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SECTION 115

DEVELOPMENT OF ANALYSIS TECHNIQUES FOR REMOTE SENSING OF VEGETATION RESOURCES

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INTRODUCTION

During the past year, the activities of the Forestry Remote Sensing Laboratory have consisted primarily of the development of various data handling and analysis techniques which will be used in our forthcoming evaluations of ERTS-A and supporting high-flight imagery. In general, these evaluations will be concerned with the application of remote sensing to wildland and agricultural vegetation resource inventory problems. The following discussion briefly summarizes several of the more significant developments which will be used in these ERTS investigations.

MONITORING OF CALIFORNIA'S ANNUAL GRASSLAND

Studies conducted using small scale (1:120,000) RB57 color and color infrared photographs of the annual grassland areas of the state of California have indicated a potential for the development of models which would permit a prediction of regional forage production in the annual grassland type.

Specifically, sequential synoptic coverage of the area during the fall (between October 1 and November 30) and the spring (mid-February to mid-May) should allow an estimate of the time of seed germination and the time of "near-peak foliage development". The time of seed germination in the fall is monitored by observing when the range, which remains dry all summer, suddenly appears green. The time of peak foliage development can be estimated with reference to that time in the spring when the grassland reaches an "optimum photogenic stage" wherein grasses have dried on shallow soil sites but are still green on deeper soils (see Figures 1 and 2).

Presumably the greatest forage production will occur in those years when the seeds germinate early in the fall, and in which growth continues until late in the spring. Conversely, poorest production will result from late germination and early maturation, both of which are affected by the timing and intensity of rainfall, and temperature fluctuations. In order to actually make quantitative estimates of forage production for specific parts of the state of California, it will be necessary to establish "benchmark" dates of germination and maturation which correspond to minimum, average, and maximum production, and to provide allowance for interaction between germination and maturation dates for the various regions within the annual grassland type. However, preliminary investigations indicate that it should be possible to establish such reference data which can be correlated with those parameters observable on small scale sequential imagery.

Information acquired about the development of the annual grassland crop has many applications. First, one can predict which areas may be over-utilized because crops are below average, or under-utilized because the existing number of cattle cannot possibly consume the above average crop of forage. Thus, information regarding expected crop yield could lead to better utilization of the crop. By predicting the length of the growing period, the rancher is in a more favorable position to know when to move his grazing animals to market to obtain the best price, or to determine how much additional hay he may need for supplemental feeding, if he chooses to keep his cattle on the annual range. Producers of livestock feed could also benefit from this information. Finally, the rancher might also use this information to determine when it is best to move his grazing animals from the annual range to other kinds of pasture.

AUTOMATIC TEXTURE ANALYSIS

The principal efforts of the automatic data processing unit during the past year have centered around modification and use of routines derived from the LARS (Purdue) facility which are based upon spectral "point cell" classification procedures, in which each data point is analyzed independently. However, our experience in the analysis of imagery of wildland areas has indicated that in many cases, considerable information can be extracted through the use of "textural" analysis as well. Our ultimate objective is that of investigating the means whereby spectral <u>and</u> textural data can be combined to facilitate feature classification procedures. The result is expected to be the achievement of an increased classification accuracy as well as a more flexible classifier routine for non-agricultural terrain features.

In an effort to extract spatial frequency (textural) information, a transform routine has been developed for our terminal/display system. The routine employs a modified one-dimensional Hadamard transform algorithm to derive the textural data. The Hadamard transform was chosen in this instance because of its relatively low computational cost, and its ease of adaptation to our small computer facility. The program generates a series of "digital masks" of increasing periodicity, and causes these "masks" to shift regularly and sequentially in relation to the scanned image, thus generating a series of energy coefficients. The minimum, maximum, and mean energy coefficients are computed for each scan line and averaged over several scan lines taken from the area of interest.

Preliminary results using this procedure have shown significant correlations between the energy coefficients of scanned images of timber stands and ground measurements of timber volume ($r = 0.97$) and basal area ($r = 0.95$) of the same stands. Thus, it appears likely that we will be able to develop useful "textural signature" responses through the automatic scanning of imagery which has been manually typed into homogeneous units which will yield estimates of parameters of interest to forest land managers (see Figures 3 and 4).

AGRICULTURAL GROUND DATA COLLECTION TECHNIQUES

In the interest of developing more efficient methods of collecting "ground" data to support our analyses of small scale imagery for conducting agricultural inventories, an experiment was carried out in Maricopa County, Arizona, wherein the use of ground crews was compared with helicopters and fixed-wing aricraft. Ten permanent "ground truth" cells, each four-square-miles in size were visited using each of the three methods, and a field-by-field crop identification was performed. Subsequently, identification accuracy, and time and cost comparisons were made of the three methods. Conventional rental rates for aircraft, helicopters, and automobiles were used in the comparison.

It was assumed that the ground inventory was 100 percent correct. Both the helicopter and the fixed-wing aircraft methods averaged 2 to 3 percent error based on number of fields. It was felt, however, that most of the errors were of the sort that could be corrected on the next monthly inventory as the crops matured, since the bulk of the errors were on young cereal grain crops which would soon become readily identifiable.

In terms of time and costs extrapolated from the ten test cells to the total of 32 four-square-mile cells in the county, it was estimated that a complete data acquisition operation would cost approximately $2200 using the helicopter, $700 with fixed-wing aircraft, and $1000 by automobile. The time of actual data collection for both helicopter and fixed-wing aircraft were about the same (and approximately five times faster than with automobiles), however, the per hour rental cost of helicopter (with pilot) is nearly five times greater than that of conventional aircraft, thus accounting for the wide disparity in overall cost of the two methods (see Figure 5).

It is planned that further studies of the relative efficiency of aircraft and ground methods will be carried out during the current growing season.

SPECTRAL MEASUREMENTS

During the past year a spectral data gathering capability has been developed which allows *in situ* measurements of the spectral reflectance of vegetation and terrain features to be gathered in conjunction with measurement of the spectral distribution of incident illumination. The acquisition of both of these parameters simultaneously makes possible the computation of standardized reflectance data, thus permitting valid comparisons of data gathered at different times, or under different atmospheric conditions. The equipment consists of a battery of two EG&G spectroradiometers which measure reflected radiation from 350 nanometers to 1200 nanometers in wavelength, and an ISCO spectroradiometer which records incident illumination over the same wavelength range. The data from both instruments is recorded on magnetic tape, which facilitates computer computation of standardized data. The system is essentially field-portable, which is necessary considering the impossibility of obtaining meaningful reflectance data of natural vegetation and terrain features if they must be transported to the laboratory (see Figures 6, 7 and 8).

During the past year several studies have been carried out using this data-acquisition equipment. At the Harvey Valley test site, over one hundred readings were made of five major plant species. This data has been used to define optimum film-filter specifications for large scale photography of the site used in a range inventory experiment. In Maricopa County, Arizona, a project was initiated to assess the feasibility of using the equipment from a helicopter in order to integrate reflected radiation from larger ground areas than is possible from the ground. The field of view from the helicopter (250 feet in diameter at an altitude of 1000 feet) approximates the resolution expected from ERTS-A. The results were promising, and further studies of this type are planned in conjunction with the flight of ERTS-A and the supporting high-flight imagery. In addition, during the next

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field season, studies will be conducted to determine the feasibility of utilizing large homogeneous natural features for calibration of high-flight imagery. This is necessary to insure repeatability of results when such imagery is viewed using additive color-enhancement devices for discrimination and identification of vegetation features in both wildland and agricultural areas.

CONCLUSIONS

While none of the techniques discussed here have been carried out to their final conclusion, it is felt, as was stated earlier, that in each case they provide a means by which the forthcoming analysis of ERTS imagery can be more efficiently conducted. Thus the past year has been viewed as one in which a state of readiness has been achieved in anticipation of the extensive experiments which are scheduled for the next several years.

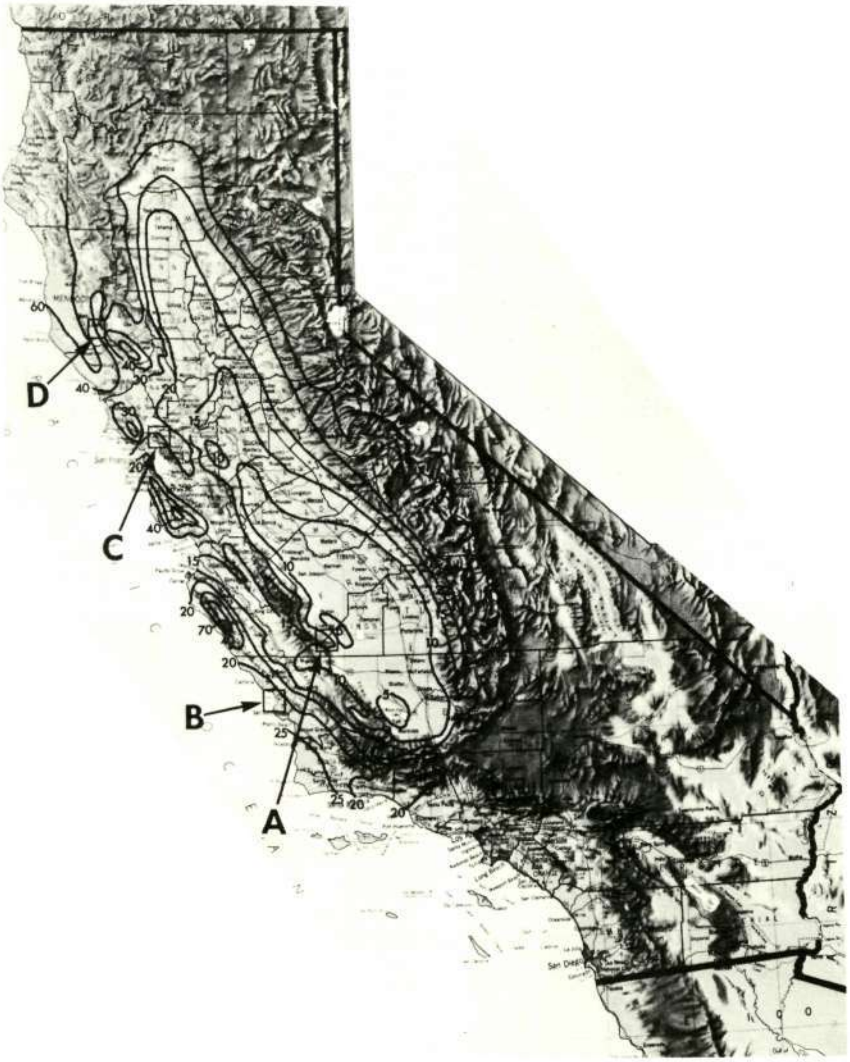


Figure 1.- The four test sites which appear in Figure 2 are indicated on this map of California. Average annual rainfall is 8" at area A, 22" at area B, 20" at area C, and 40" at area D. All of these sites are within the range of the California annual grassland type.

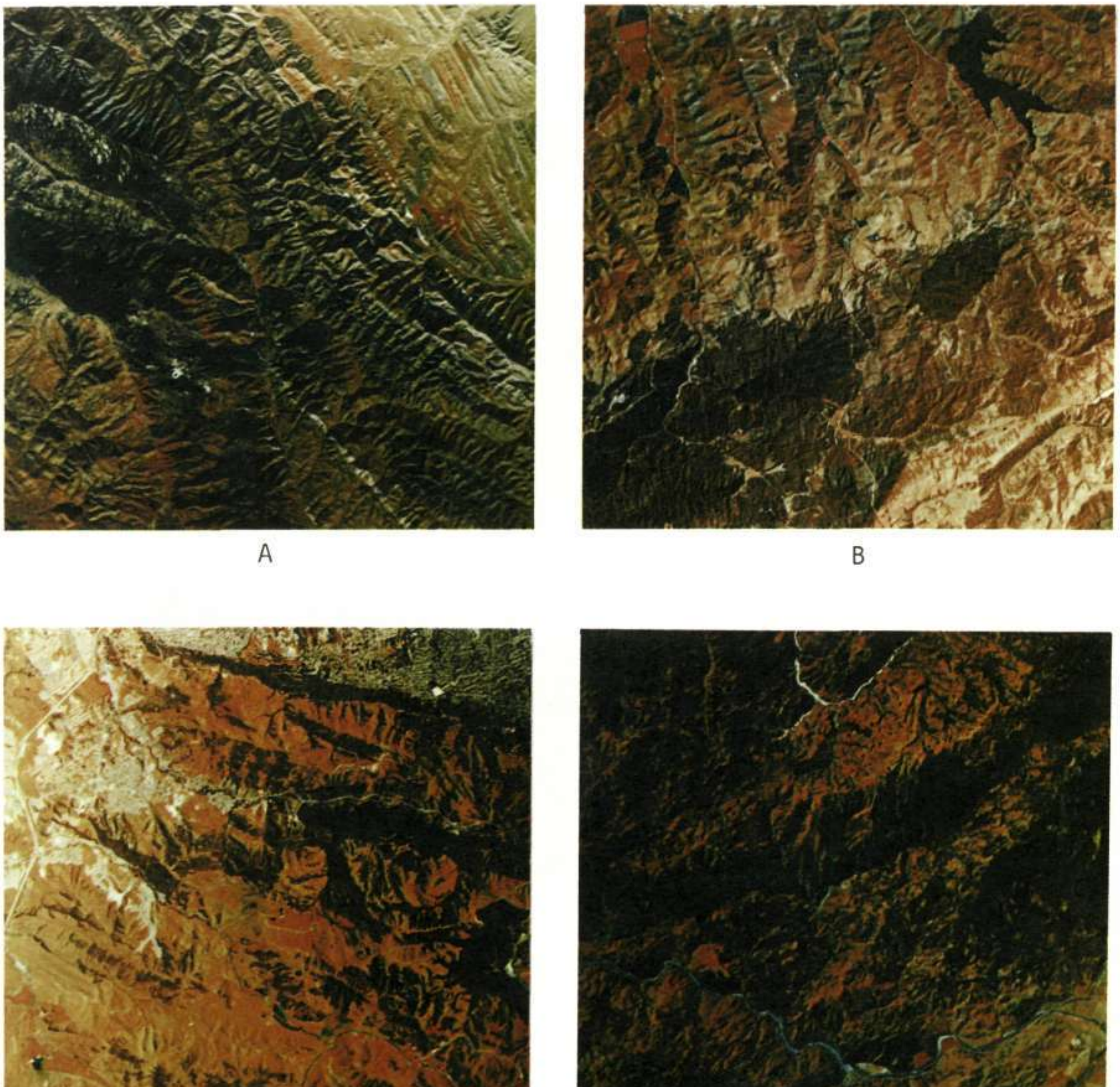


Figure 2.- These color infrared photos (scale = 1:120,000) of four annual grassland test sites were taken on April 1, 1971. At this early date the grasses at sites A and B have already reached their "optimum photogenic stage", indicating a below average forage crop, while at areas C and D the grasses are not yet mature, indicating a probable average or above-average production year for those sites.

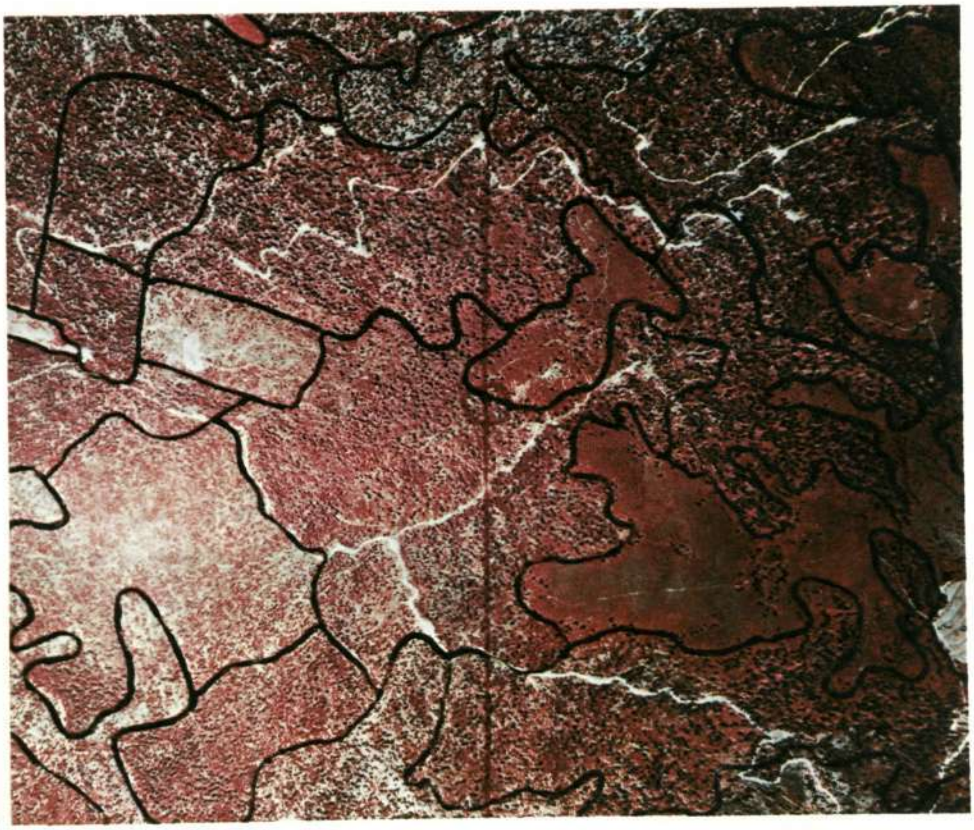
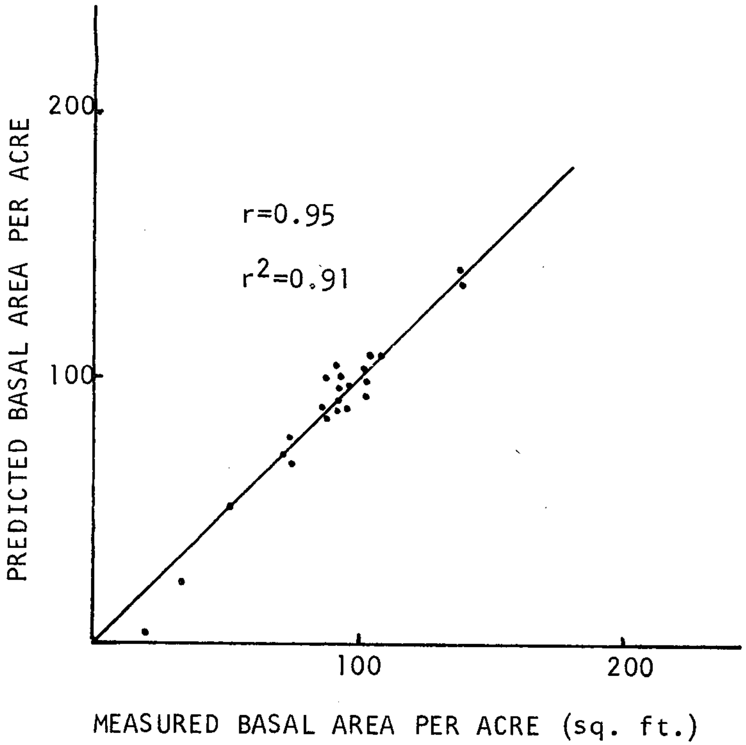


Figure 3.- This color infrared photo, scale 1:25,000 was delineated on the basis of timber size and density, and textural data for each type was extracted using a scanning densitometer and mathematical transform routines (see text for discussion). It was hoped that such textural data would be useful in estimating various timber stand parameters of interest to the wildland manager. Some results of this study are illustrated in Figure 4.



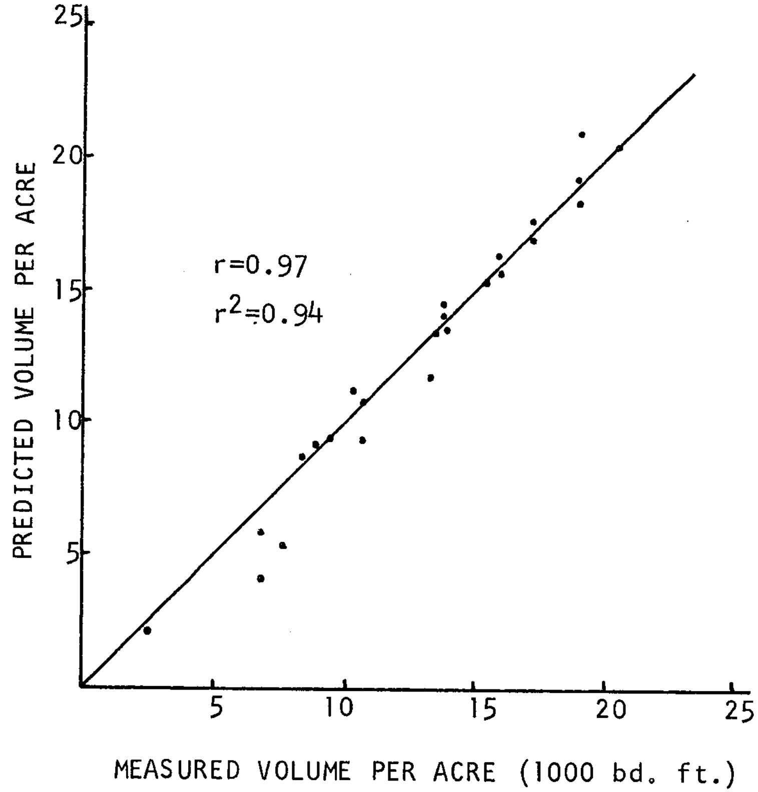


Figure 4.- These two graphs illustrate the high correlation between textural information pertaining to timber stands, such as those shown in Figure 3, and stand parameters, such as timber volume per acre and basal area per acre. In both examples, the "predicted" values were derived using textural data extracted from aerial photographs.

COMPARISON OF

DATA COLLECTION METHODS

	Automobile	Helicopter	Airplane
Average Error	0	3.2	2.2
Time of Data Collection (32 4 sq. mi. plots)	72 hrs.	13 hrs.	13 hrs.
Estimated Total Cost	$990	$2266	$706

Figure 5.- This table indicates the differences in accuracy and cost of three methods of acquiring "ground truth" information about agricultural crops to support image interpretation investigations. The data were gathered at the Maricopa County, Arizona test site. The error is expressed in percent based on number of fields, while the total cost is estimated on the basis of acquiring crop type information for all fields within the 32 permanent sample plots within the test area.

Figure 6.- The Forestry Remote Sensing Lab spectral measurements equipment consists of two EG&G spectroradiometers (above) for measuring _in situ_ reflectance of natural features, and an ISCO spectroradiometer (right) for gathering simultaneous incident illumination data.

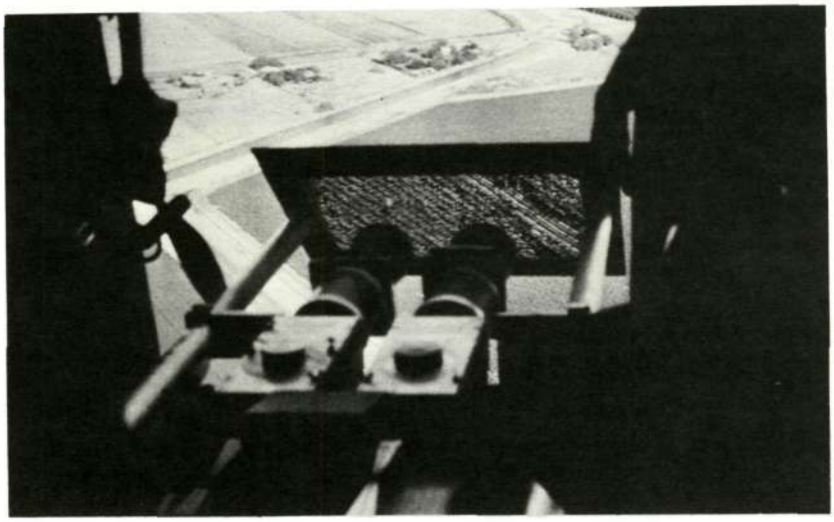


Figure 7.- In order to gather spectral reflectance data of large integrated areas such as will comprise a resolution element of ERTS imagery, measurements of agricultural and rangeland areas have been taken from a helicopter. The bottom photo shows a cotton field as seen from the helicopter with the two EG&G radiometers in operation. Using this equipment, from an altitude of 1000 feet the field of view is roughly 250 feet in diameter, approximating the resolution expected from ERTS-A.

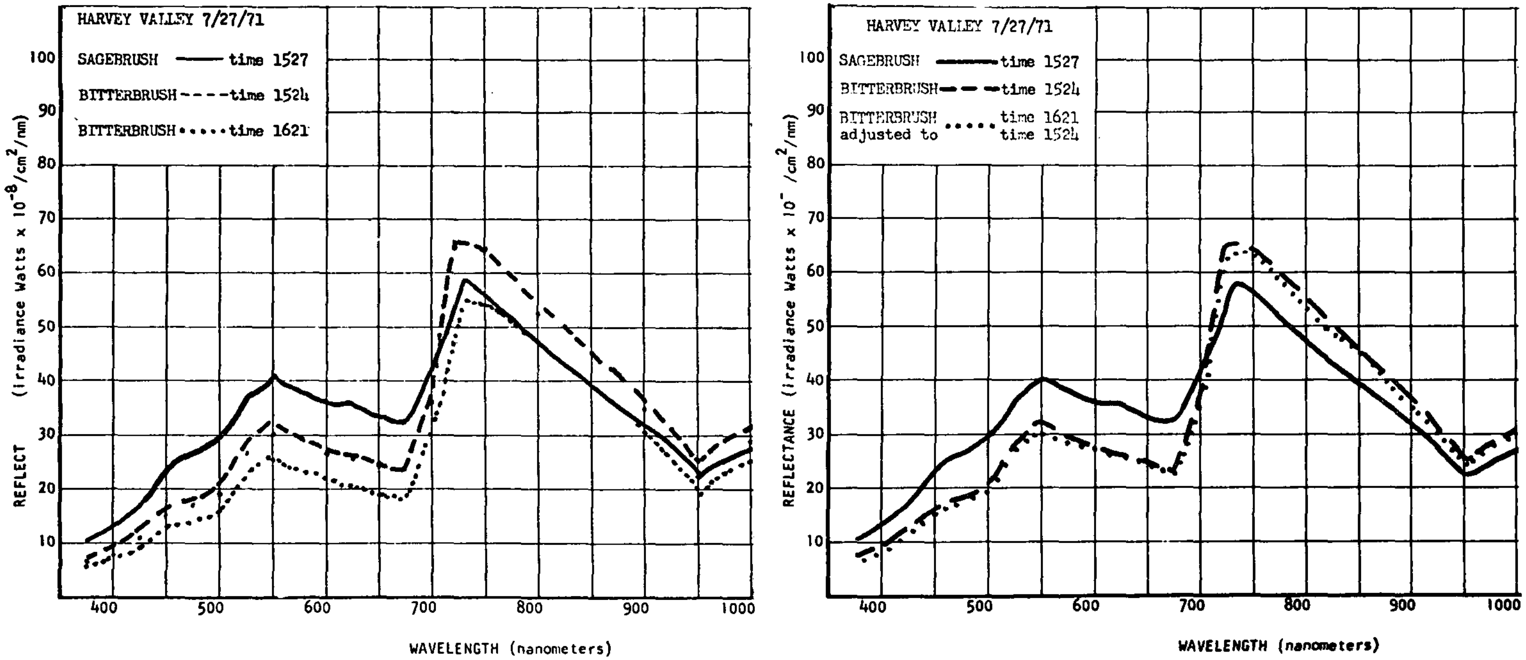


Figure 8.- These graphs illustrate the value of incident illumination data in standardizing *in situ* reflectance measurements. Note that on the left, reflectance of the same bitterbrush plant taken at different times appears quite different, whereas on the right, where the two readings have been adjusted to a common time, they appear nearly identical. This makes possible a direct comparison of readings taken at different times or under different atmospheric or lighting conditions.