A PROJECT TO EVALUATE MOISTURE STRESS IN CORN AND SOYBEAN AREAS OF WESTERN AND SOUTHWESTERN MINNESOTA

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INTRODUCTION

This report summarizes a continuing effort to assess soil moisture stress through crop signatures in southwestern Minnesota using remote sensing techniques and particularly LANDSAT data (Rust and Robert, 1977, 78). Related objectives are: localization of droughty, well drained, and poorly drained soils; detection of stress from hail, wind, and disease damage; and the use of remote sensing data for agricultural management.

The 1979 ground data collection network was similar to that used in 1978, but site #10 in Chippewa County was dropped because the soil survey terminated. Generally similar procedures were used for ground data collection, greenhouse experiments, and remote sensing data types. The 1978 progress report gives the site locations (Figure 1: See Volume XII, 1978) and summarizes equipment characteristics and procedures.

Since the amount and distribution of precipitation were adequate during the 1977 and 1978 growing seasons, no significant stress occurred. Crop conditions were very favorable. As a result, crop signatures were too uniform to reflect soilscape variations and crop condition changes. In 1979 precipitation was again adequate to excess, particularly in June and August (Table 1). In some cases, poorly drained sites especially,

Table 1. 1979 growing season monthly precipitation and normals for some weather stations of SW Minnesota

		Precipitation (inches)							
Location		April	May	June	July	August	Sept	Oct	Total
Montevideo	Normal	2.29	3.31	4.72	3.48	3.69	2.92	1.62	22.03
	1979	3.26	3.98	8.32	2.17	6.87	0.40	3.60	28.60
Marshall	Normal	2.46	3.30	4.49	3.95	2.68	2.70	1.61	21.19
	1979	3.90	4.13	7.12	4.13	6.32	0.97	3.27	29.84
Pipestone	Normal	2.22	3.60	4.62	3.35	2.96	3.20	1.73	21.68
	1979	3.13	2.82	3.84	3.44	6.38	2.13	4.31	26.05
Redwood Falls	Normal	2.22	3.25	3.92	3.86	3.24	2.42	1.74	20.65
	1979	1.56	5.48	4.71	6.70	8.30	1.44	3.24	31.43
Windom	Normal	2.35	3.61	4.50	3.74	3.30	3.54	1.70	22.74
	1979	1.11	6.02	5.13	3.76	7.82	2.43	4.68	30.95
Average	Normal	2.38	3.49	4.42	3.69	2.99	3.07	1.70	21.66
	1979	2.59	4.78	4.98	4.04	7.14	1.47	3.82	28.82

stress conditions developed as a result of excess of water and could be identified on color infrared photographs.

CORN LEAF REFLECTANCE IN GREENHOUSE EXPERIMENTS

Field reflectance[1] is the result of interactions between a variety of factors such as crop condition, soil type, and farming techniques. The relationship between water availability and plant reflectance can be most adequately isolated in a greenhouse experiment.

Five experiments measuring corn leaf reflectance were conducted from fall 78 to spring 79 using equipment and techniques previously described (1978 progress report). Figure 1 summarizes the main results of one experiment. We observe a general trend toward increased reflectance in response to increased plant water potential[2], a result also found in 1978 on soybean plants. However, the detailed relationship is much more variable, for example, as in the last measurement. Furthermore, correlations may be smaller in some other experiments, particularly in the near infrared waveband. Additional experiments will be conducted during the 1979-80 fall to spring period.

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[1]Reflectance is use for "reflected energy intensity". The differential normalized reflected energy (DNRE) is defined as

$$\text{DNRE} = \frac{\text{E.I. of stressed leaf}}{\text{E.I. of standard}} - \frac{\text{E.I. of turgid leaf}}{\text{E.I. of standard}}$$

where
E.I. = Energy Intensity of the reflected light. The standard is magnesium oxide at 600 nm.

[2]Water potential is the energy status of the contained water in leaves (or other plant parts) expressed in units of pressure (bars).

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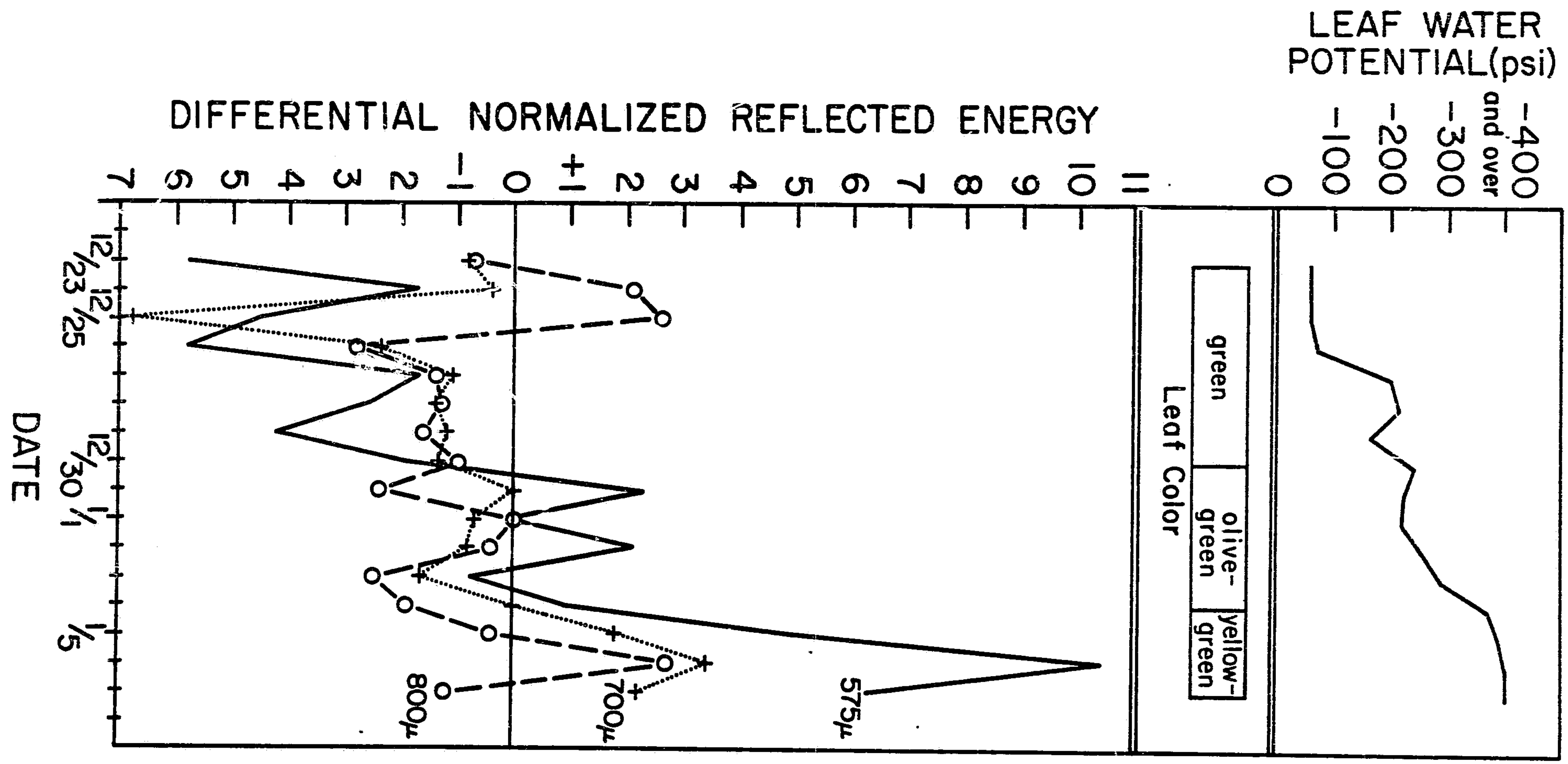

Figure 1. Differential Normalized Reflected Energy(3), Water Potential and Color of Progressively Stressed Corn Plants.

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ASSESSING CROP HAIL DAMAGE

Ground data on hail damage were collected and mapped by the field collaborators using local informaion.

The main hail damage in 1978 occurred on July 6 in Chippewa, Jackson, Pipestone, and Redwood counties. The July 15 LANDSAT imagery (near infrared B & W, 1:1,000,000 scale) gives the best signature of the damaged areas. Figure 2 shows the characteristic signature change of the damaged areas. A better identification could result from the ratio of the July 17 to June 23 data. The ratio might reduce background noise. This will be tested on the IMAGE 100 system during our next session at the Eros Data Center.

LANDSAT DIGITAL DATA ANALYSIS

Data from the three related scenes of 1977 (June 23, July 29, and September 9) were analyzed at the EROS Data Center, Sioux Falls, during a three-day session. Most of the image processing was performed using the IMAGE 100 system (General Electric Co.). One information extraction was done using the more powerful IDIMS (interactive image processing) system (Electromagnetic System Laboratores, Inc.).

From the original computer compatible tape, overviews of the three scenes (3% sampling) were computed by sampling every sixth column and every fifth line. Windows (256 columns by 185 lines) corresponding to six sites were extracted from the three tapes and stored on a "working" tape.

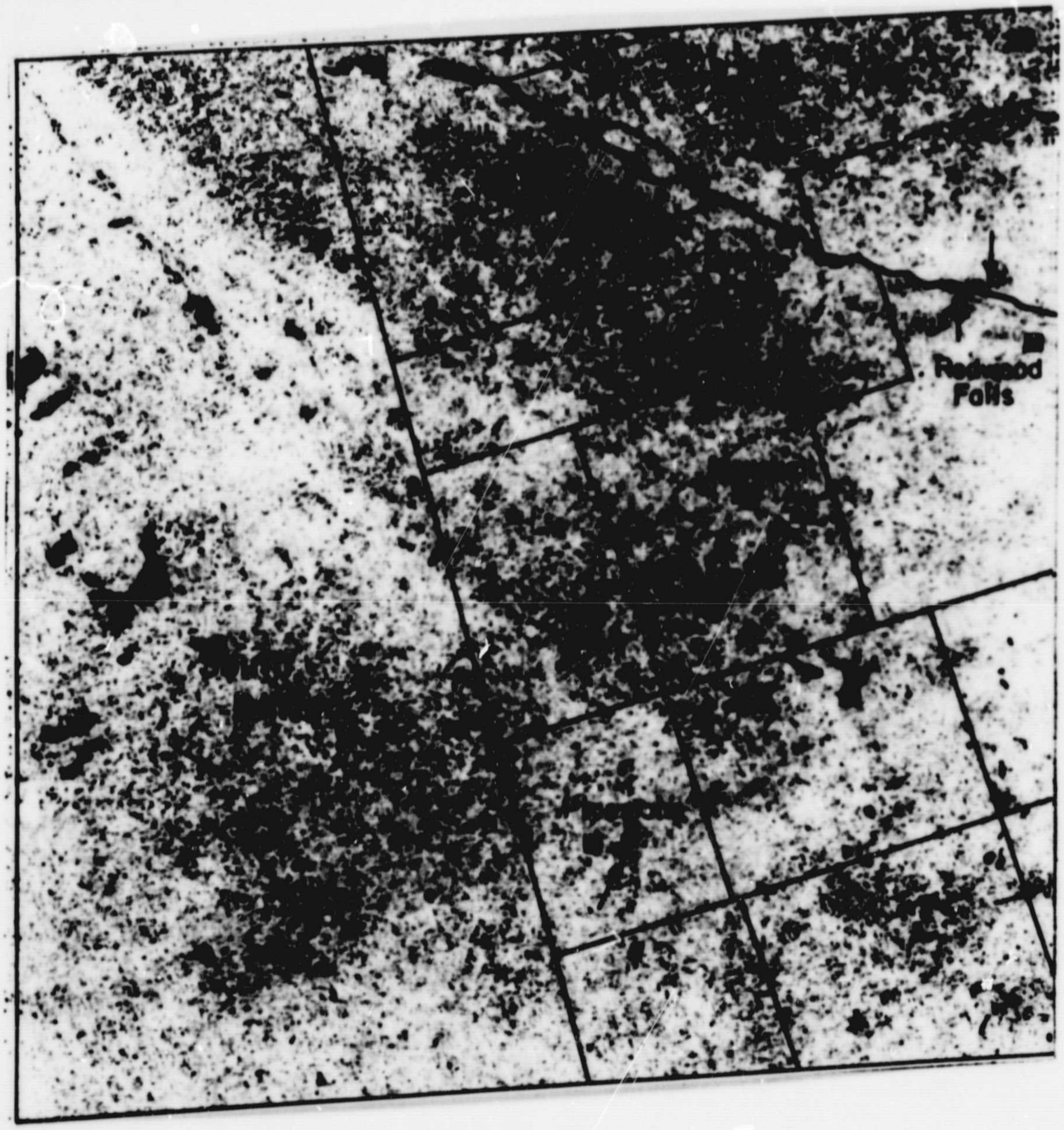

Figure 2. July 15, LANDSAT imagery over southwestern Minnesota (Band 7, 1:1,000,000 scale, path 31, row 24). Arrows indicate hail damage.

Site number 5 (Tracy) was selected for a detailed study on both image analysis systems.

On the IMAGE 100 system the following operations were performed: (1) dumping pixel values; (2) establishing video levels between 0 and 255 for each pixel within the cursored area, which are then printed so that a 1:1 map is obtained; (3) alphanumeric plotting of the training sections using 8 different themes corresponding to 8 equal groups of pixel values; (4) clustering the June (Figure 3) scene and displaying the result on the electrostatic plotter using a 1:1 and 9:1 ratio; (5) temporal overlaying of bands 5 and 7 for the June and July scenes with classification of the resulting image.

On the IDIMS system, alphanumeric maps with 64 classes for the June and July scenes were produced after clustering using the "Isoclass method" (nearest neighbor algorithm) on the 4 channels.

The most significant result came from the temporal signature of the June and July scenes. Corn, soybean, and small grain fields were readily identified. Because of the homogeneity of the signature within crops (the result of favorable weather conditions), it was not possible to make further differentiations, particularly in soil drainage classes.

ANALYSIS OF SOIL WATER

Soil water content is one of the principal parameters correlated to the crop signatures. Its value is monitored throughout the growing season on each site.

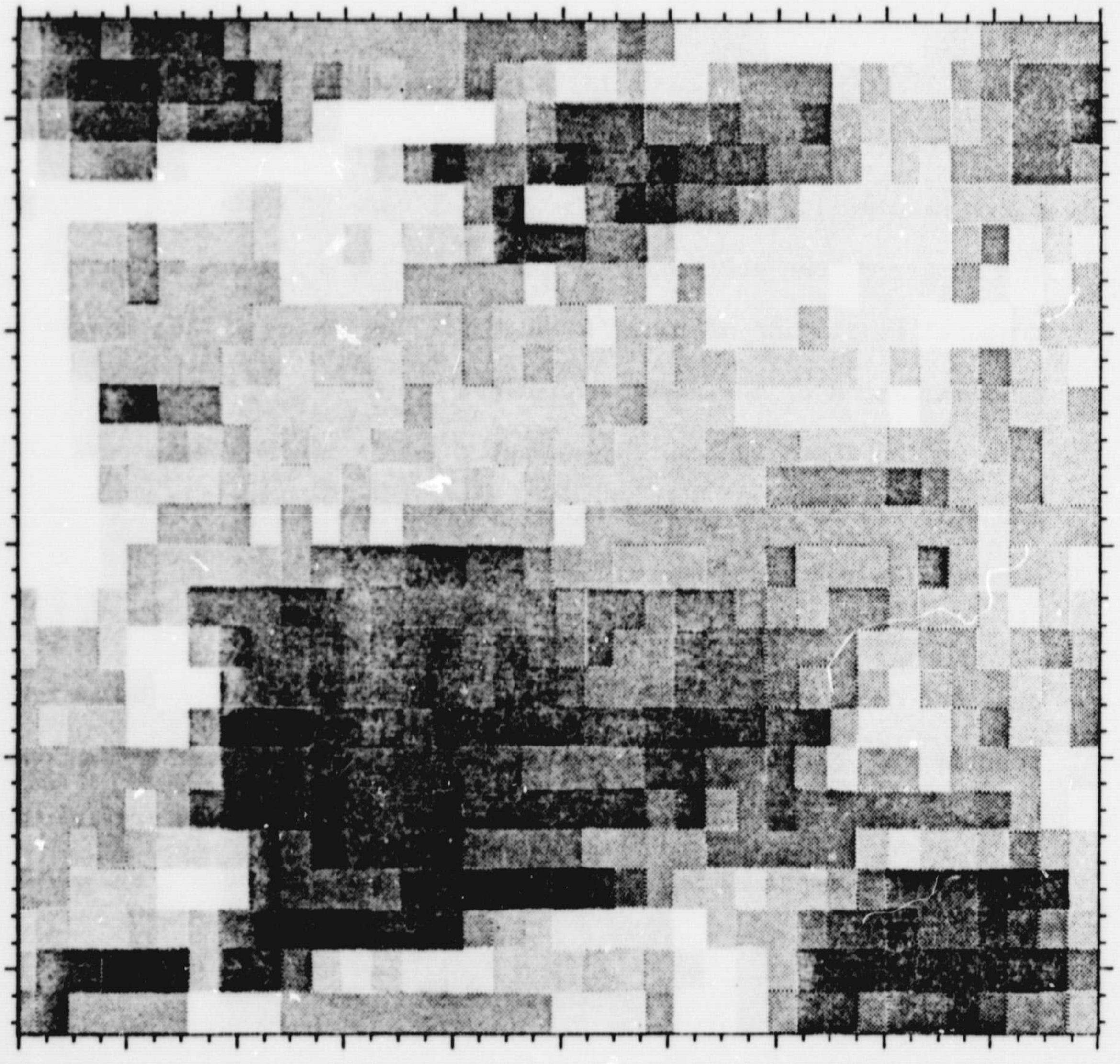

Figure 3. Clustering of the June, 1977 Scene (Band 5).

Soil water content was previously expressed water per unit mass of soil because most of the soil bulk densities were not available. A preferred expression is water per unit volume of soil. This is a better evaluation of the soil water content since it takes account of soil texture and structure. However its computation requires a correct measure of the soil bulk density, which introduces some error due to soil variability and requires a lengthy laboratory analysis. Table 2 gives the oven dry and 0.3 bar soil bulk densities for most of the ground data soil sites. Values in parenthesis seem questionable.

Another expression of the soil moisture is the available water, which is the moisture retained in the soil between the field capacity (a pressure of 0.3 bar) and the permanent wilting coefficient (15 bars). Values are usually expressed on disturbed (crushed, artifically packed) samples because it is easier and faster to do so. However, such measurements eliminate the soil structure effect and have to be applied with caution to field situations, particularly for low matric potential (wet end of soil moisture range).

A method was developed to measure soil water retention on undisturbed soil cores. Soil cores are sampled using a hydraulic probe, saturated with water, frozen, installed in a special holder (Figure 4), mounted on a diamond saw, and cut to the thickness of the rubber ring used in the pressure chamber.

If the sawing produces a "polish" on the faces, the sample surface is roughened on a grinder covered with a medium sand paper to reopen all the pores.

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Table 2. Oven dry and 1/3 bar soil bulk densities for ground data sites.

Soils (Sites)	Oven dry density (g/cm^3)					1/3 bar density (g/cm^3)				
Depth	- 0-6"	6-12	12-24	24-36	36.48	0-6"	6-12	12-24	24-36	36-48
Ves (02)	1.74	1.64	1.53	1.56	1.50	1.51	1.38	1.38	1.42	1.47
Seaforth (03)	1.39	1.32	1.32	1.38	1.48	1.18	1.15	1.15	1.26	1.35
Letri (05)	1.21	1.39	1.41	1.51	1.56	1.04	1.16	1.26	1.45	1.44
Everly (05)	1.46	1.39	1.40	1.42	1.47	1.32	1.32	1.30	1.30	1.34
Okoboji (06)	(.95)	1.19	1.27	1.23	(1.19)	(.87)	1.04	1.06	1.03	(.99)
Everly (10)	1.46	1.39	1.40	1.42	1.47	1.32	1.32	1.30	1.30	1.34
Tara (10)	1.30	1.42	1.44	1.45	--	1.11	1.27	1.32	1.30	--
Kranzburg (11)	1.48	1.40	1.47	1.61	1.58	1.40	1.24	1.25	1.46	1.48
Ves (12)	1.49	1.57	1.42	1.42	1.50	1.32	1.32	1.21	(1.04)	1.47

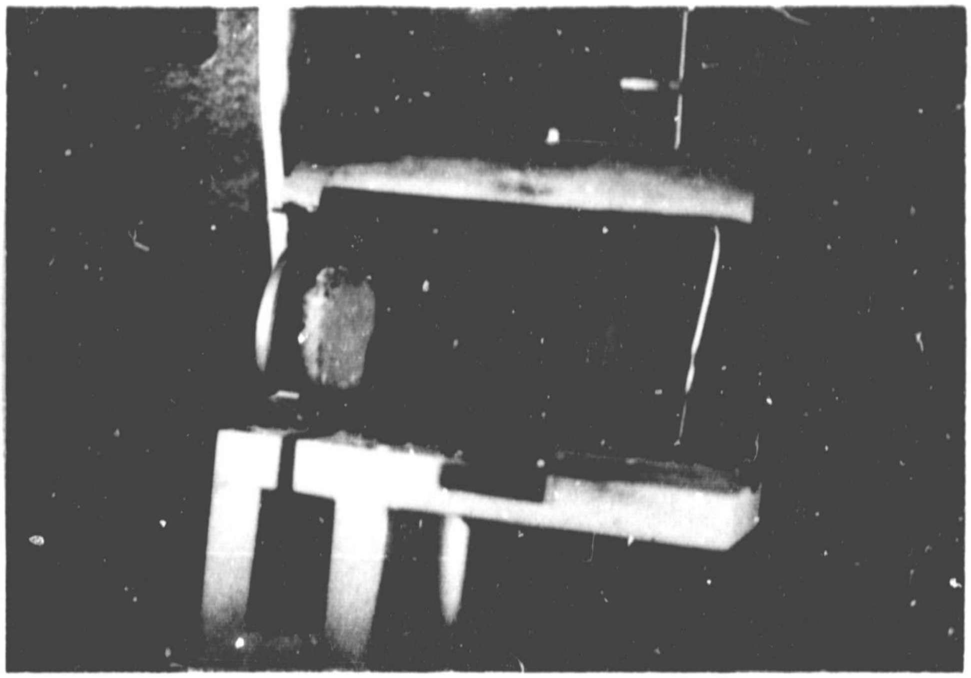

Figure 4. Cut soil core in the special petrographic saw holder.

Table 3 gives a summary of differential water content (disturbed less undisturbed samples) at 0.3 and 15 bars for on site soils. The differential values are statistically highly significant ($p < .001$) at 0.3 bar, but they are not significant at the .05 level for the 15 bars samples ($.05 < p$ value $< .10$). Therefore, water retention at 0.3 bar should always be measured on undisturbed samples.

ATTEMPT TO DEVELOP REAL TIME AGRICULTURAL MANAGEMENT

The development of timely recommendations for crop and soil management was an initial objective of the project. It appears that this objective cannot presently be accomplished using Landsat data. The acquisition of imagery requires a long delay of at least two months. However,

Table 3. Difference in water content per unit vol[illegible] between disturbed and undisturbed soil samples at 0.3 and 15 bars.

Site		Soil	Depth in inches for well-drained soils 0-6	6-12	12-18	18-24	24-36	Soil	Depth in inches for poorly-drained soils 0-6	6-12	12-18	18-24	24-36
02	1/3 bar	Ves	1.6	5.9	5.1	-	3.4	Canisteo	3.2	0.8	0	4.2	0.7
	15 bars		-0.9	-2.0	-	-5.0	-						
03	1/3	Seaforth	1.9	0.9	2.8	3.2	3.9						
	15		-0.5	-0.4	0.5	0.6	-						
04	1/3	Clarion	0.5	3.4	2.9	1.9	2.5						
	15		-0.5	0.5	-1.3	-0.1	-						
05	1/3	Everly	3.8	1.9	0.7	5.2	-	Letri	3.0	1.4	0.4	4.5	3.6
	15		0.4	-1.1	-0.2	1.1	-		1.0	-0.7	-1.7	-0.2	0.8
06	1/3	Ves						Okoboji	8.2	9.5	3.3	2.7	8.6
	15								-	-	0.4	-	0.3
10	1/3	Tara	5.2	4.7	-	3.7	-	Sletten	5.0	3.2	6.9	1.8	3.8
	15		-0.4	-0.8	-3.9	-1.8	-		0	-1.7	-0.8	-1.0	0.3
11	1/3	Kranzburg						Hidewood	6.9	4.6	5.1	4.9	4.9
	15								-3.3	-3.4	-2.8	-0.2	-1.0
12	1/3	Ves	3.0	2.3	3.4	6.9	5.0	Webster	-1.0	1.5	-0.7	-	-0.3
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since improvements in processing time and in data resolution are expected in the near future, a cooperative project between the Waseca and Lamberton experimental stations, and twelve farmers located in southcentral and southwestern Minnesota (see Figure 5) was started in Spring 1979 to test the practical use of remote sensing techniques for "on time" corn and soybean field management.

The objective was to give the cooperators, throughout the growing season, a color infrared print within ten days of flight date at approximately 1:10,000 scale and contain interpretation of soils - and crop-conditions on an overlay (Figure 6). Information which can be extracted from aerial photographs includes germination success (equipment failure, disease, herbicide effectiveness), a check on stand growth and development (plant damage, misapplication of chemicals), drainage effectiveness, soil moisture stress, harvesting problems (lodging, weed infestation, variable ripening), regrowth pattern, and hail, wind and flood damages.

Unfortunately, the cloudy conditions encountered during most of the 1979 growing season allowed only two flights, July 15 and September 16. Table 4 gives the features we were able to distinguish on the September photographs. An important practical result was to show a precise spatial distribution of drainage effectivness.

Interest in continuing the project was expressed at the evaluation meeting held in St. James on November 14 by the farmers, county agents and extension agents.

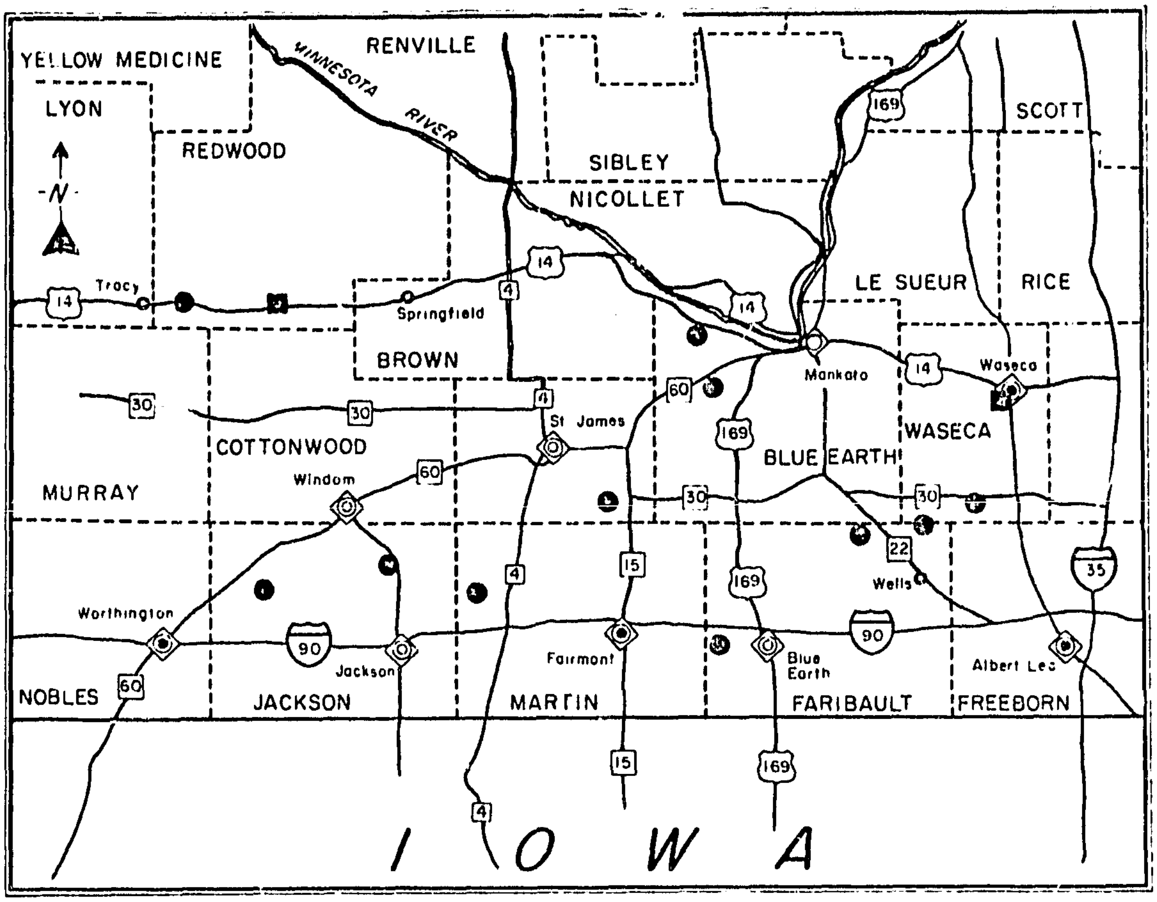

Figure 5. Locations of Cooperators in the Agricultural Management Project

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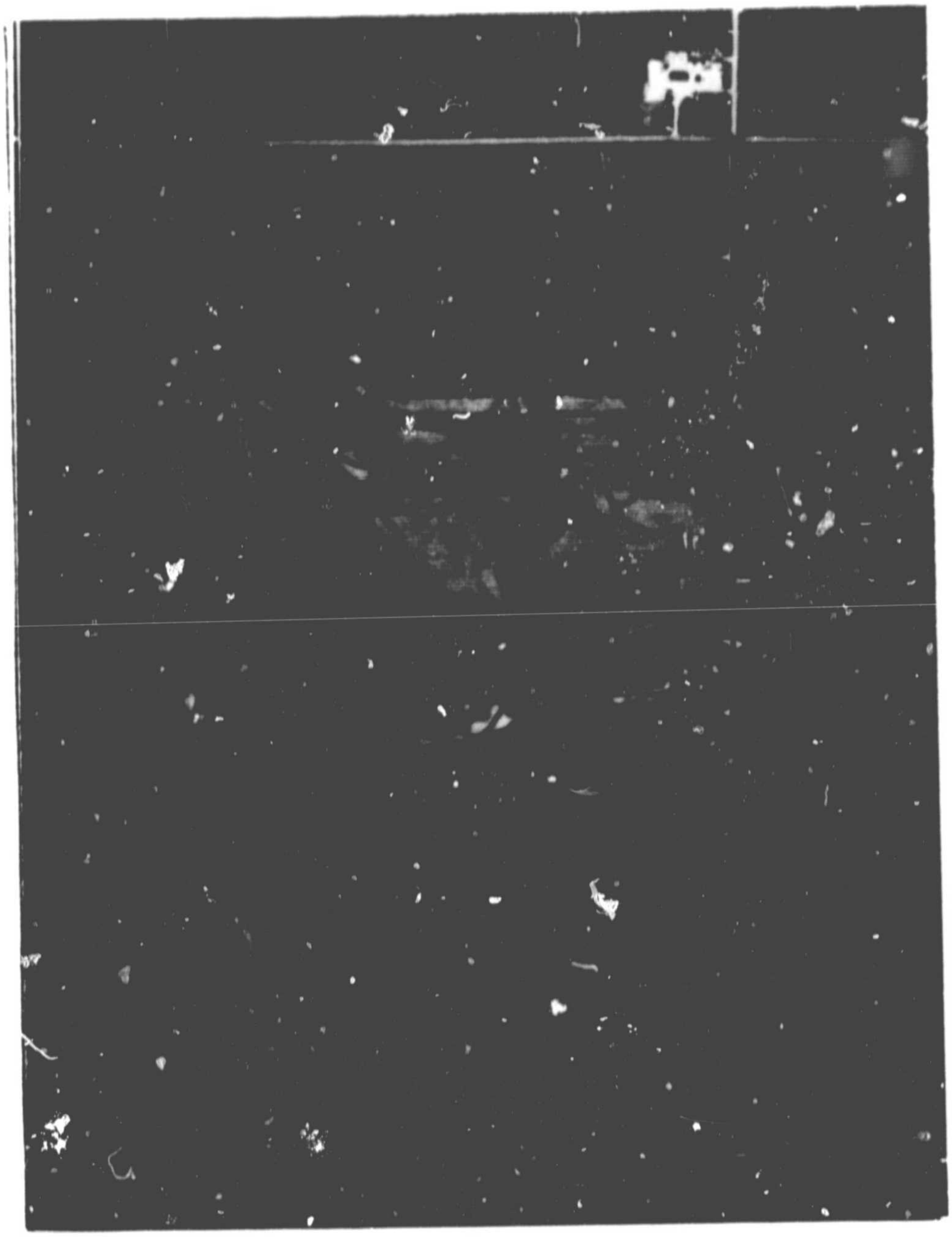

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Figure 6. Color infrared print with interpretation of soils and crop conditions (at 1:10,000 scale).

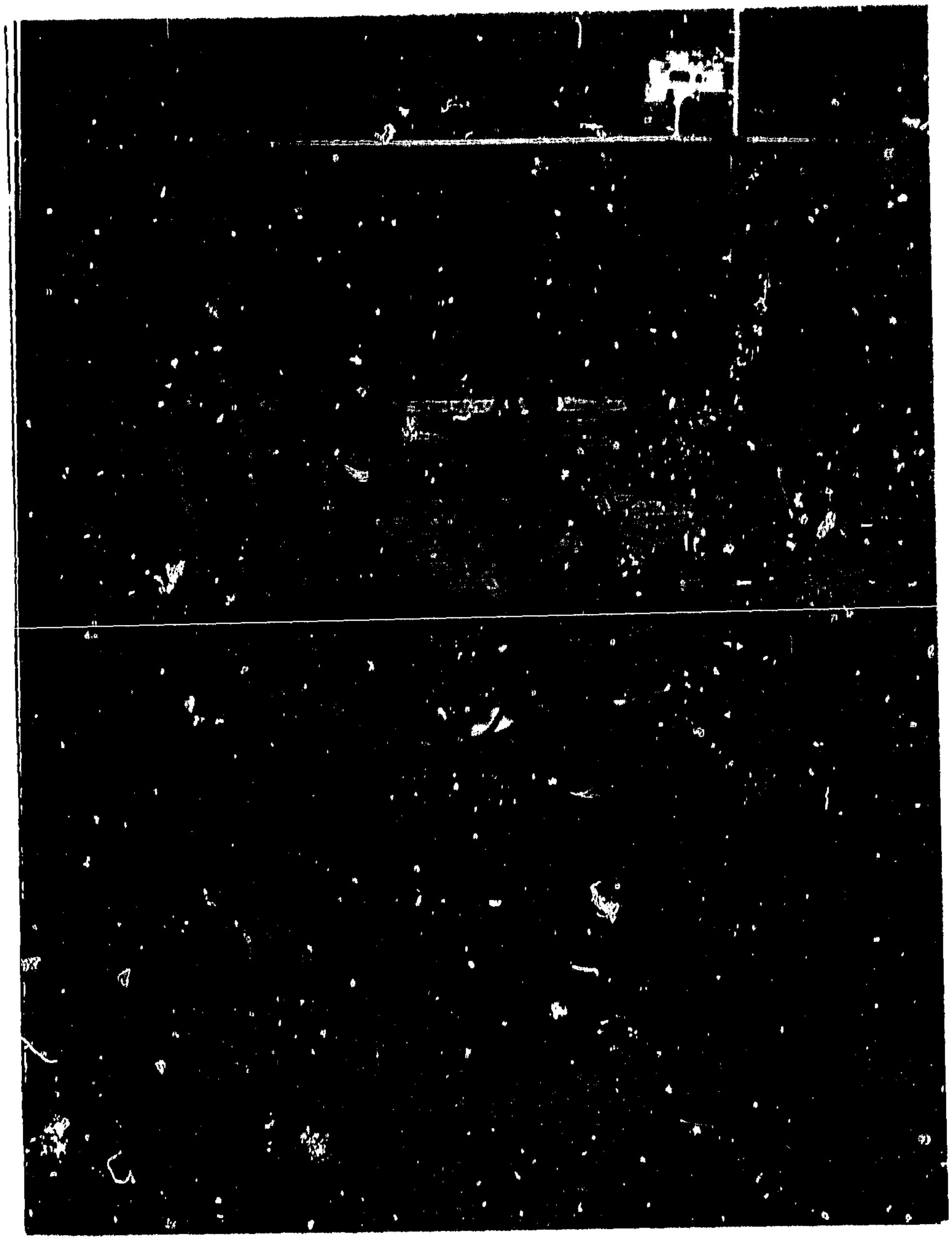

Figure 6. Color infrared print with interpretation of soils and crop conditions (at 1:10,000 scale).

Table 4. Interpretative legend for the September 16 photographs.

1 : slight reduction in growth or crop stand by excess of moisture;

2 : significant reduction in growth or crop stand by excess of moisture;

3 : plant loss or damage by high excess of moisture;

5 : reduced growth by soil erosion.

S1: (greenish color) soybeans, reduced stand, delayed maturity.

S2: (brownish color) soybeans, good stand;

C1: (darker brown) corn, reduced stand, delayed maturity;

C2: (lighter brown) corn, good stand;

B1: (darker green) bare field, poorly drained soil type;

B2: (lighter green) bare field, well drained soil type;

T1: (light tone) thin surface horizon, sandy;

T2: (light tone) thin surface horizon, high lime;

Df: differential maturity related to planting date or seed variety;

W : (reddish color) significant weed problem;

? : unknown problem.

SUMMARY AND CONCLUSIONS

The 1979 growing season received significantly above average precipitation in the study area. As a result, the poorly drained soils had some moisture excess which probably will be reflected in the LANDSAT data.

As a result of the wet season, the percentage of cloud cover was also higher than usual. This greatly reduced the availability of LANDSAT scenes. There are only 3 scenes available with less than 10% cloud cover for the study area. There is no usable scene available from June 6 to September 20, 1979.

Corn leaf reflectance does not show a strong relationship with plant stress or plant water potential as measured with the technique used for soybeans in the 1978 greenhouse experiment. Additional measurements will be made in 1980.

Hail-damaged areas show a characteristic signature on the LANDSAT black and white infrared product. Further identificaion will be tested using the digital data.

Information extraction from the 1977 digital tapes was performed at the Eros Data Center using the IMAGE 100 and the IDIMS systems. The study of one site showed that crop identification is feasible using temporal signatures. But because of uniformly excellent crop conditions, reflected in nearly homogeneous signatures, it was not possible to make further differentiations, e.g., soil drainage classes.

To evaluate more accurately the soil water content of the ground data sites, their soil bulk densities and soil water retentions at 0.3

and 15 bars were measured. A method to prepare undisturbed soil samples was developed. A highly significant difference in water retention was found between disturbed and undisturbed samples at 0.3 bar. Undisturbed samples should be used.

A cooperative project between the Waseca and Lamberton Experiment Stations and 12 farmers tested the feasibility of using remote sensing techniques for real time agricultural management. The objective was to produce, within 10 days of the flight date, color infrared prints and interpretation of soils and crop conditions related to plant growth, equipment failure, chemical efficiency, drainage effectiveness, and stress as a result of moisture extremes, hail, and diseases. Cloud cover and the processing time of color infrared films were the two main problems. Positive results were obtained such as indication of a need of drainage, weed control, and the management of eroded fields. Interest in continuing the project was expressed by the cooperators.

REFERENCES

Rust, R. H. and P. Robert. 1977. Evaluation of soil moisture stress in W. and SW. Minnesota. Section F in NASA Progress Report (NGL 24-005-263, Vol. XI).

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