1969

# Spectral Infra-Red Reflection Measurements From Natural and Treated Aspen Forests

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## Introduction

The Utah Center for Water Resources Research has recently terminated a project entitled, "Evaluation of Remote Electro-Magnetic Sensors for Detecting Transpirational Water Use by Plants Subjected to Various Foliar Chemical Treatments Designed to Reduce Transpirational Losses." As a part of that study, spectral reflectance measurements were made during the summers of 1967 and 1968 on a natural stand of aspen, part of which was treated with foliar chemicals. The previous year spectral reflectance measurements were made on individual plants in the laboratory. The laboratory measurements have been summarized in a previous report (1). The purpose of this report is to describe and summarize the field measurements.

## Test Area

A relatively uniform, dense stand of quaking aspen was selected for study in a side drainage of the Logan River in Cache County, northern Utah. The stand which averages about 55 feet in height is on a south facing slope of about 25 percent and is located in the aspen zone of vegetation of the Wasatch Mountains at an elevation of about 7800 feet. Mean annual precipitation at the site is approximately 30 inches. The soil is deep and generally well drained but includes clay lenses and gravel pockets at various depths. Access to the area is good. The site is approximately 15 airline miles northeast of the city of Logan.

The test site was confined to an area approximately 300 feet wide and 200 feet long, this long dimension being up and down the slope. The 300 foot dimension was subdivided into three 100' x 200' plots. Separation of the plots was accomplished by digging trenches around each plot to sever the root systems. Climatic instrument stations and soil moisture probes were established in each of the plots.

The test site slopes downward to the bottom of a small stream. Crossing the stream the terrain slopes upward again, the two slopes forming the V-shaped walls of a small canyon. On the north facing slope opposite the test area, a platform was built from which observation of spectral reflectance from the quaking aspens on the test site could be made. The test area as viewed from the platform is shown in Figure 1.

The test plots have been designated A, B, and C to represent the various treatments applied to reduce transpiration. Plot A was treated with 245-T and will be referred to as the defoliated plot, Plot B was untreated and is referred to as the control plot, and Plot C was treated with phenol mercuric acetate and is referred to as the treated plot.

## Data Acquisition - 1967

Spectral reflection data in the near infrared was obtained using a Central Scientific Company spectrograph with a 4" reflecting telescope attached to collect the reflected energy and limit the field of view.

The spectrograph was operated from a platform located across a valley, and approximately 1/3 mile from the test area. The photo of

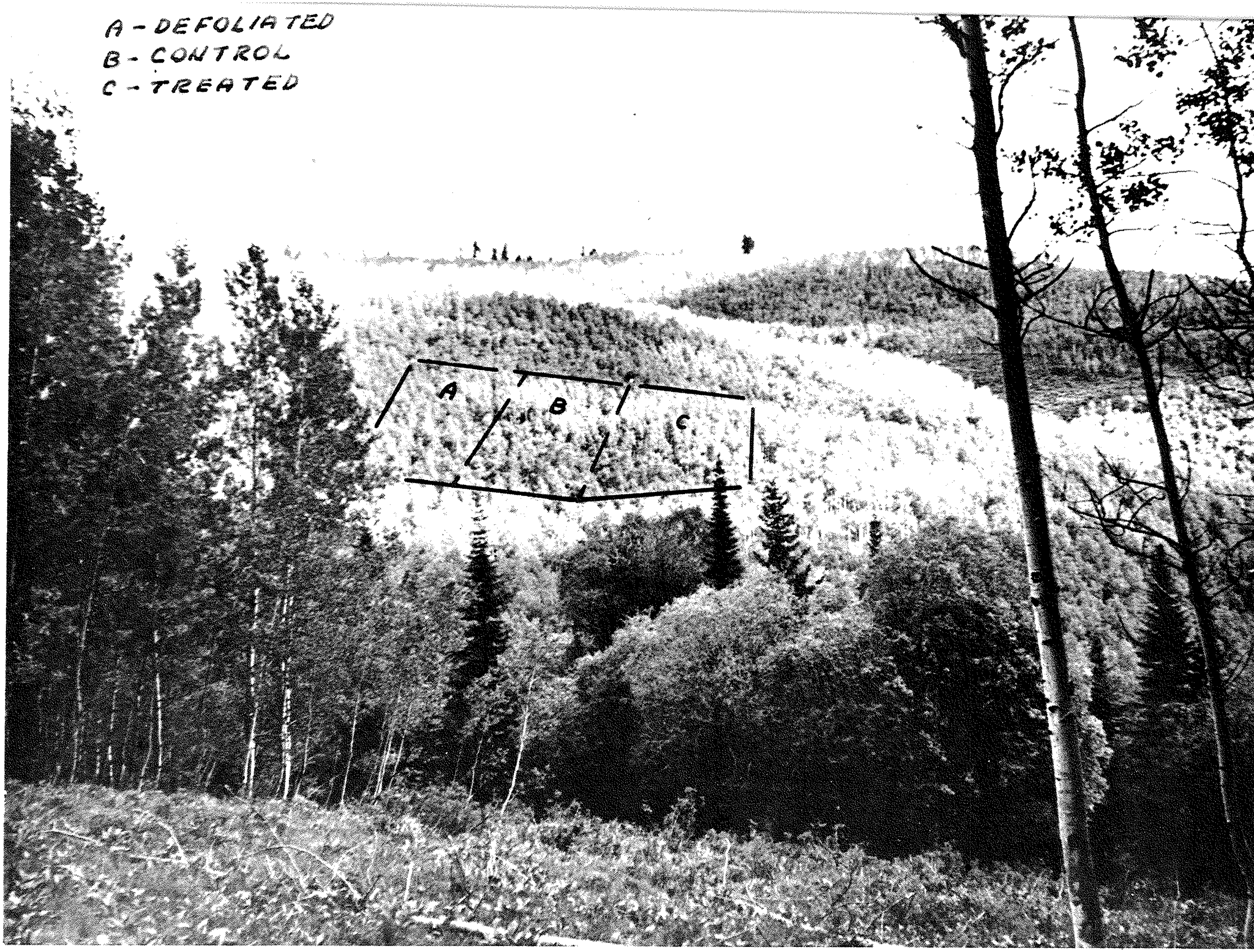


Figure 1. Test areas as viewed from platform.

Figure 2 shows the spectrograph on this platform. The spectrometer was set to record energy over the spectral range of 0.5 to 0.9 μ using high speed infrared film as a recording media. The small field of view of the instrument made it necessary to view each area for one hour to expose the film to the desired density. Spectral information from all three areas could be recorded on one piece of film by vertically positioning the film cassette on the spectrograph after each exposure. The spectral information was recorded in strips on the film, one strip above the other. It was therefore not necessary to load or unload film in the field. Care was taken to insure that the film developing process was the same each time spectral information was taken.

Spraying of chemicals on plots A and C occured on June 28, 1967. Data was taken approximately once a week beginning June 28 and extending until September 24, depending partially on weather conditions. Spectral information was obtained more often during the first two weeks after the areas were treated since it was suspected that spectral changes would be more rapid during that period. It was desired to start taking data before the areas were sprayed, but rainy weather conditions made it impossible. The observation platform was in a rather inaccessible area, and it was necessary to have three hours of sunshine to adequately view the test sections.

During the 13 week period from June 28 to September 24, reliable data were taken 13 different days. An example of densitometer traces of the data obtained is shown in Figure 3. Solar spectra reflected from white

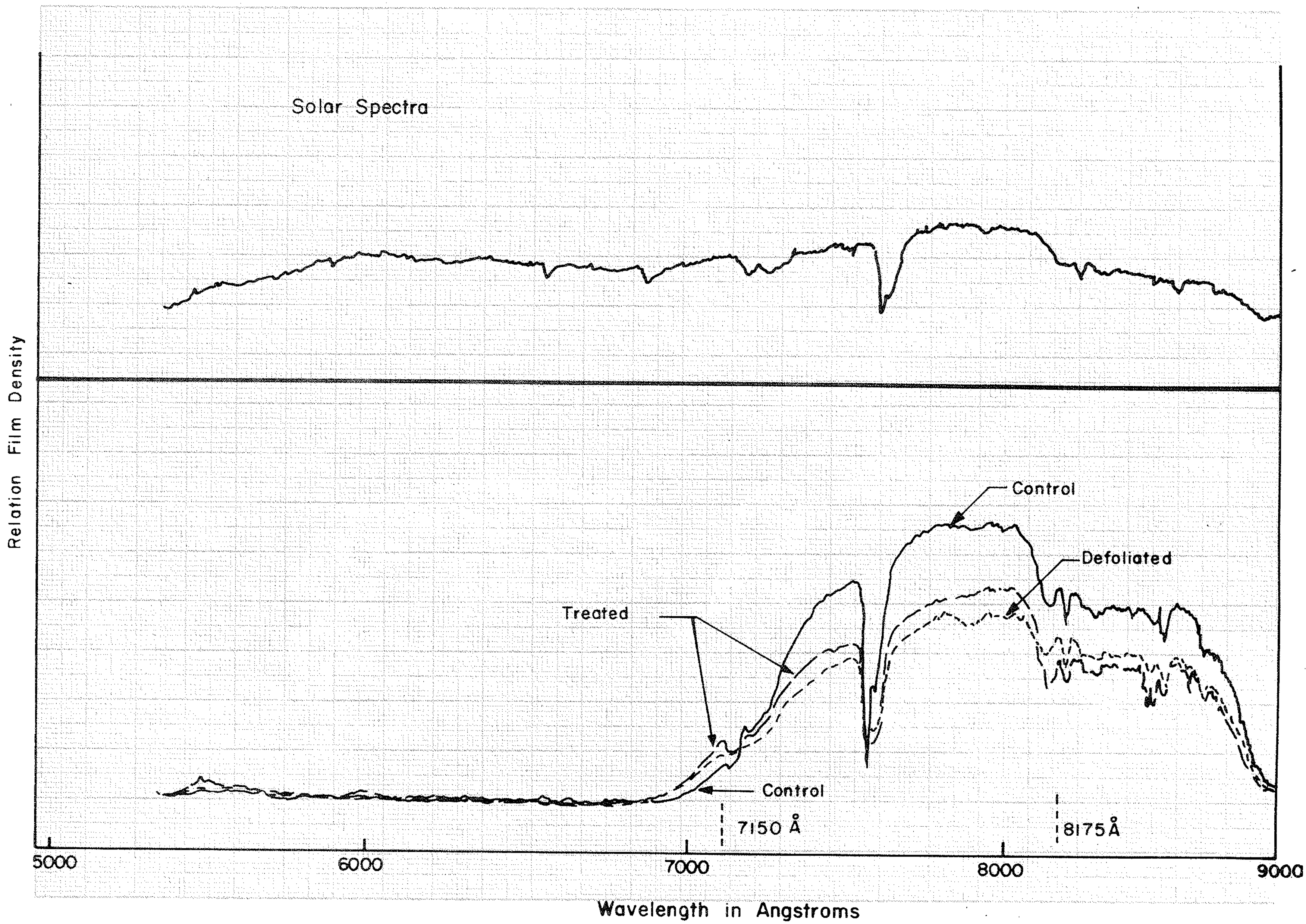


Fig. 3. Spectral reflectance of test areas taken July 18, 1967 (solar spectra is reflected from white sheet of paper.)

Figure 2. Spectrograph recording spectral reflectance from test areas. - 1967

paper is also shown in this figure. This particular spectral information was obtained July 18. It can be seen that most of the rapid fluctuations appearing in the test area reflectance data is due to absorption bands in the solar spectra.

After about one week following the spray treatment the infrared reflectance from the defoliated and treated area was reduced and more spread out than the infrared reflectance from the control area. This is shown in Figure 3. The treated area plot is much lower than the control area plot at 8000 Å, but is higher than the control area plot at 7150 Å. This same type of spread and reduction in infrared reflectance was also seen in the control area toward the end of the summer.

It is difficult to obtain absolute spectral information with this method of data acquisition since there are fluctuations in atmospheric conditions as well as difficulties in controlling the film developing process. In an effort to find some way of presenting the data that would be less dependent on atmospheric conditions and film processing procedures, it was decided to determine the infrared reflectance reduction and spread by comparing the amplitude of the signal at 8175 Å with the amplitude at 7150 Å. These two wavelengths were chosen since they both appear on peaks due to solar spectra and are easy to identify. Also, 8175 Å is near the peak of the infrared reflectance as it appears on the film, and 7150 Å is in a wavelength region where the spread effect seems to have the greatest influence.

Figure 4 shows a plot of the ratio of the amplitude at 8175 Å to the amplitude at 7150 Å for each of the areas throughout the summer. It is seen that these ratios were approximately the same for the three areas during the first week of the experiment, but after July 2 there appears a considerable difference in the ratios of the controlled area and the other two. In all three plots the ratio tends to decrease throughout the season. Plotting the water content in the upper 6 feet of soil against the same time period indicates a similar decreasing trend, Figure 4. The data suggests that it may be possible to take the ratio of reflected energy of two wavelengths to determine moisture conditions. The two wavelengths selected above are probably not the most favorable ones. Much greater differences could possibly be found if other wavelength ratios were investigated. The great advantage in looking at ratios is that atmosphere conditions should have much less effect on the data.

## Data Acquisition - 1968

During the summer of 1968 measurements of reflected sunlight from quaking aspen trees were continued. Measurements were conducted in the same area as those made in 1967. The same plots were sprayed with chemicals at the beginning of the season.

A field spectrograph designed and built at Utah State University was used in the 1968 measurements. The specifications for this instrument are shown in Table 1.

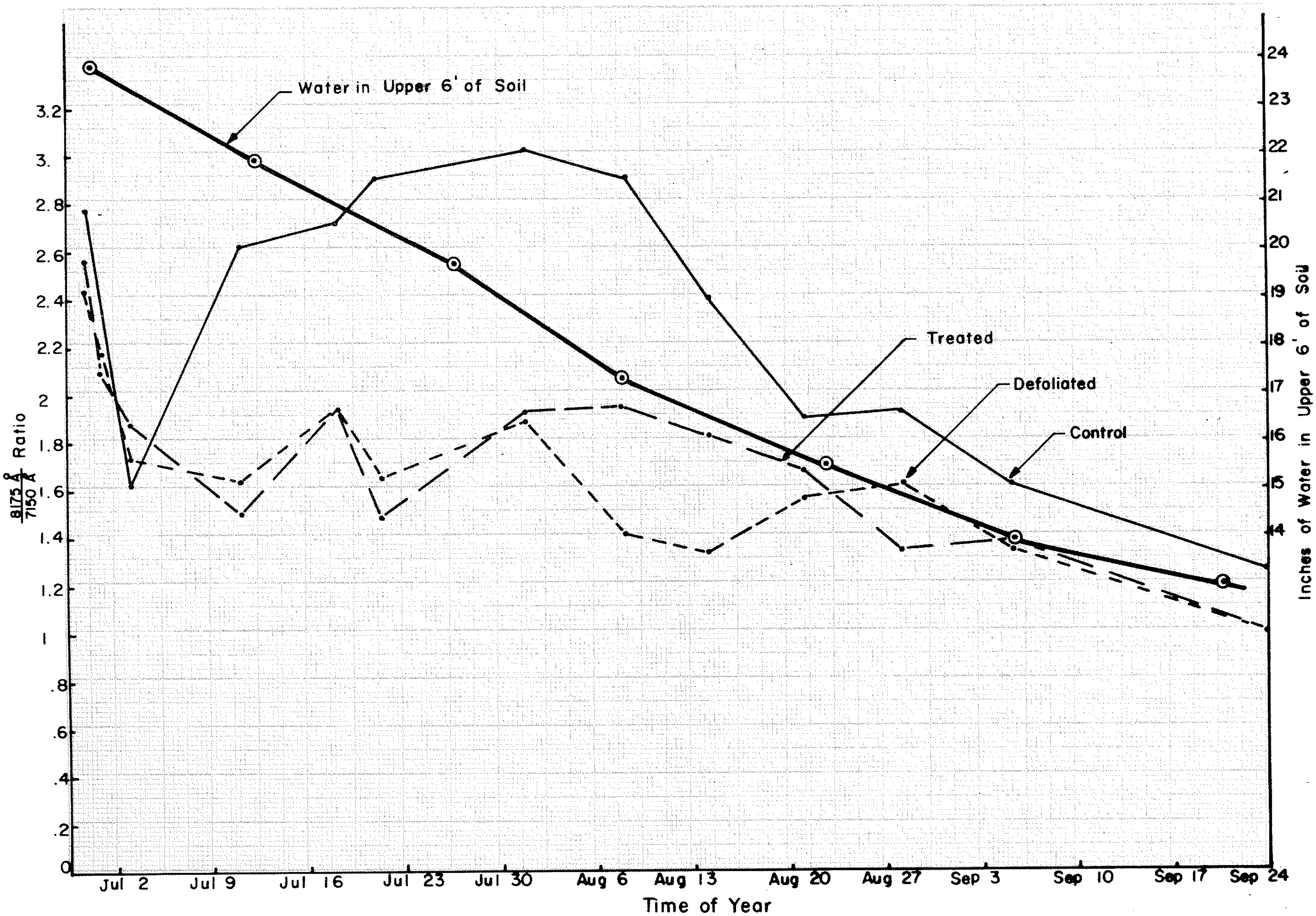


Fig. 4. Plots showing ratio of reflected energy at 8175 Å to reflected energy at 7150 Å - 1967.

Table 1. Specifications for USU field spectrograph used in 1968 field reflectance measurement.

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Optical

Collector: 6-in. dia., front surfaced with $Al_2O_3$ or SiO overcoating.

Focal length: 60 in., folded.

Focus: 35 ft. to ∞ at entrance slit.

Entrance slit: 10, 30, or 60 μ selectable, Al on quartz.

Configuration: 1-meter Paschen-Runge.

Grating: Bausch and Lomb 50 x 90 mm, 600 lines/mm, 5000 Å blaze.

Grating mount: Independent triaxial and focus adjustments.

Resolution: 0.12 Å.

Spectral range: UV to near-IR, depending upon emulsion used.

Spectral coverage: nominally 3000 to 7200 Å; gratings available for other ranges.

Mechanical

Size: 52 x 33 x 10 in.

Weight: 125 lbs.

Construction: Rugged Al channel optical framework; .04-in. Al skin on angle frame; white polyurethane exterior finish; 3M nonreflective black interior.

Film cassettes: Individual cassettes with guarded loading and dark slides, accepts 10-in. by 35 mm strip.

Transport mechanism: 5-position detented, exterior manual control knob; remote drive available as an option.

Shutter: Vane type, exterior manual control knob; exposure duration indicator switches; remote solenoid actuator available as an option.

Since the spectrograph has a larger collecting aperture and a larger grating, the time required to make a reflectance measurement was reduced to approximately one minute for proper exposure of the high speed infrared film. Three cassettes were available so that a total of 15 exposures could be made without reloading the film. It was felt that due to the much shorter time required and the ability to obtain more individual exposures better control of the reflection measurement could be obtained.

Measurements of the spectral reflectance of the sunlight from the quaking aspen trees were made on 18 days during the period from June 12 to September 18.

The first two or three measurements were not satisfactory since the proper exposure time had to be determined by experimentation and some of the data was overexposed.

Care was taken that the measurements were made under conditions which were as nearly identical as possible with respect to the position of the sun, receiving position of the spectrograph, interference from clouds, etc. Figure 5 shows the spectrograph and platform as used in 1968.

In the 1968 study the spectrograph was positioned so that two measurements were made from each area. One of the measurements was made on the bright sunlit side of the trees (light) and one measurement made from the shady area of the trees (dark).

The data taken from the light areas in 1968 follows the pattern of the 1967 measurements with the control area reflecting better in the infrared

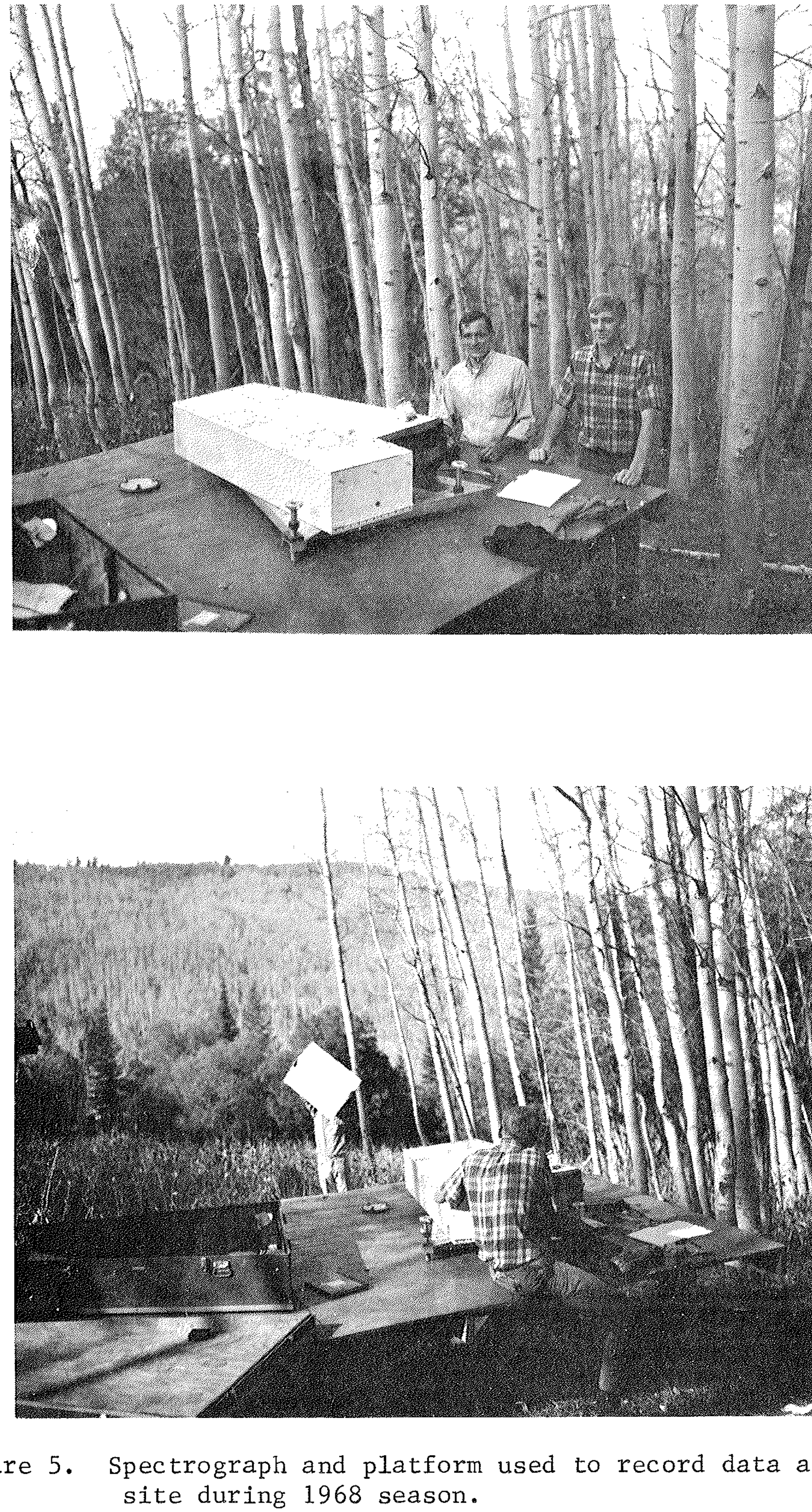

Figure 5. Spectrograph and platform used to record data at test site during 1968 season.

and the ratio of 8175 Å to 7150 Å decreasing in all areas toward the fall. The difference between the various areas was less than the differences measured in the 1967 studies. The ratios for the sunlit portions are plotted in Figure 6. The water content in the upper 6 feet of soil is also shown on the graph. The water content decreases with time but has an unexplained increase occuring near the end of August. Precipitation during the summer was very small and could not account for the sudden increase in moisture content in the soil. The change may not be real but due to calibration of the neutron measuring equipment.

The data taken from the shady areas in the trees is shown in Figure 7.

## Conclusions

The reflectance from the vegetation due to various environmental changes is highly wavelength dependent. That is, reflectance does not change the same amount at all wavelengths, and in certain cases may increase at one wavelength and decrease at others.

The laboratory measurements showed a definite decrease in infrared reflectance as the soil moisture was depleted. The field measurements in the natural watershed showed a similar reduction in infrared reflectance after a considerable number of days without precipitation. In both the laboratory and the field measurements the infrared reflection loss occurred while the apparent visible reflection remained constant.

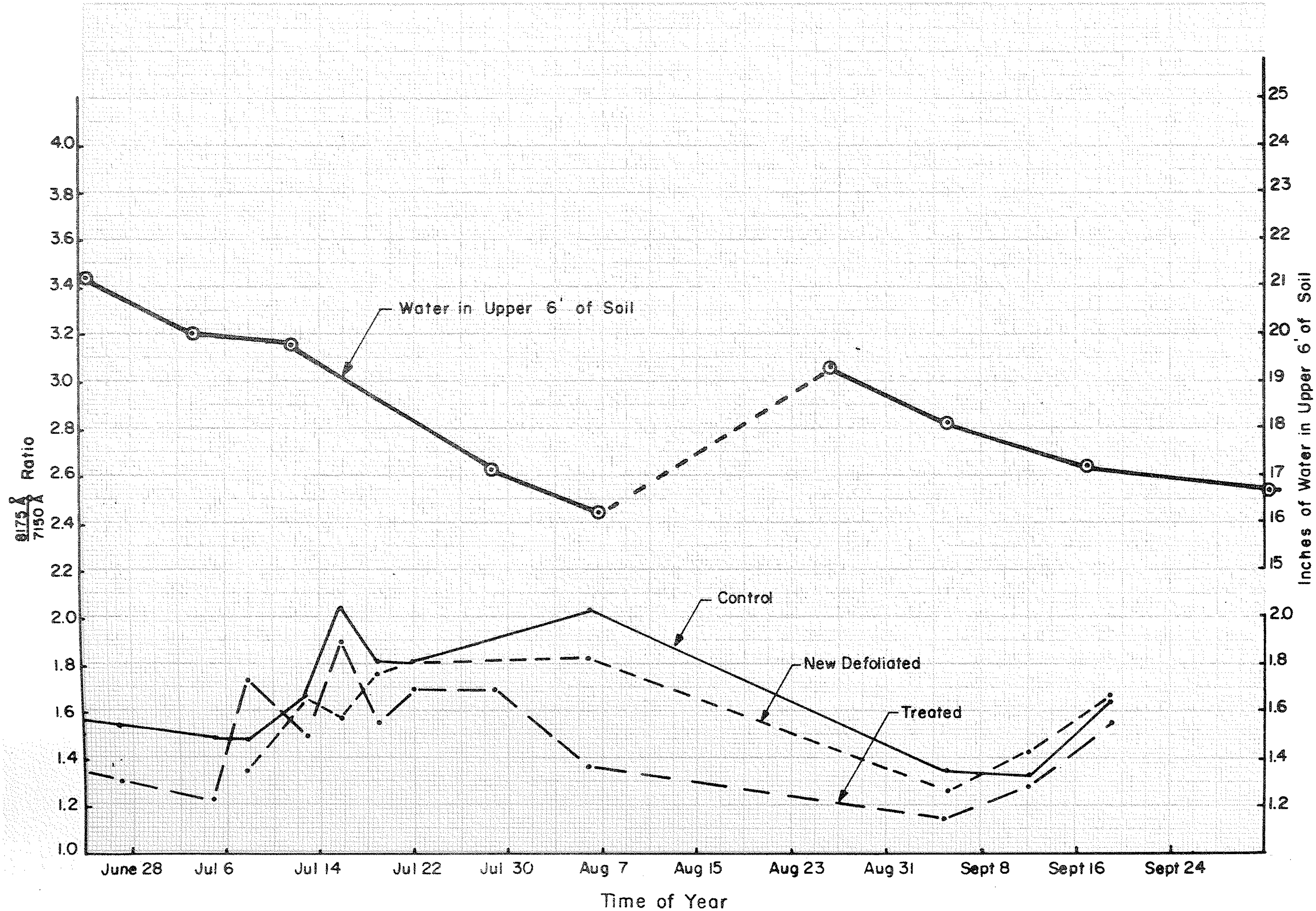


Fig. 6. Plots showing ratio of reflected energy at 8175 Å to reflected energy at 7150 Å - 1968,

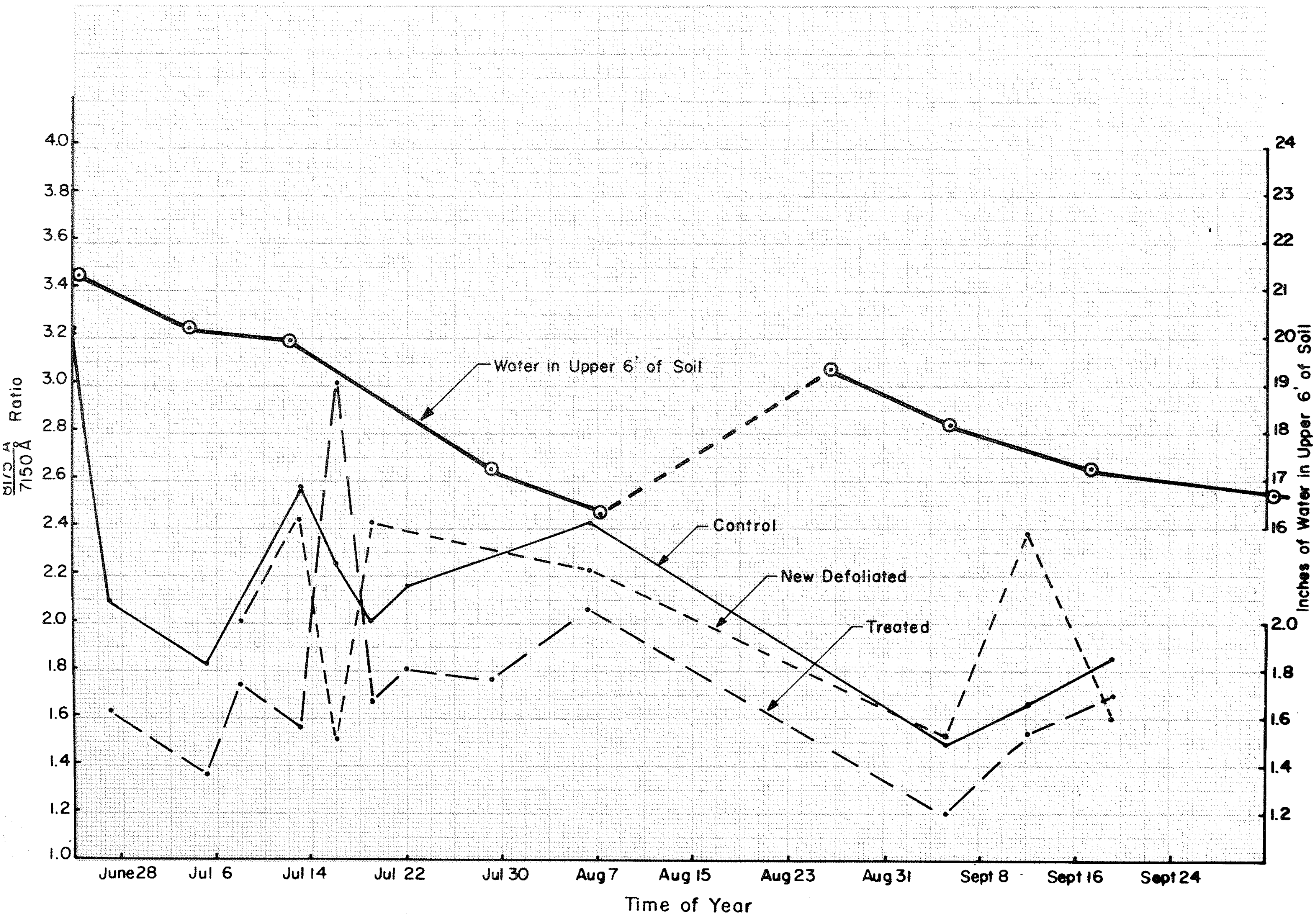


Fig. 7. Plots showing ratio of reflected energy at 8175 Å to reflected energy at 7150 Å - 1968, shaded areas

A simple and relatively inexpensive filter radiometer could be used to obtain a large quantity of data which would require minor data reduction to allow interpretation and correlation with water condition data obtained directly from the soil and vegetation.

The radiometer would be able to cover a larger wavelength range than the spectrograph used in this project because it would not be limited by the film's spectral sensitivity. Several filters could be interchanged allowing a wide variety of wavelength vs. reflection comparisons. The data already obtained would aid in selection of the wavelengths of the band-pass filters. Other wavelengths outside the capability of the film spectrograph could be investigated simultaneously with very little additional effort.

## Publications

Other phases of this project have been reported in the following publications.

Briscoe, R. D., and F. W. Haws. Using remote infrared sensors to detect changes in moisture conditions on natural watersheds. No. CWRR-14(a)-1, College of Engineering, Utah State University, Logan, Utah. 1967.

Schultz, J. D., G. B. Coltharp, G. E. Hart, Jr., and M. Zan. Manipulation of water use in an aspen forest. Proceedings of the Third Annual American Water Resources Conference, American Water Resources Association, San Francisco, California, November 8-10, 1967.

Hart, G. E., J. D. Schultz, and G. B. Coltharp. Controlling transpiration in aspen with phenylmercuric acetate. Water Resources Research, 5:407-412. 1969.

Goode, D. C. Industrial design study for an airborne ir mapper. Unpublished Masters Thesis, Utah State University, Logan, Utah. 1969.

Zan, M. Evaluation of the effects of reduced transpiration upon soil moisture retention in an aspen stand throughout the growing season in northern Utah. Department of Forest Science, Utah State University, Logan, Utah. Masters Thesis. 1968.