MEASUREMENT OF PLANT COMMUNITY COVER FROM AERIAL PHOTOGRAPHS USING EKTACHROME INFRARED AERO FILM 1/

by

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INTRODUCTION

Color-IR (infrared) aerial photographs of arid-zone vegetation have been used to estimate the amount of green plant material on the ground. The purpose has been to estimate plant cover as it varies with time and space and relate this vegetative measure to hydrologic conditions.

Aerial photographs of the 6,000-acre target area were taken periodically during the past 3 years. The study site is a 15-mile reach of the Gila River valley, San Carlos Indian Reservation, Arizona and is part of the U.S. Geological Survey's Gila River Phreatophyte Project (Culler and others, 1970) under the general direction of R. C. Culler, research hydrologist.

METHODS

Kodak Ektachrome Infrared Aero (EKIR) Film, Type 8443, in 9-inch format was used. Photographs were taken in 1968, 1969, and 1970 from elevations of 8,500, 3,600, and 1,500 feet above ground surface. The photography and film processing was done by the U.S. Geological Survey.

The data collection program was supported by NASA and is supplemental to the NASA aircraft program because the coverage needed could not be scheduled for the Houston-based aircraft. The K17 camera used by the USGS was equipped with a 6-inch Metragon lens. Three Wratten filters, numbers 12, CC20B, and CC30M, were used for all photography.

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As with the previous year's work (Culler and Turner, 1970), the film images were analyzed by use of a transmittance densitometer. As a new approach, data in the current year's report are expressed in terms of adjusted transmittances which have been calculated from "analytical densities." The data manipulation attempts to accomplish the following: (1) calibrate and standardize all photography so that photographs taken on different dates may be directly compared; and (2) derive a parameter from the films that is directly proportional to the green plant tissue. It should be emphasized that the photographic process is affected by many variables which have been assumed constant in the analysis. Conversion of integral densities to analytical densities is only semi-quantitative; however we hope in the next year to obtain the necessary photoscience support to correct this deficiency.

Three different sets of ground-truth data are being evaluated. The first is estimates of plant volume determined, as noted in an earlier report (Culler and Turner, 1970), by broadly classifying the vegetation into volume classes based on a combination of field reconnaissance observations and estimates from black-and-white aerial photographs. Because the ground truth is based in part on aerial photographs, it does not provide a wholly independent description of conditions on the ground.

A second set of ground-truth data represents estimates of plant foliar coverage. These values are independent measures of plant ground cover and are arrived at by estimating, in the field, plant coverage with 2 x 5 dm (decimeter)plots. These small plots are located within four plant communities on or adjacent to the Gila River Phreatophyte Project.

The third set of ground-truth data are evapotranspiration values measured at three stations by the energy-budget method.

The densitometric data are expressed as "adjusted red transmittance values." These values, derived from analytical densities on the IR photograph, are defined as the red transmittance (obtained when using the red filter, no. 92), divided by the sum of the transmittances in the red, green, and blue spectral bands, (Wratten filters number 92, 93, and 94, respectively). Each adjusted transmittance is derived from a single area on the photograph.

The rationale behind the use of red transmittances, adjusted as we have done, is based upon the premise that most of the scene reflectance that is expressed as red on the photographs is proportional to IR reflectance from the plants.

RESULTS AND DISCUSSION

Adjusted red transmittances during late March to late December 1968 are shown in figure 1. The curves represent adjusted densitometer readings.

from three separate volume categories of saltcedar. (The data upon which these curves are based were presented in different form at the Second Annual Aircraft Status Review Meeting). Differences with time and differences in space are apparently measureable using the data manipulation outlined above. One important item has not been tested, however; how well do the adjusted densitometer values represent plant foliage cover?

To make a valid comparison between the adjusted transmittances and plant cover, we needed a coverage measure acquired without the use of aerial photographs. To do this, 60 plots 2 x 5 dm in size were established in each of four different plant communities. The plots were spaced 1 meter apart along four 5-meter lines. At the time of each photographic mission foliar coverage was estimated on the 60 plots in each plant community. (Foliar coverage may be conceived as the sum of the shadows that would be cast by green leaves and green branchlets if the sun were at zenith and expressing the value as a percentage of the soil surface covered.) From these values an estimate is obtained of the foliar coverage of the entire community. Because foliar coverage estimates are difficult to make where plants are tall, work has been concentrated in plant communities of low stature that occur within or adjacent to the Gila River Phreatophyte Project.

We made ground-truth measurements on 11 different dates during 1970 but obtained photography on only three of these dates (Fig. 2). The lack of better photo cover is due partly to a change from EKIR Type 8443 film to Type 2443: color-IR film was unavailable to us for several months during this change. We are also in the process of changing camera systems, resulting in further photographic coverage loss. On two dates for which we have acquired ground truth, NASA photographed the target area from about 60,000 feet. We have not yet received these data.

The scanty data are not exactly compelling but we are moderately encouraged by them. Foliar coverage values, expressed as percentage of ground surface covered, appear to be of about the same order as the adjusted transmittance percentages (fig.2). Both values are high (80-90 percent) in the dense alfalfa-barley field and both are lower in the other, more open, plant communities. The correspondence between transmittance and foliar coverage is closest in the two homogeneous cultivated communities. That the differences are greater in the relatively heterogeneous wildland communities (creosotebush and whitethorn) may be the result of sampling error--the 60 plots established there may be too few to adequately sample the communities, at least during certain seasons.

The third set of data show evapotranspiration and corresponding adjusted red transmittances for three different plant communities during September and October 1969 (fig. 3). The evapotranspiration values were obtained by the energy-budget method from three installations on the target area. These values were provided by O. E. Leppanen, research physicist, U.S. Geological Survey. The adjusted red transmittances were derived from aerial photos of the energy-budget stations taken during three flights at an elevation of 1,500 feet above ground. The densitometry (Culler and Turner, 1970) was accomplished with a 1-millimeter aperture which views, on the photographs, a circular area equivalent to 76 square feet on the ground. Four or five readings were taken in the area surrounding each of the energy-budget towers.

Since evapotranspiration comprises two water-loss components, evaporation from the soil and transpiration from plants, the agreement may not always be close between evapotranspiration and values representing plant volume, expecially when the soil surface is wet. Such is the case on the last date in the figure: more than an inch of rain had just fallen and, in spite of the presence of little green plant tissue, evapotranspiration increased over the previous date. The October date represents a period of drouth when leaves and green branchlets were still present. By determining plant volume from the photographs, it may be possible to partition the evapotranspiration values into portions attributable to transpiration and to soil evaporation.

CONCLUSIONS

When in operation, orbiting satellites, such as those planned for the ERTS experiment, will have the capacity for determining short-term changes in the appearance of the earth's surface. Weather conditions permitting, a larger part of the earth will be observed at intervals of only a few weeks. Most of the detectable variability will result from fluctuations in snow cover and changes in the amount of green plant material. Measurements of vegetation change occurring within periods of 2 or 3 weeks can be used to pinpoint likely areas for livestock grazing, to help identify crop types and wildland communities, and to estimate primary productivity and evapotranspiration in plant communities. Although measurements of the earth's variable plant cover are of importance to many resource management fields, the actual measurement of the earth's green covering remains one of the most elusive variables with which biologists and hydrologists must deal. The development of suitable techniques to measure this parameter is a challenge for the photographic scientist and for the hydrologist. The work on the Gila River Test Site support this development.

The future objectives of this study will be to further refine the measurements of plant volume by making the necessary sensitometric and environmental measurements for calculating analytical densities.

Film of 70-millimeter format is now being used instead of the 9-inch film originally employed. This change has been made to improve the feasibility of microdensitometric analysis and yet retain a scale that can be viewed with the macrodensitometer in present use. NASA photography from the current and past highflight series will also be analyzed when data are made available.

REFERENCES

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Culler, R. C., and Turner, R. M., 1970, Relations of remote sensing to transpiration of flood-plain vegetation: Second Annual Earth Resources Aircraft Program Status Review, Vol. III, p. 37-1 to 37-8.

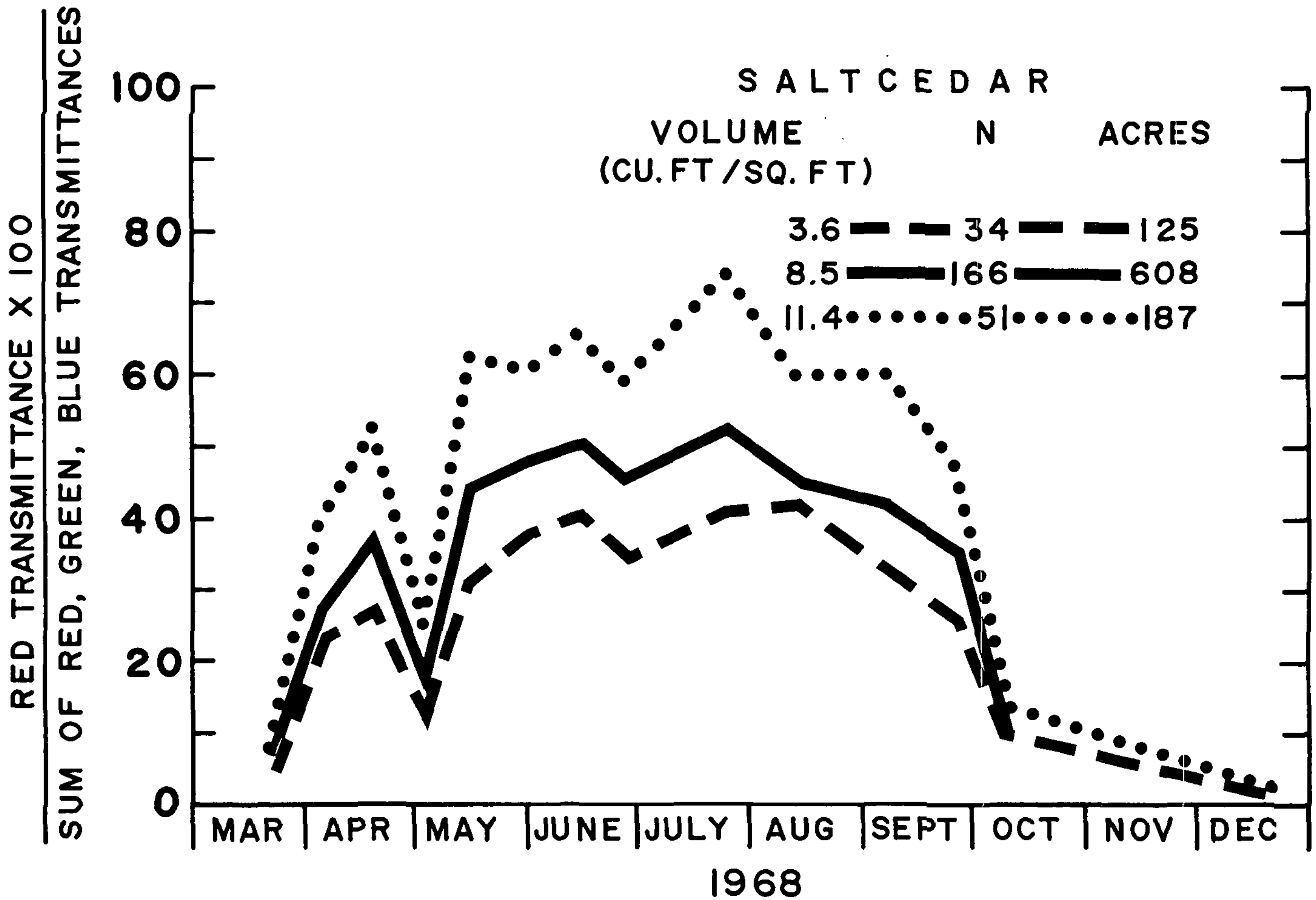

Figure 1.--Seasonal variation of adjusted red transmittances obtained from Ektachrome-IR images of a saltcedar forest, Gila River, Arizona. Data points are mean density values for forest plots representing three different foliage volume classes. N = sample size.

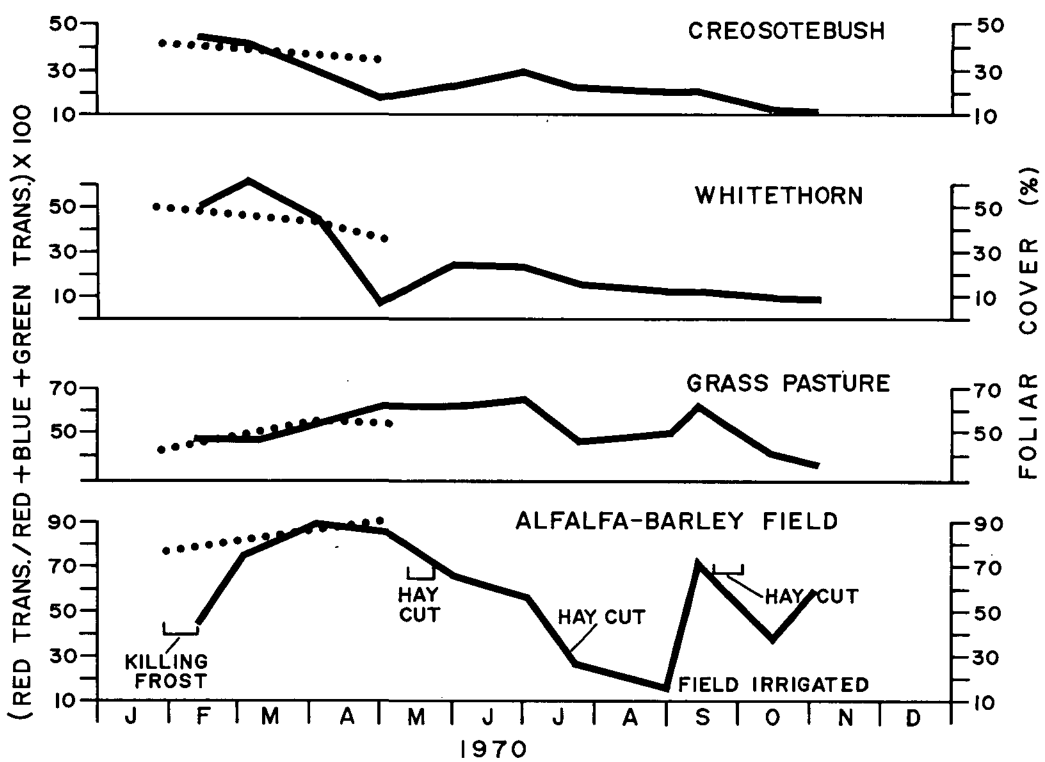

Figure 2.--Comparison of adjusted red transmittances and foliar cover in four plant communities. Transmittance values (dotted lines), were obtained for three dates from 9-inch Ektachrome-IR photographs taken from 8,500 feet above four plant communities. Foliar cover (solid lines), an estimate of the amount of green plant tissue covering the ground, was determined from estimates of 60 small plots in each of the plant communities. The low cover value for February in the alfalfa-barley field resulted from frost damage; cover would have been considerably higher 2 weeks earlier at the time of the first photographic mission.

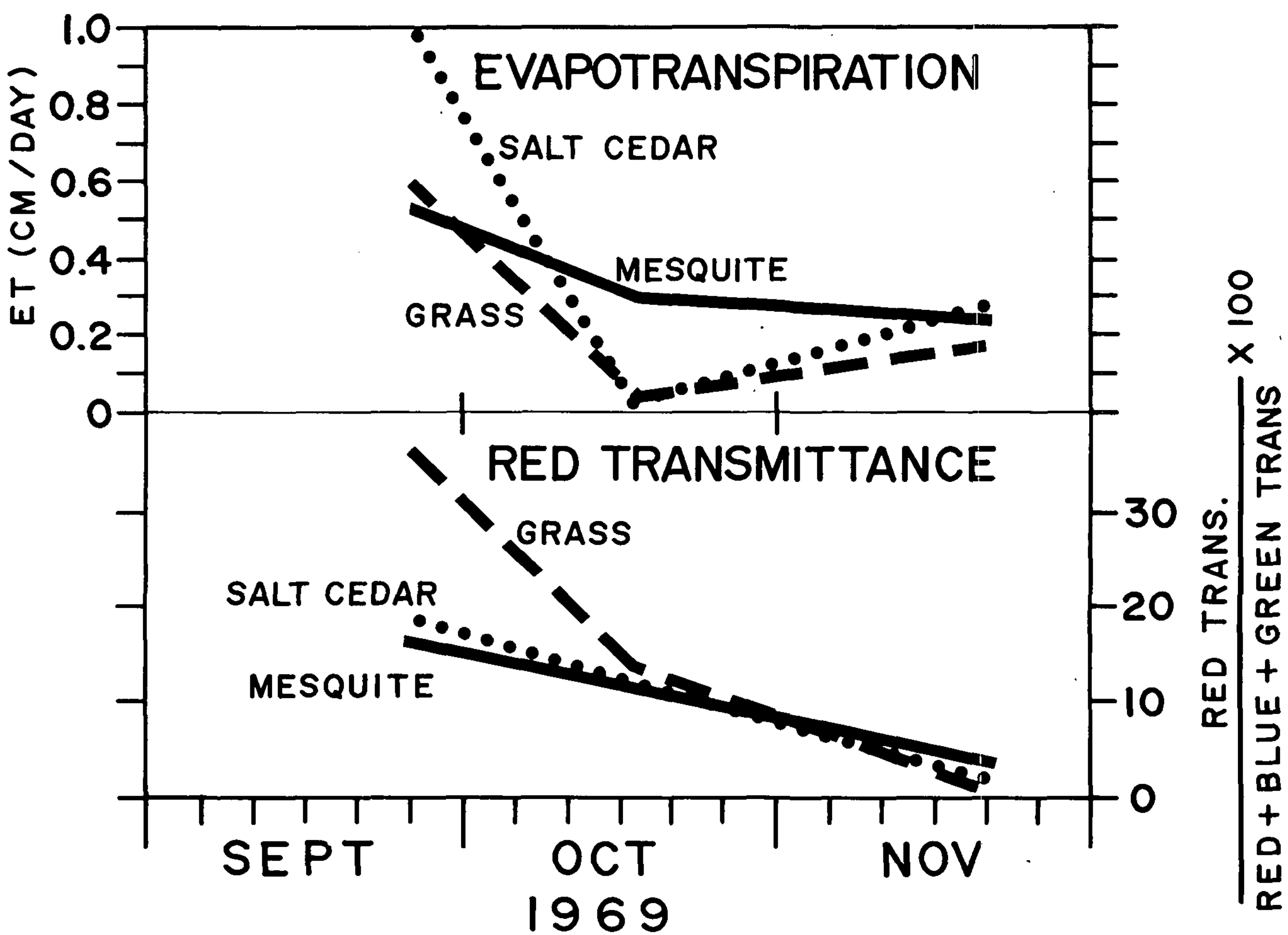

Figure 3.--Comparison of evapotranspiration and adjusted red transmittance in three plant communities on three dates in 1969. Evapotranspiration estimated by energy-budget method. Adjusted red transmittance was obtained from 9-inch Ektachrome-IR photographs taken from 1,500 feet above ground.