this project was to use satellite remote sensing data to observe natural vegetation systems both as forage crop and as phenological indicators throughout the Great Plains of the central United States. It was hypothesized that the vernal advancement and retrogradation of natural vegetation could be monitored using LANDSAT imagery and digital multispectral scanner (MSS) data. It was further assumed that natural vegetation systems used as phenological indicators of seasonal development would provide an important means of measuring bioclimatic effects on a regional basis.

The Great Plains Corridor Study has emphasized and developed techniques for quantitative analysis of LANDSAT MSS spectral radiance data as quantitative indicators of the amount and seasonal condition of rangeland vegetation. The techniques used are viewed as a viable alternative to qualitative assessments made through image interpretation.

The Great Plains Corridor project has also been responsible for the development of related LANDSAT activities in the Great Plains and especially in Texas. The spinoff projects have been user-generated; consequently, the investigation is impacting on established management efforts. These projects include monitoring the management of leased public rangelands and mapping wildlife habitat.

PROJECT ACCOMPLISHMENTS

Specific accomplishments achieved in studying the use of LANDSAT data for the quantitative assessment of natural vegetation are as follows:

1) An effective test site network consisting of ten primary test sites was established throughout the Great Plains Corridor. More than 217 sets of cloud-free satellite data and 200 sets of ground truth data were collected for the test sites involved in the study. Cooperators from state and federal agencies acquired vegetation measurement data at the time of LANDSAT overpass during the non-dormant seasons for a period of 23 months. Out of the data sets collected, 124 satellite data sets with corresponding ground data were utilized in the analysis.

2) An algorithm was employed and tested for correcting MSS digital data for changes in solar intensity as a function of solar elevation angle. Changing illumination conditions are a serious problem for making temporal comparisons of digital data values. The successful application of the solar angle correction model made it possible to compare digital data from frame to frame, cycle to cycle, and location to location throughout the duration of the investigation. Since development and application of atmospheric correction

algorithms was not an objective of this study, data requiring large corrections for haze or thin cirrus were omitted from the analysis.

3) The theoretical derivation of the normalized band difference led to the development of the Transformed Vegetation Index (TVI). Investigations early in the project led to development of the hypothesis that the normalized difference between the red and infrared bands was potentially useful for the quantitative measurement of green biomass. This potential was realized initially through the development of the Transformed Vegetation Index (TVI). TVI was formulated as the following ratio using MSS Bands 7 and 5 values:

$$TVI = \sqrt{\frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}} + 0.5}$$

In the final analysis, it was found that the difference between Band 5 and Band 6 is generally more sensitive to the detection and quantitative assessment of green biomass differences. The new parameter is called TVI6, where Band 6 replaced Band 7 in TVI. R^2 values for TVI and TVI6 regressed on green biomass, plant moisture content and the combination of the two (Table I) illustrate the general superiority of TVI6.

4) Detailed statistical analyses show that the TVI6 parameter, along with limited weather data, is adequate to quantitatively assess rangeland feed conditions. Using the most extensive data set collected at a single test site (the Throckmorton, Texas test site), detailed statistical analyses show the potential for the use of the LANDSAT-derived parameter for the quantitative measurement of green biomass. A comparison of the LANDSAT TVI values to the green biomass measured at the Throckmorton test site is shown in Figure I. Factors such as moisture content of the vegetation, or the alternative use of precipitation and temperature data, are necessary for modeling a predictive equation for estimating green biomass to the desired accuracy.

With TVI6 as the dependent variable, a stepwise multiple regression analysis was performed to select the variables most likely to explain the variation observed in the LANDSAT observations. The best four-variable model is expressed by the following equation:

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

where \hat{Y} = TVI6,

X_1 = green biomass (kg/ha)

X_2 = precipitation since last satellite overpass
[18 days] (inches)

X_3 = precipitation on the day before the overpass
(inches)

X_4 = maximum temperature on the day of the satellite
overpass ($^{\circ}$ F)

These independent variables accounted for more than 90% of the variation in the TVI6 values. The above parameters were utilized to obtain a four-variable model with green biomass as the dependent variable and utilizing TVI6, precipitation during the previous 18 days, precipitation on day before the overpass and maximum temperature on overpass day as the independent variables. The ability to estimate green biomass in increments of 250 to 300 kg/ha with a 95% probability from TVI6 data and readily available weather data is indicated.

5) It was clearly demonstrated that the vernal advancement could be monitored through its northward movement in the Great Plains. Ground observations and satellite data collected in 1973 show that the vernal advancement progressed from the most southerly sites through the northernmost sites according to an expected progression calculated from the generalization commonly known as Hopkins Bioclimatic Law. It is of interest that in 1973, four of ten test sites were six days or more later than the expected progression and two

test sites were more than six days early. Spring developed as much as 18-20 days from the expected progression.

Observations from satellite data would be useful in monitoring the actual advancement of spring throughout this vast region for application to crop surveys. That is, these data can support phenological crop models or be used in determining crop calendars. The satellite data can be used to establish crop calendars based on phenological events for crop yield prediction.

6) The successful use of LANDSAT data for measuring green biomass had led to an approach for a follow-on investigation which will evaluate the use of LANDSAT data to monitor rangeland feed conditions on a regional basis. A quasi-operational system for monitoring range readiness and range feed condition is being developed using LANDSAT images, high-flight color-IR photography, soil maps, and topographic maps as data base information. After the vegetation/soils resource has been mapped for the region, the TVI6 plus precipitation and temperature values will be applied for quantitative determination of vegetation conditions at the time of satellite overpass. Vegetation condition will be contour mapped over a region in a manner similar to the maps now compiled by the Statistical Research Service, ARS, from

post card surveys. The potential also exists for mapping distribution of grazing use and forage condition on a pasture by pasture basis. These data will be disseminated to ranchers and range management organizations for use in their operations.

TABLE I. R^2 VALUES FROM REGRESSION ANALYSES OF LANDSAT BAND RATIO PARAMETERS AND SELECTED GROUND PARAMETERS FOR SELECTED G.P.C. TEST SITES.

Test Site	Green Biomass		Green Biomass + Moisture Content	
	TVI	TVI6	TVI	TVI6
Throckmorton	.7252**	.8254**	.8598**	.9117**
Chickasha	.2150	.3170*	.6799**	.8280**
Woodward	.6024*	.7749**	.6932 [†]	.8509*
Hays	.5066**	.5410**	.5873	.6028*
Sand Hills	.8231**	.8003**	.8370*	.8293**
Cottonwood	.4264*	.5583**	.7455**	.7431**
Mandan	.7105*	.6346*	.9011*	.9531**

** regression significant at the 99% level of probability
 * regression significant at the 95% level of probability
 † regression significant at the 90% level of probability

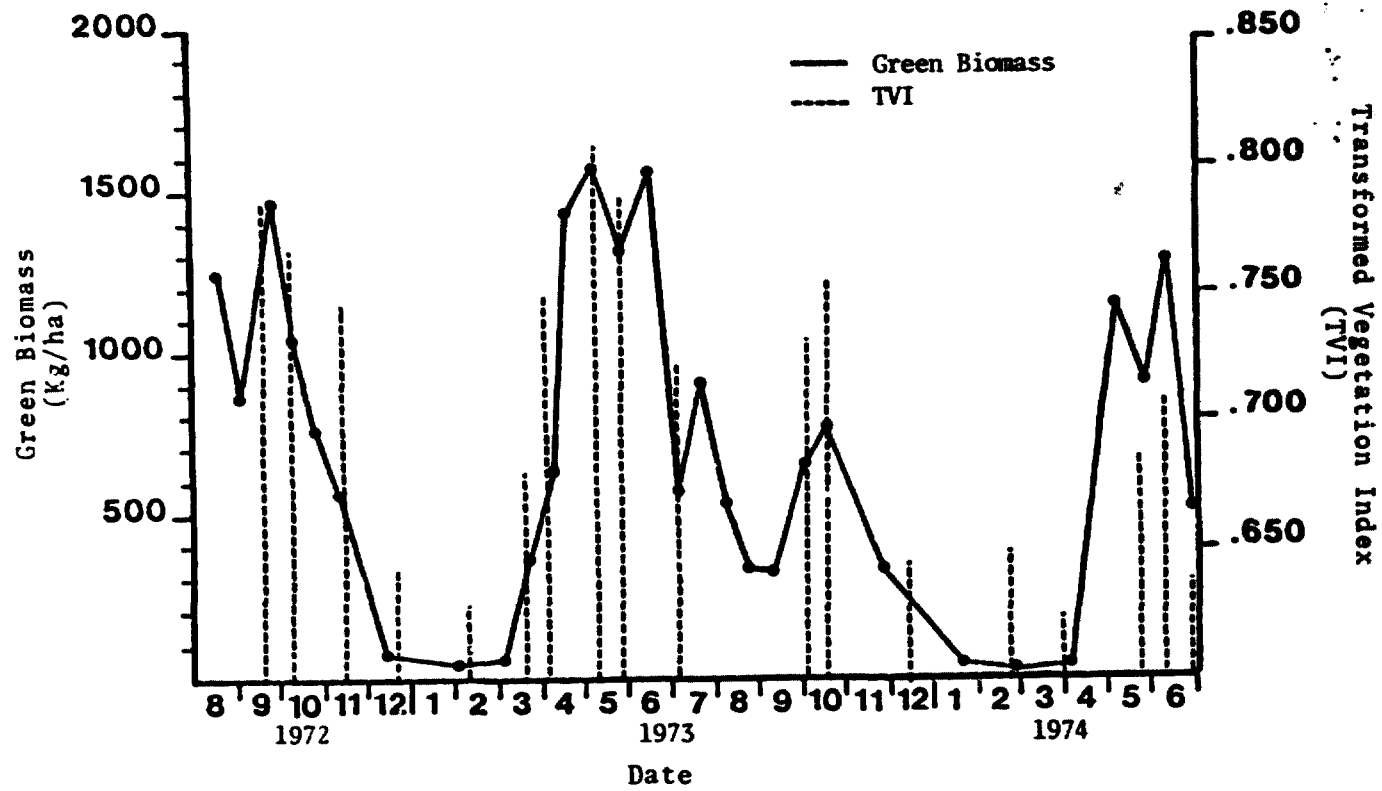


Figure 1. Graph showing the relationship of the transformed vegetation index (eighteen dates) and green biomass (all data) at the Throckmorton test site.