SUMMARY -- REMOTE SENSING SOIL MOISTURE RESEARCH
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by

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INTRODUCTION

Knowledge of soil moisture conditions is of prime importance to the management of water resource systems. Remote sensing may be able to provide considerable additional information to our water resource managers. Of special concern to agriculture is the ability to evaluate soil moisture conditions in order to enhance our production potential.

During the 1969 and 1970 growing seasons research was conducted to investigate the relationship between remote sensing imagery and soil moisture. The research is being accomplished under two completely different conditions; (1) cultivated cropland in east central South Dakota and, (2) rangeland in western South Dakota. Aerial and ground truth data are being studied and correlated in order to evaluate the moisture supply and water use. Results show that remote sensing is a feasible method for monitoring soil moisture.

RESEARCH UNDER CULTIVATED CROPLAND CONDITIONS

1969 RESEARCH EFFORT

Methodology

The study area for the cultivated cropland condition was located on the South Dakota State University Redfield Irrigation Farm in north central South Dakota. In 1969 soil moisture was studied on various crops on the irrigated part of the experimental farm. The experiment was designed on the basis of correlating data from sensors on repetitive flights with data taken on the ground. Sensors which were flown include the optical mechanical thermal scanner, the gang of four Hasselblads, and the precision radiation thermometer. Least squares analysis of variance was computed on optical density data as read by a Macbeth densitometer. Days, as a source of variation, was very significant, as were crops and days by crops.

Results and Conclusions

Conclusions drawn were that extraneous variation, namely varying levels of incoming radiation and film processing, affected the optical density to a large extent. Regression analyses on a within day basis yielded large r^2 values of .95 to .97 for each of the days in question.

Simple correlations between Ektachrome infrared optical density and the moisture profile were .7 using a neutral filter, .7 with the red filter, and .02 using the green filter. This leads to the conclusion that in the tri-layered film, the infrared layer was most effective in delineating the moisture profile. However, in the Ektachrome MS film the correlations were .5 to .7 for all four filters. The thermal relationship to depth profile was .021 or extremely low. This occurred in the corn field and leads to the conclusion that the corn canopy effectively destroyed the correlation between the thermal optical density and the depth profile or moisture profile. However, the opposite occurred when the area was fallowed. The correlation between thermal and the moisture profile was .857 in the fallow field. This leads to the conclusion that thermal scanning in the infrared region is highly useful for delineating soil moisture where no crop canopy exists to destroy its affect. However, Ektachrome infrared film is superior where there exists a viable crop canopy and should be used in this manner.

1970 RESEARCH EFFORT

Methodology

In 1970 the study area was reduced in size, different soil moisture conditions were included by the addition of irrigated and non-irrigated plots, and only one crop, grain sorghum, was used. Besides the irrigated and non-irrigated sorghum, a fallow plot was incorporated into the design as a reference. The field experimental setup is given in Figure 1.

Detailed ground truth data from the field were collected, including soil moisture by soil sample and neutron scattering, soil tension, crop and soil conditions, 35 mm ground photos, incoming and net radiation, and intensive weather data such as rainfall, wind, and temperature. Most of these were directly recorded in digital form.

Aerial data collection was planned in order to correlate closely with data collection from the future EROS projects. The film-filter combinations used correspond to the same general segments of the spectrum as the ERTS satellites. One color and three black and white films were used. Color reversal film was used with three-layer response in the green, red, and near-infrared regions of the spectrum. The black and white films were filtered for corresponding bands. A thermal scanner provided infrared imagery in the region from 4.5μm to 5.5μm. Incoming and reflected radiation was recorded generally by three solameters filtered in the green, red, and near-infrared portions of the spectrum. In addition, specific weather conditions relating to cloud and haze conditions were recorded at the time of each overflight.

Both aircraft and ground truth missions were scheduled so that the data taken would be most effective in analyzing changes in soil moisture. Missions were planned as soon before and after irrigations as possible and at other critical times of soil moisture and plant maturity. Thirteen aerial missions were flown in 1970 from shortly after plant emergence until just before harvesting of the sorghum. Flight altitudes were at 1000, 2000, and 5000 feet above ground level. Ground truth was collected during each overflight and at other selected times.

Imagery analyses are presently being performed by three methods: (1) visual interpretation, (2) film density measurements, and (3) use of a color encoding film density analysis system specifically designed for imagery interpretation. The timing of this report is such that data analysis has not been completed. However, visual observation of the imagery does allow interpretation of moisture differences during periods of plant stress.

Final analysis will be accomplished by correlation of film densities, and the output from the color encoding density analysis system, with the ground truth data. The overall difference between the total soil moisture supply within the irrigated and non-irrigated sorghum was smaller than expected. Soil moisture differences were substantial in the upper two feet of the profile, but the differences tended to disappear with increasing depth in the profile. The presence of this subsurface moisture could be attributed to the fact that the area with non-irrigated sorghum had been irrigated in preceeding years. Therefore, the non-irrigated sorghum was never severely stressed. Yield results of 7375 pounds per acre for irrigated and 5766 pounds per acre for non-irrigated, or only 21.8 percent difference, supports this theory.

Results

The preliminary results indicate that the soil-crop combination can provide information as to the changing moisture conditions throughout the season. Imagery analyses appear to show that the sorghum will provide an adequate indication of the available soil moisture. While the spectral reflectance of the soil seems to indicate only surface moisture, the crop relates moisture conditions of the soil profile, especially with increased plant maturity.

RESEARCH UNDER RANGELAND CONDITIONS

1970 RESEARCH EFFORT

Water resources is of prime importance to range management. The location and management of water in range areas is many times the ultimate control of stock numbers. Availability of soil moisture is the determining factor in range production. Therefore, during the 1970 growing season a research effort on rangeland conditions in western South Dakota was initiated. In this research effort we are concerned with the delineation of water resources in rangeland.

Methodology

This research effort is being conducted on the South Dakota State University Cottonwood Range Field Station. This experimental station comprises approximately 2,640 acres located in west central South Dakota approximately 75 miles east of Rapid City. Figure 2 depicts the layout of the experimental station. The six summer pastures are the area of interest in this study.

This research is being accomplished as a cooperative effort with the Animal Science Department at South Dakota State University. The ground truth data to be utilized in the analysis of the remote sensing data are being collected by other active research projects at the station. The collection of ground truth data has been fully coordinated with the collection of remote sensing data.

Biweekly soil moisture data are being collected with a neutron probe to a depth of at least four feet and gravimetric sampling is also being utilized at the shallower depths. Soil temperatures to a depth of 150 cm are obtained daily. Evaporation from a standard weather bureau evaporation pan, maximum and minimum temperatures, continuous recording of humidity and temperature in a standard weather bureau shelter, wind velocity and solar and sky radiation are being recorded. Precipitation is measured with a standard weather bureau recording rain gage. Soils are being described including mechanical analysis, moisture release curves, bulk density, soil organic matter and exchangeable cations by horizons. Above ground biomass is being determined at two week intervals during the period of rapid growth from approximately May 15 to August 15 and at approximately monthly intervals during the remainder of the year except when snow cover prevents sampling. Below ground herbage biomass is being determined at monthly intervals during the period of active growth and at two month intervals the remainder of the year except when frozen soil or snow cover prevents sampling.

Remote sensing data collection missions were made on June 9, 1970, July 7, 1970, August 4, 1970 and September 3, 1970. No data were obtained on the August 4, 1970 mission because of unfavorable cloud conditions. The missions were scheduled during the time period when below herbage biomass was being collected (all other data were also collected at this time) in order to obtain the maximum amount of ground truth data during the approximate time of the overflight. Multispectral imagery compatable with the ERTS A and B film-filter combinations, reflective and incoming radiation data and thermal scanner imagery were scheduled to be collected on each mission.

Imagery Analysis

Analysis of the first year data will be primarily directed toward interpretation of the remote sensing data as it relates to grazing conditions and available soil moisture. Densitometer measurements obtained with a Macbeth Model TD-404 densitometer, and soil moisture data, will be statistically analyzed. A Spatial Data Systems color encoding system will be utilized in interpreting the imagery for grazing conditions and soil moisture. The various remote sensing imagery collected will be evaluated for its effectiveness in determining the resource management factors under study.

Due to the limited amount of available processed ground truth data no detailed analysis of the data has been accomplished as of the writing of this report. However, some visual relationships are evident. As time progresses during the summer season the effect of grazing intensity is evident. Ungrazed areas in pastures 2 and 4 are also easily identified. The black and white imagery with the green filter (number 58) and the color infrared imagery show the grazing practice differences quite well. Pastures 1 and 4 have been heavily grazed, pastures 2 and 5 moderately grazed, and pastures 3 and 6 lightly grazed. Figure 3 is an example of the imagery collected. Figure 3 is a print made from black and white Plus-X film filtered with a 25A Wratten filter. Soil type differences are best identified on the black and white film with the red filter (25A) and these data will be fully interpreted at a later date with the available soils survey of the area.

Results

Preliminary results from the remote sensing data are quite encouraging. Different grazing intensities are quite evident on the imagery. Considerable analysis needs to be accomplished before any conclusions and/or recommendations can be made. The ground truth data and the remote sensing data will be statistically analyzed as soon as the ground truth data is available. The Spatial Data Systems color encoding system will be used for the soil type study and the aerial moisture distribution study.

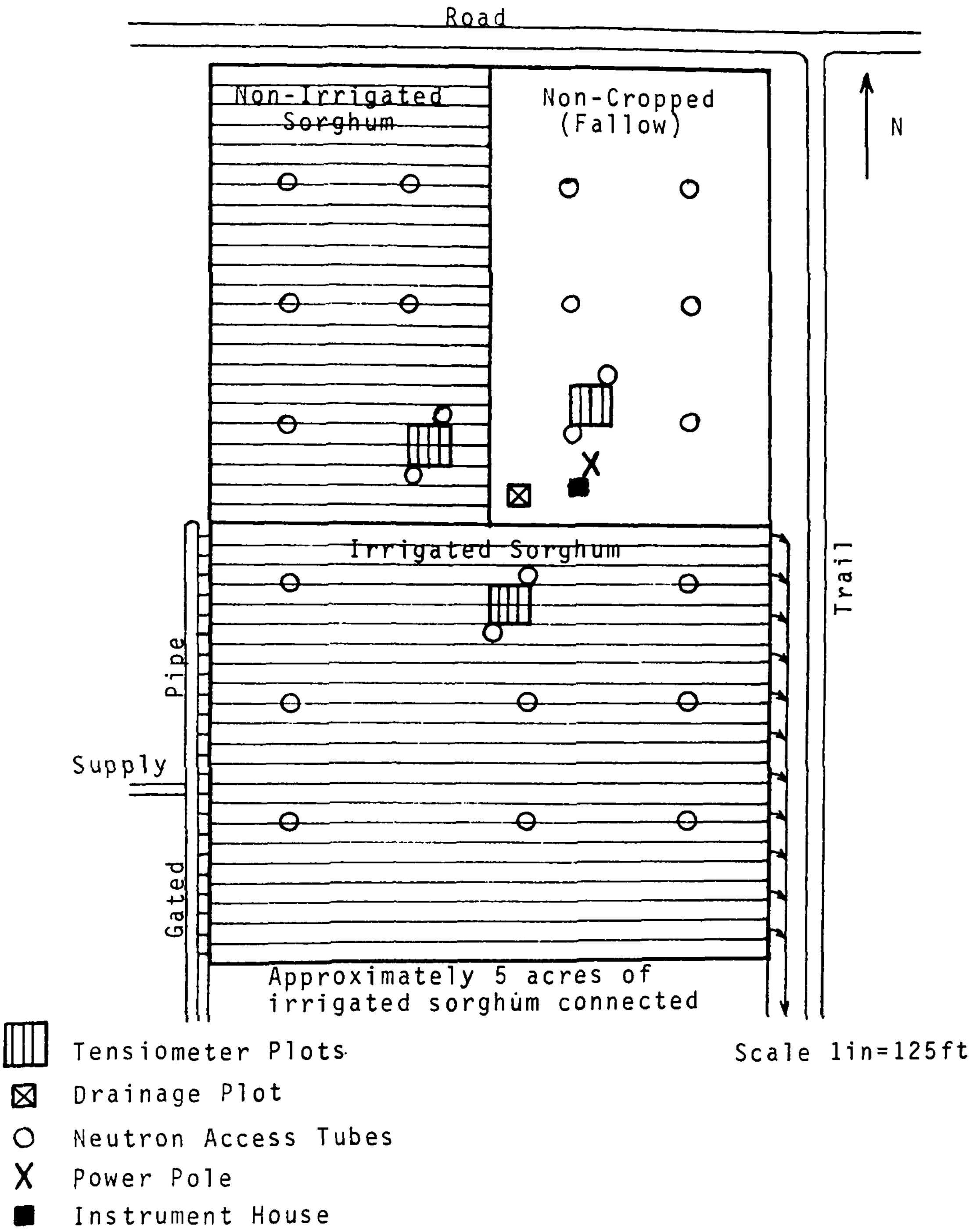

Figure 1. Experimental ground setup for remote sensing soil moisture research under cultivated cropping conditions.

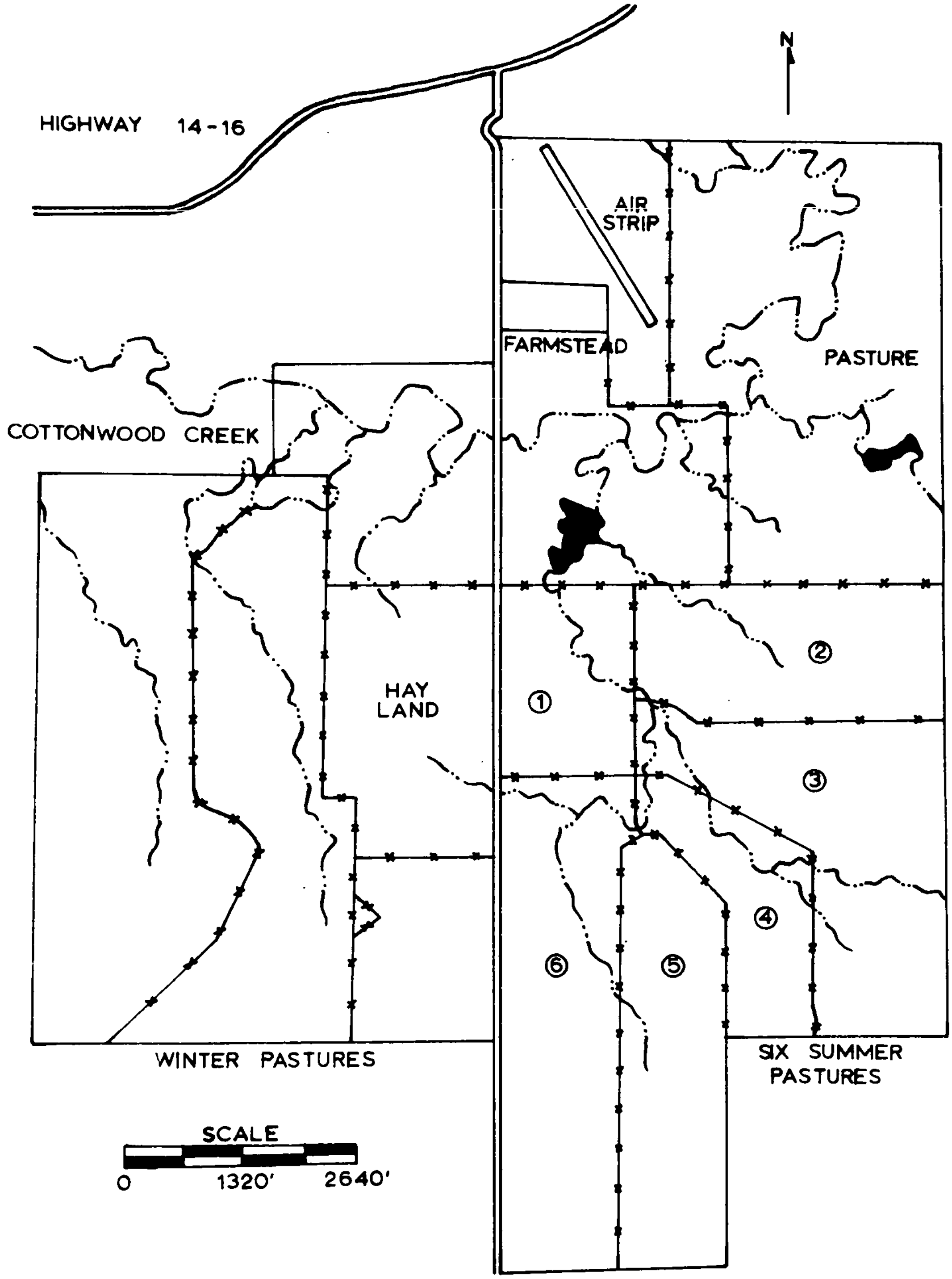

Figure 2. South Dakota State University Cottonwood Range Field Station, Cottonwood, South Dakota.

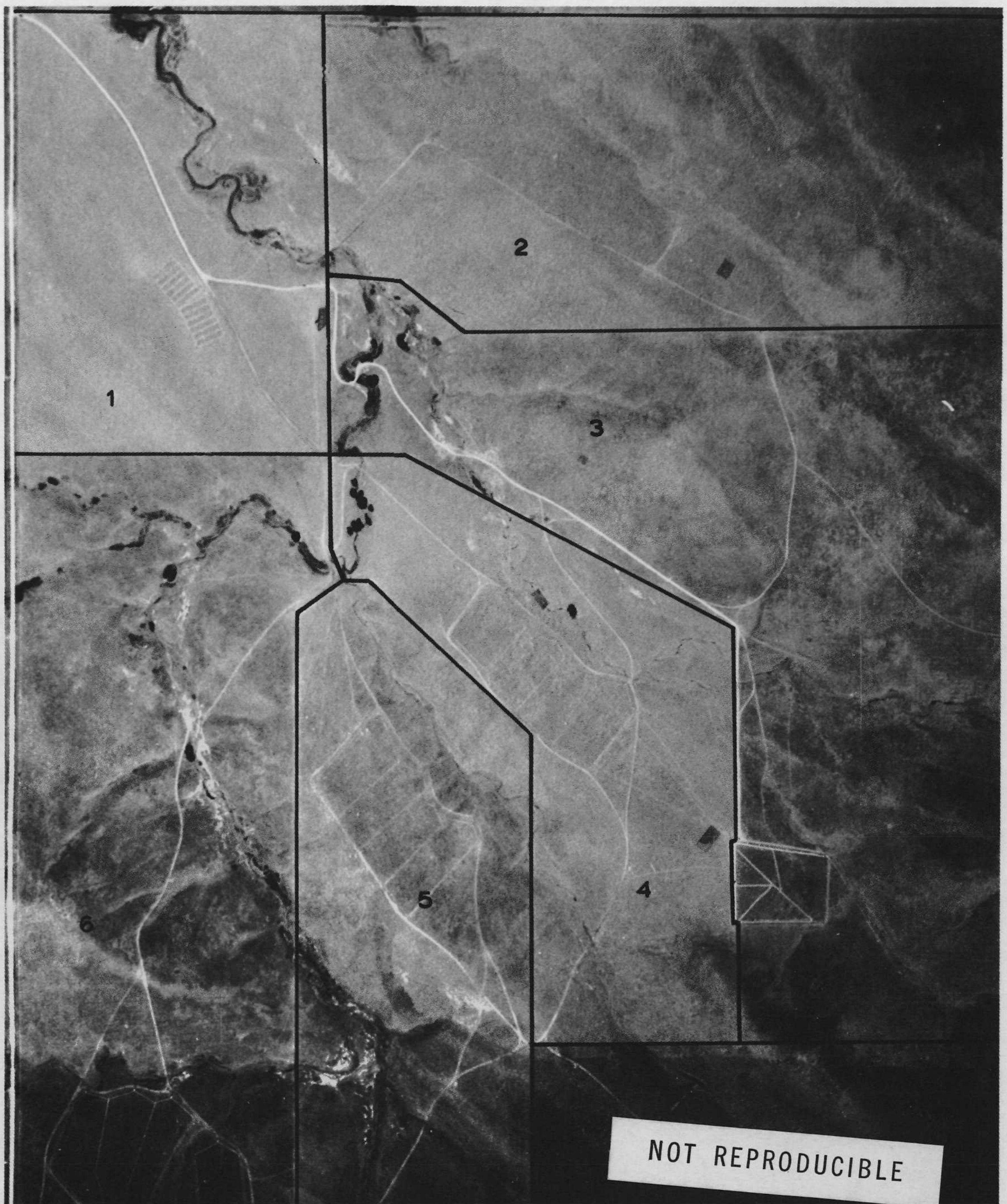

Figure 3. Six summer pastures on South Dakota State University Cottonwood Range Field Station printed from black and white 70 mm Plus-X filtered with a 25A filter.