LACIE-00437
JSC-11666

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

CROP INVENTORY
LARGE AREA
EXPERIMENT
LACIE

NASA NOAA USDA

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RESULTS OF LACIE DROUGHT ANALYSIS

(SOUTH DAKOTA DROUGHT 1976)

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

SEPTEMBER 1976

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

Results of LACIE Drought Analysis

(South Dakota Drought 1976)

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September 1976

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

LACIE using techniques developed from the southern Great Plains drought analysis indicated the potential for drought damage in South Dakota in early May 1976. This potential was monitored throughout May and as it became apparent that a drought was developing, LACIE implemented some of the procedures used in the southern Great Plains drought.

The technical approach used in South Dakota involved the normal use of LACIE sample segments (5 x 6 nm) every 18 days. Full frame color transparencies (100 x 100 nm) were used on 9 day intervals to identify the drought area and to track overtime. The green index number (GIN) developed using the Kauth transformation was computed for all South Dakota segments and selected North Dakota segments. A scheme for classifying segments as drought affected or not affected was devised and tested on all available 1975 and 1976 South Dakota data. Yield model simulations were run for all CRD's in South Dakota. This is the second of three reports on the 1976 droughts in the U.S. Great Plains and summarizes the results of the LACIE drought analysis for the drought in South Dakota.

1.1 OBJECTIVES

The objectives of monitoring the South Dakota drought in real time were to determine the extent of the drought, to determine the effect upon acreage, yield and production of wheat and to improve procedures developed in the southern Great Plains for monitoring drought using remote sensing based criteria.

1.2 HISTORY OF SOUTH DAKOTA DROUGHT

The 1976 South Dakota drought goes back to the summer of 1975 when subsoil moisture was not fully recharged. Precipitation was adequate for winter wheat from emergence to greening up in spring. Spring wheat had adequate moisture for planting, emergence, and greening up. The crop was in fair shape through April 1976. If May rains had occurred, the wheat crop probably would have been developed normally. Under normal conditions with adequate subsoil moisture, the lack of May precipitation would not have been a serious factor. May precipitation (Table 1) was considerably below normal for CRD (Crop Reporting Districts) in the central and northeastern parts of the state. It was reported in the Southern Great Plains analysis (LACIE 00424) that a 30 percent of normal precipitation for one month may be the flag necessary to evaluate the potential for drought. This has been proven to be the case in South Dakota. The CRD's that were as low as 30 percent of normal precipitation for May were the CRD's where the most severe drought damage occurred, as will be reported on later in this report.

2.0 AREAL EXTENT OF DROUGHT

The areal extent of the drought was determined using full-frame color infrared transparencies (figure 1). This extent was determined by monitoring full frame images from April 18, 1976, until harvest of the wheat by comparing 1976 full frame to past years of essentially the same date when available and also to previous 9-day acquisitions.

TABLE 1

SOUTH DAKOTA MAY PRECIPITATION STATISTICS

	ACTUAL (1976) (INCHES)	NORMAL (INCHES)	% OF NORMAL
CRD 10 Northwest	1.30	2.48	52
CRD 20 North Central	.80	2.60	31
CRD 30 Northeast	.70	2.82	25
CRD 40 West Central	2.75	2.91	94
CRD 50 Central	.80	2.68	30
CRD 60 East Central	.70	2.94	24
CRD 70 Southwest	2.00	2.91	69
CRD 80 South Central	1.00	3.05	33
CRD 90 South East	1.90	3.23	59

2.0 AFFECTED AREA

The initial drought affected area was determined, from full frame, to be located within the state of South Dakota. From April 18, 1976, to June 1976, the area appeared to be deteriorating some, but the full frame signature did not show severe damage. The June 11-13 overpass did, however, show drought damage. A June 13, 1976 image shows part of the area affected by drought (figure 2). The southern part of the full frame shows the lack of red signature associated with healthy vegetation. This area should have the same signatures as the upper half of the frame. The affected area on June 11-13, 1976 was located in the central and eastern part of South Dakota (figure 3). The June 20-23 overpass was cloud covered. By June 29-July 2, 1976 the area affected by drought had expanded but was still contained within South Dakota (figure 4). The July 9, 1976 Landsat image (figure 5) shows the southern limit of drought damage. The lack of red signature is readily visible in the upper part of the image. The July 10, 1976 Landsat image (figure 6) shows the western edge of drought damage. The lack of red signatures is visible in the right side of the image. The left side of the image contains red signatures especially in natural drainage ways. During this overpass, the drought area was subjectively rated as having severe and moderate drought damage. The areal extent of the drought during 8-11 July is shown in figure 7. This areal extent had not changed with the 17-20 July overpass.

In most cases the boundary between drought and non-drought was a fairly defined boundary. Outside the drought area, the vegetation

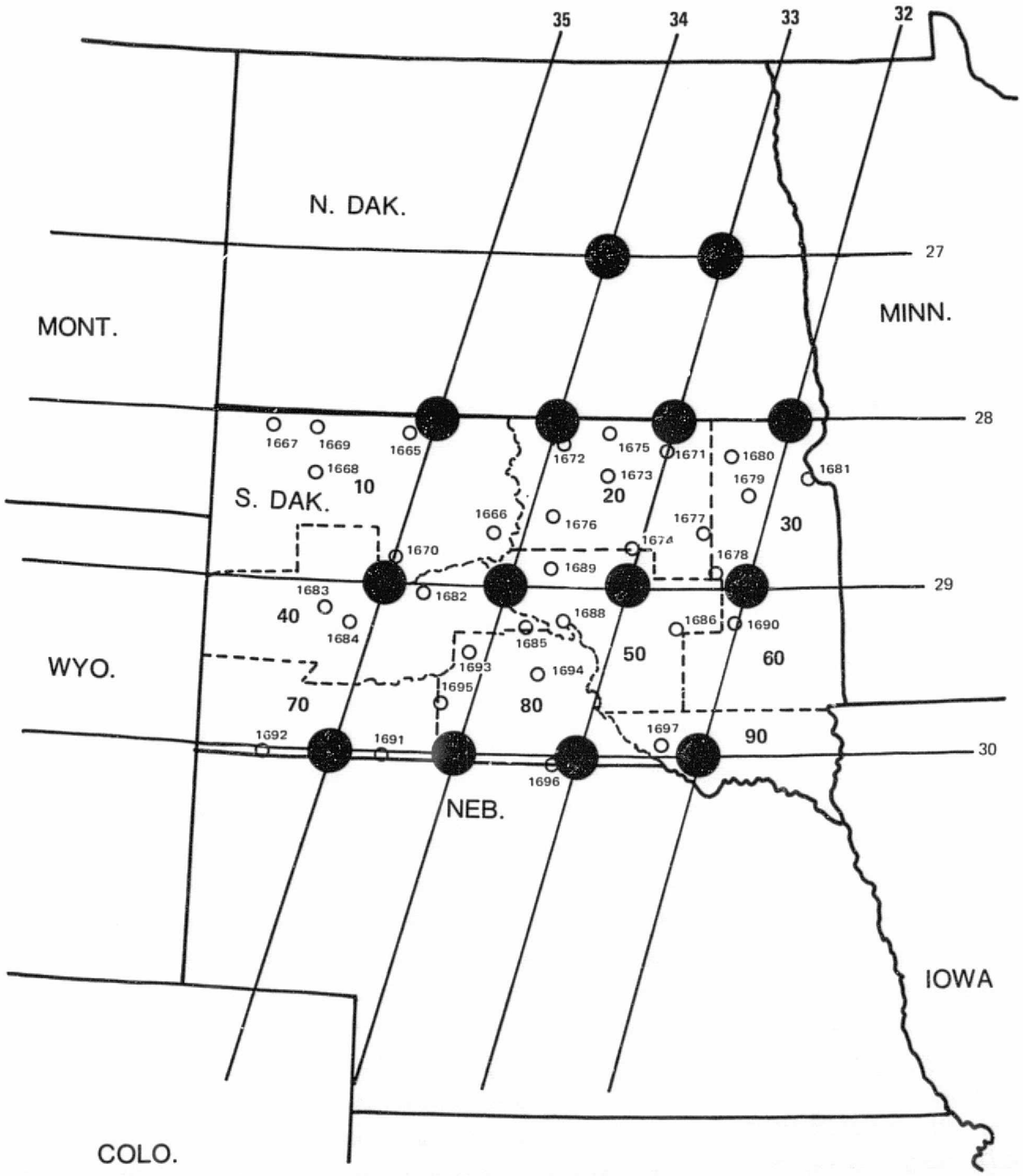


Figure 1. Location of full frame center points, sample segments, and Crop Reporting Districts used in South Dakota drought analysis.

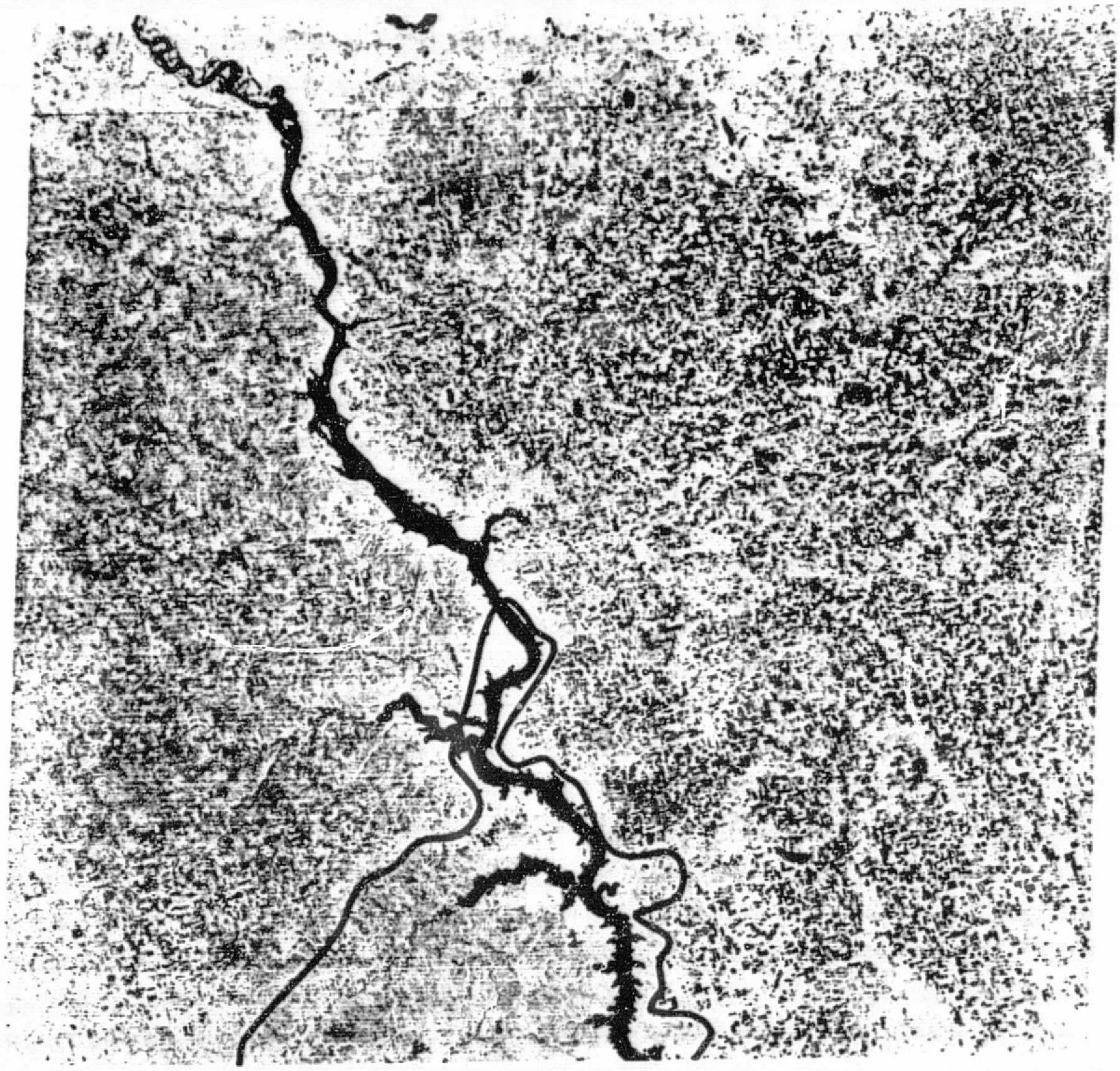


Figure 2. Northern edge of drought in South Dakota on Landsat image 2508-16425 acquired June 13, 1976.

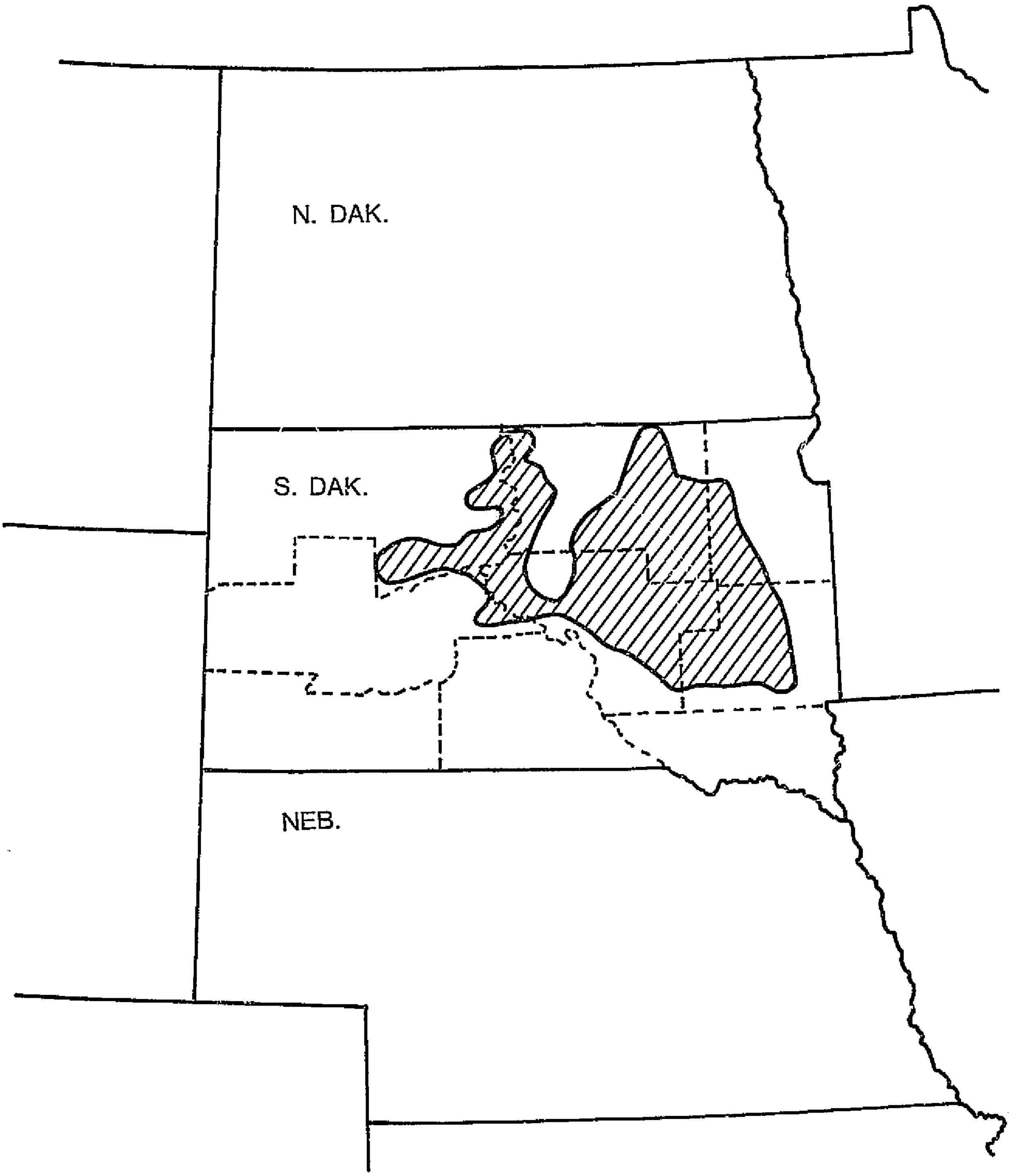


Figure 3. Drought affected area in South Dakota as determined from Landsat full frame imagery for June 11-14, 1976.

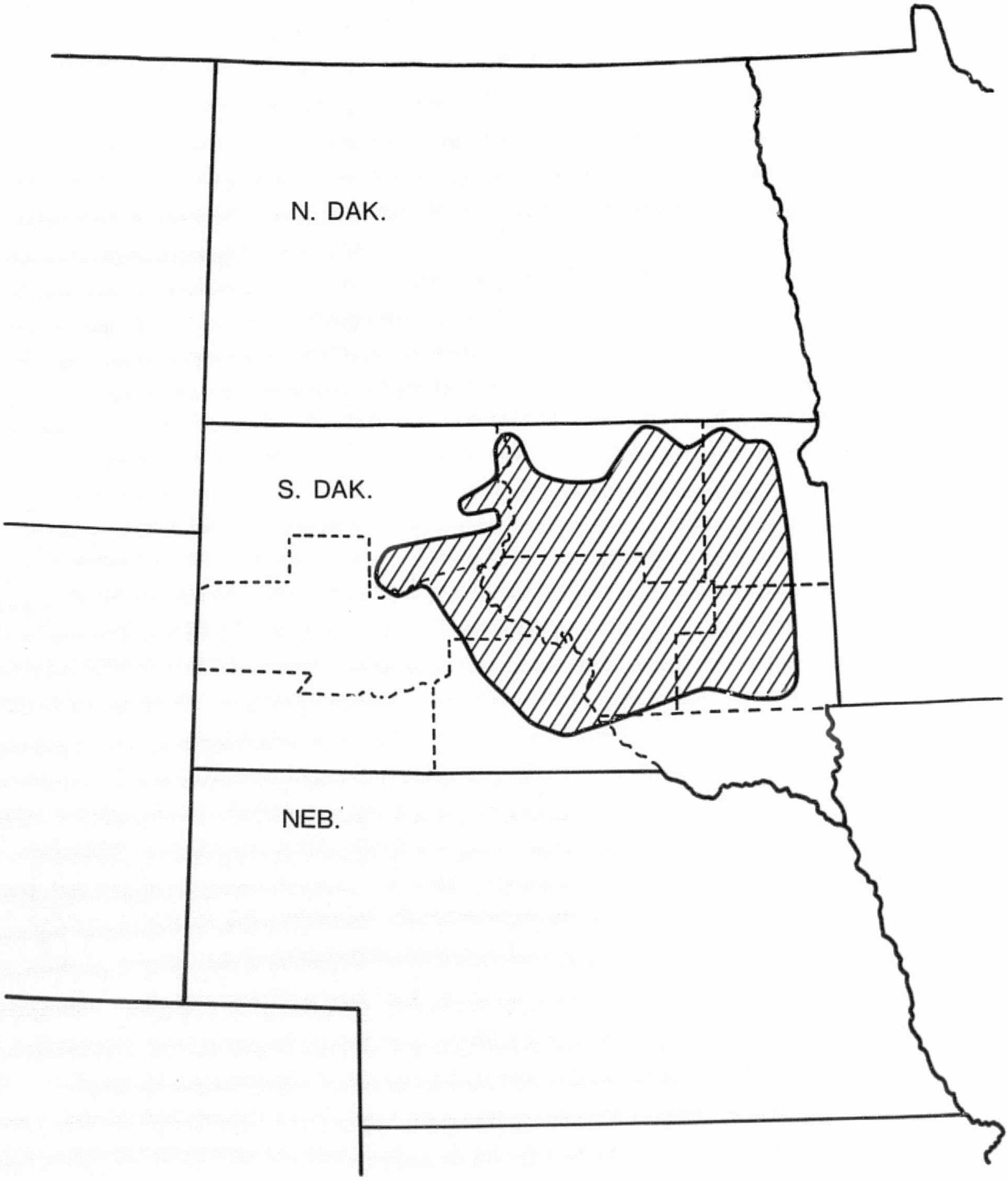


Figure 4. Drought affected area in South Dakota as determined from Landsat full frame imagery for June 29 - July 2, 1976.

Figure 5. Southern edge of drought on Landsat image 5447-16083 acquired July 9, 1976.

Figure 6. Western edge of drought on Landsat image 5448-16135 acquired July 10, 1976.

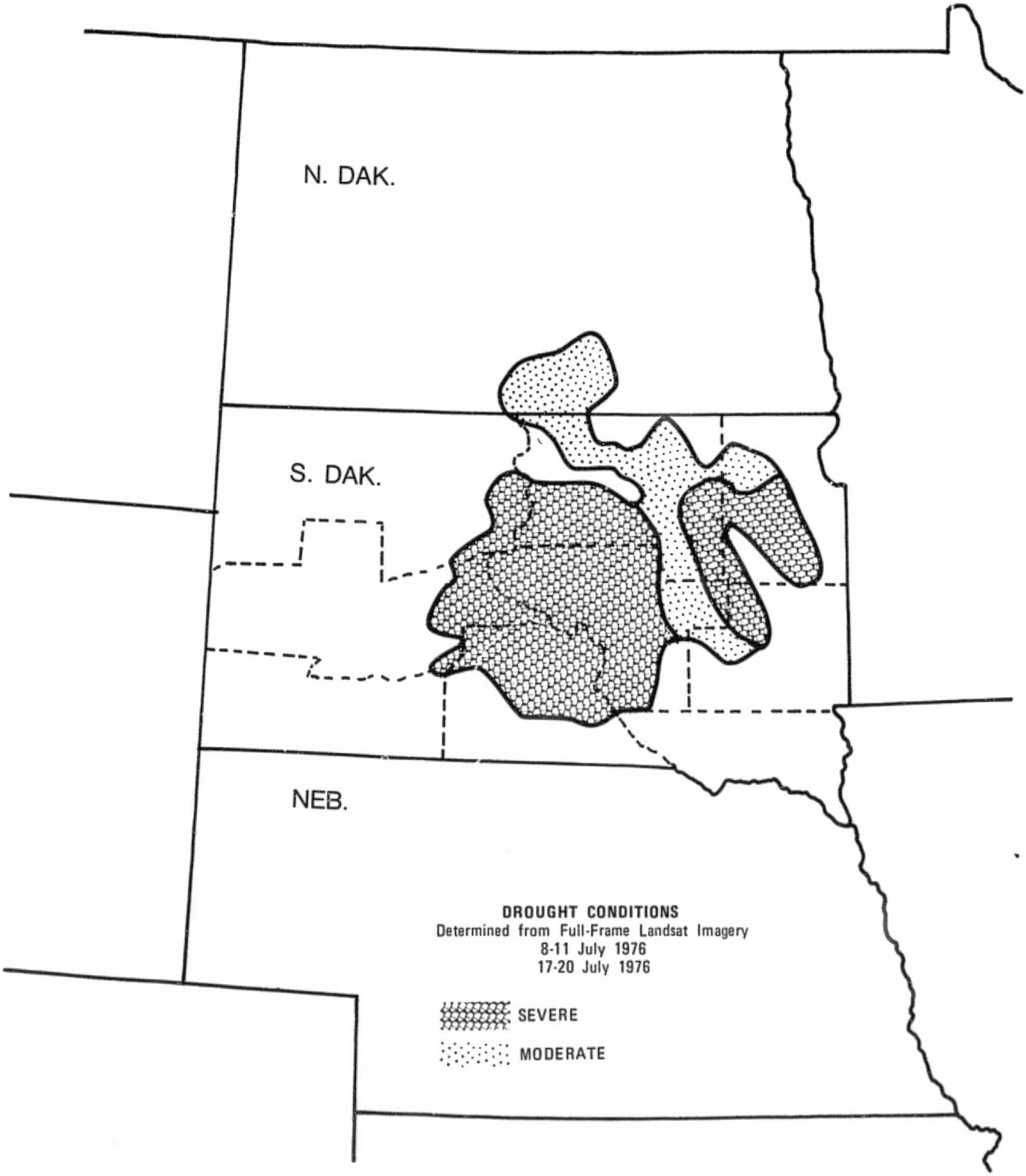
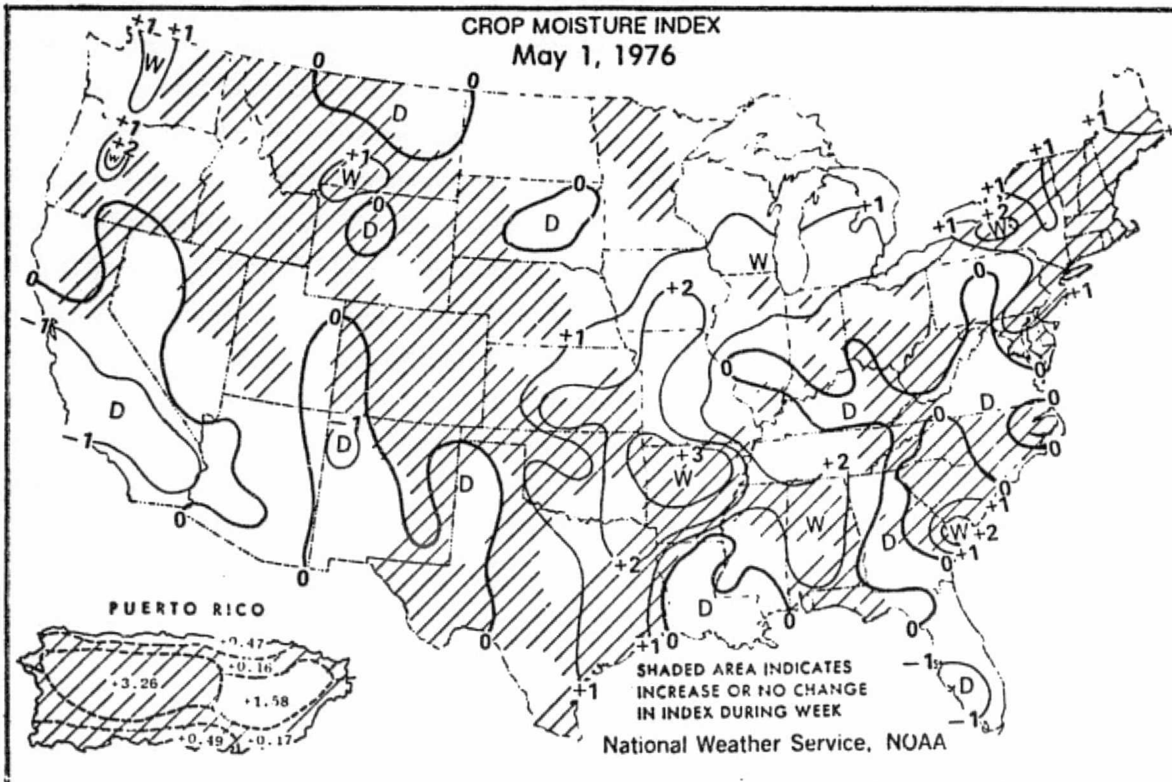


Figure 7. Drought affected area as determined from Landsat full frame imagery for July 8-11 and July 17-20, 1976.

appeared to be healthy. The signatures were not as pronounced as in past years, but appeared to be adequate for the maturing of wheat. The hardest hit area was CRD 50 located in the center of the state. Crop Reporting Districts 20, 30, 40, 80, and 60 also had areas that received damage.

2.2 CRITERIA FOR EVALUATING AREAL DELINEATIONS

The areal extent determined from Landsat full frame color images were evaluated by comparing against the Crop Moisture Index. The Crop Moisture Index is developed each week by the National Weather Service, NOAA. The CMI from May 1, 1976 to July 10, 1976 (figures 8 -17) shows the steady decrease in the moisture available to growing crops. The CMI through May (figures 8-12) shows the lack of precipitation during May. By June 5, 1976(figure 13), the CMI in South Dakota dropped to -2, or abnormally dry, prospects deteriorating. The June 12, 1976 CMI (figure 14) has decreased to -3. This was reflected in the full frame analysis (figure 3, p. 7). The CMI for July 3, 1976 (figure 15) and full frame analysis for June 29-July 3 (figure 4, p.8) have a good correlation. The CMI for July 10, 1976 (figure 16) and the full frame analysis for July 8-11 (figure 7) agrees if the -3 line is used from the CMI for comparison in South Dakota. However, the full frame analysis showed an area in south central North Dakota that was drought stricken during this time. The CMI had this area in the eastern corner of the state. The full frame analysis on July 17-20 (figure 7) showed that the drought area remained stable.



The Crop Moisture Index measures the degree to which moisture requirements of growing crops were met during the previous week. The index is computed from average weekly values of temperature and precipitation. These values are used to calculate the potential moisture demand. Taking into account the previous soil moisture condition and current rainfall, the actual moisture loss is determined.

If the potential moisture demand, or potential evapotranspiration, exceeds available moisture supplies, actual evapotranspiration is reduced and the CMI gives a negative value. However, if moisture meets or exceeds demand the index is positive.

Shaded areas indicate the index was unchanged or increased from the previous week's value; soils dried in the unshaded areas. Centers of positive and negative areas are identified by W for wet and D for dry.

Local moisture conditions may vary because of differences in rainfall distribution or soil types. The type of agriculture and stage of crop development must be considered when assessing the impact of moisture conditions based on the Crop Moisture Index. Some general guidelines follow.

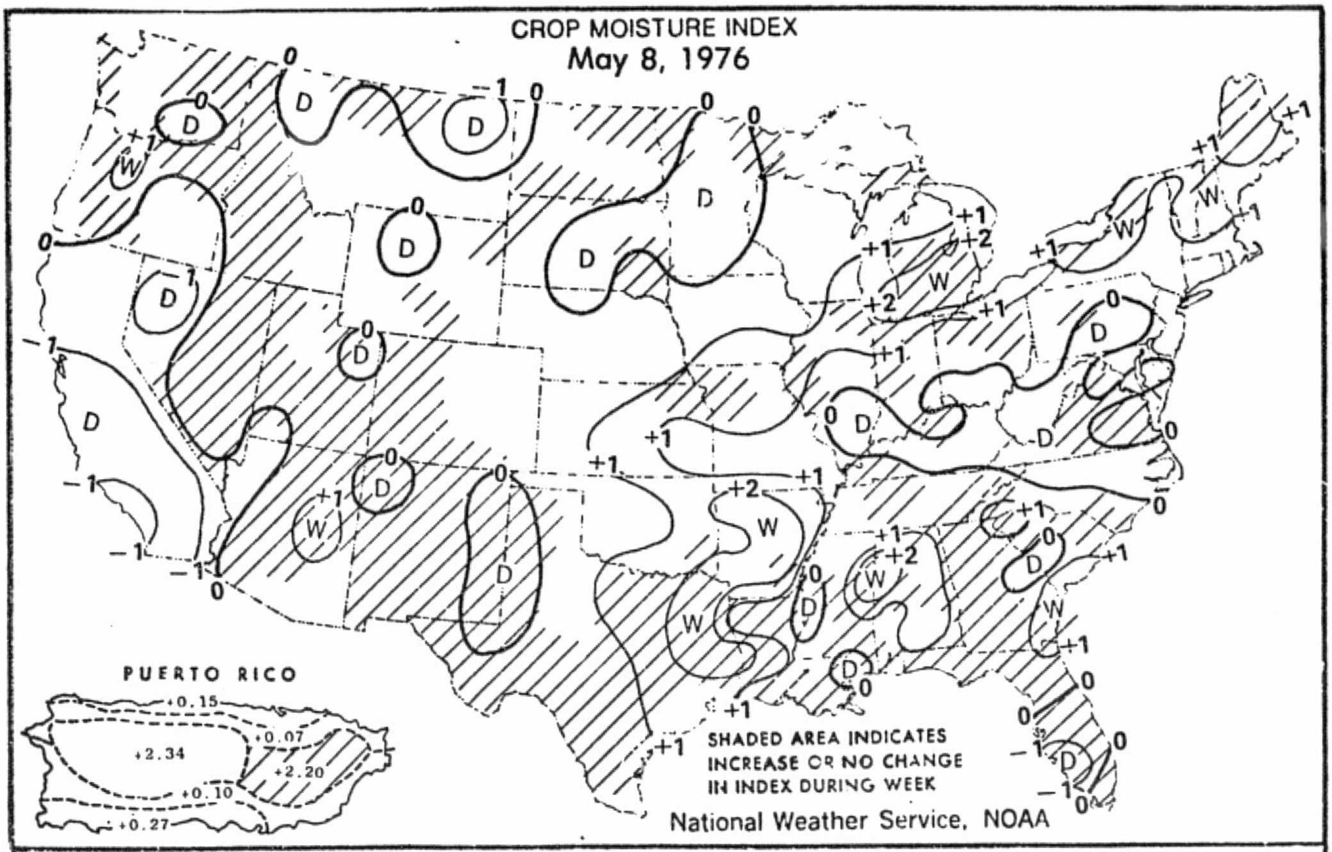
UNSHADED AREAS: INDEX DECREASED

ABOVE	3.0	SOME-DRYING BUT STILL EXCESSIVELY WET
2.0 to	3.0	MORE DRY WEATHER NEEDED. WORK DELAYED
1.0 to	2.0	FAVORABLE, EXCEPT STILL TOO WET IN SPOTS
0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0	TOPSOIL MOISTURE SHORT, GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
-2.0 to	-3.0	TOO DRY, YIELD PROSPECTS REDUCED
-3.0 to	-4.0	POTENTIAL YIELDS SEVERELY CUT BY DROUGHT
BELOW	-4.0	EXTREMELY DRY, MOST CROPS RUINED

SHADED AREA: INDEX INCREASED OR DID NOT CHANGE

ABOVE	3.0	EXCESSIVELY WET, SOME FIELDS FLOODED
2.0 to	3.0	TOO WET, SOME STANDING WATER
1.0 to	2.0	PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0	MOISTURE ADEQUATE FOR PRESENT NEEDS
0 to	-1.0	PROSPECTS IMPROVED BUT RAIN STILL NEEDED
-1.0 to	-2.0	SOME IMPROVEMENT BUT STILL TOO DRY
-2.0 to	-3.0	DROUGHT EASED BUT STILL SERIOUS
-3.0 to	-4.0	DROUGHT CONTINUES, RAIN URGENTLY NEEDED
BELOW	-4.0	NOT ENOUGH RAIN, STILL EXTREMELY DRY

Figure 8. Crop Moisture Index for May 1, 1976.



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0 to	1.0 FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0 TOPSOIL MOISTURE SHORT, GERMINATION SLOW
-1.0 to	-2.0 ABNORMALLY DRY, PROSPECTS DETERIORATING
-2.0 to	-3.0 TOO DRY, YIELD PROSPECTS REDUCED
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1.0 to	2.0 PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0 MOISTURE ADEQUATE FOR PRESENT NEEDS
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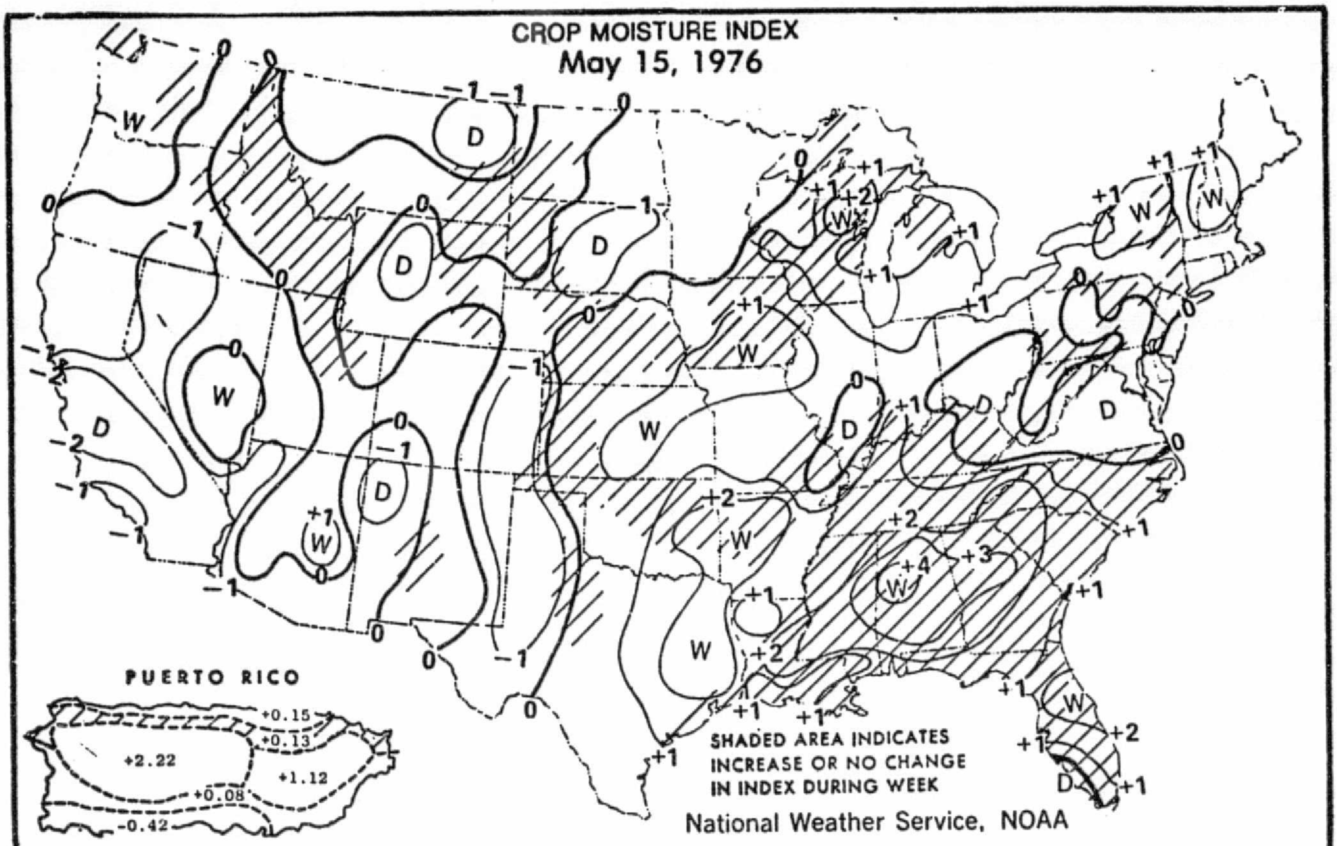
Figure 9. Crop Moisture Index for May 8, 1976.



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0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
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-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
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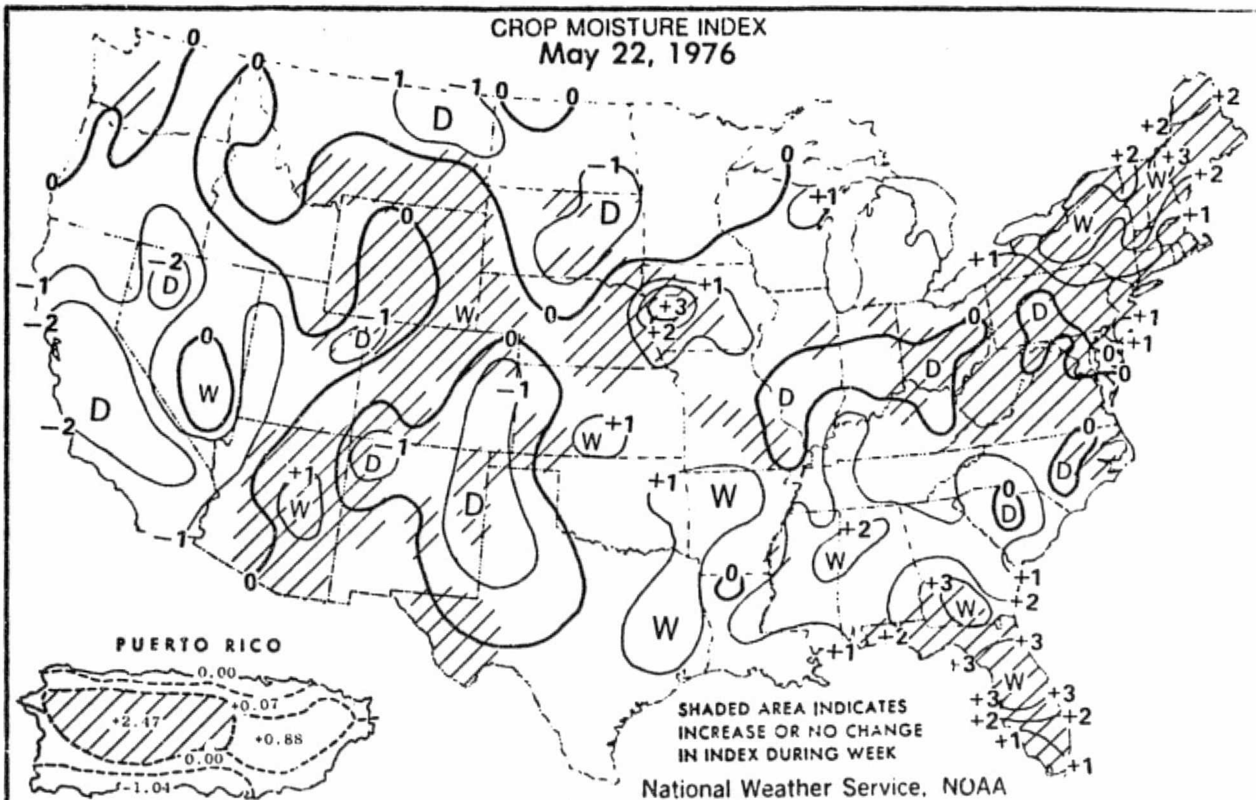
Figure 10. Crop Moisture Index for May 15, 1976.



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0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0	TOPSOIL MOISTURE SHORT GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
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Figure 11. Crop Moisture Index for May 22, 1976.

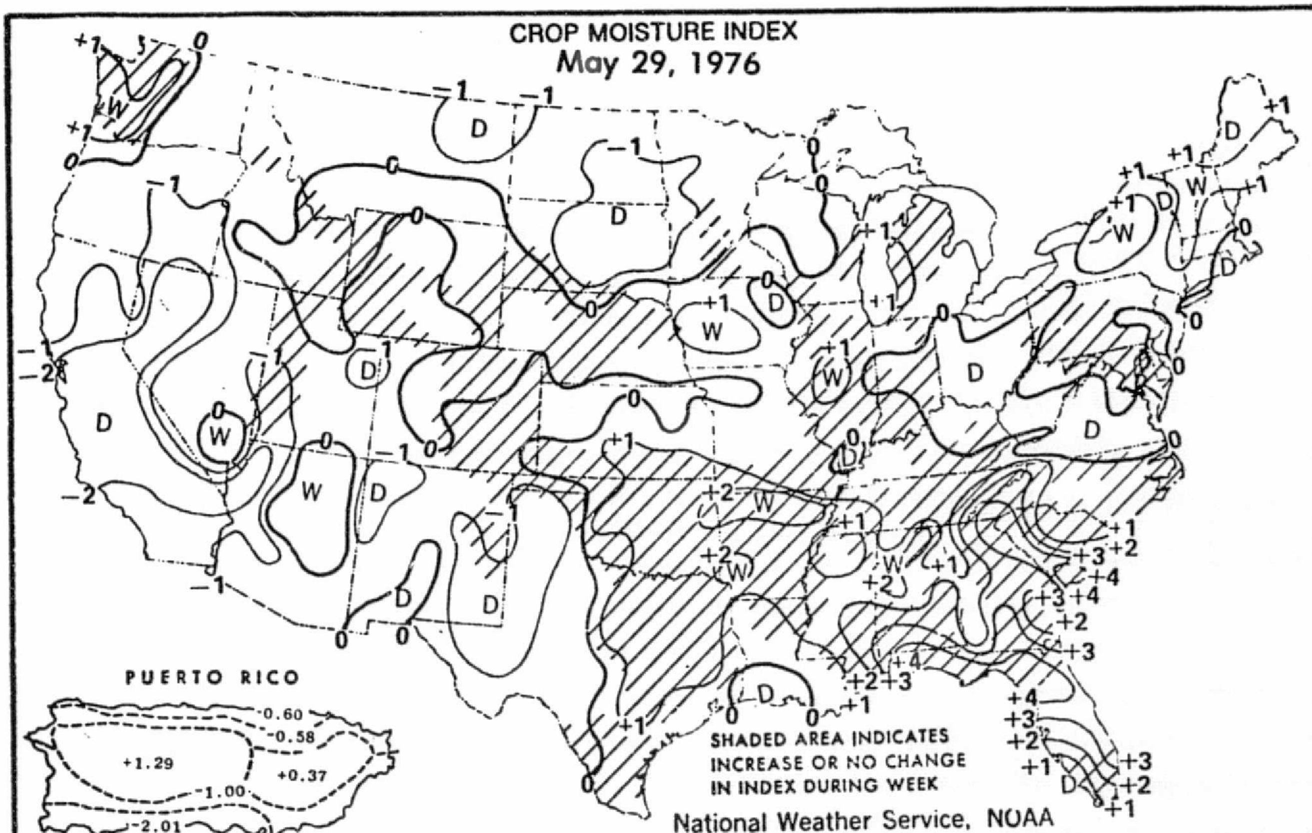

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Figure 12. Crop Moisture Index for May 29, 1976.

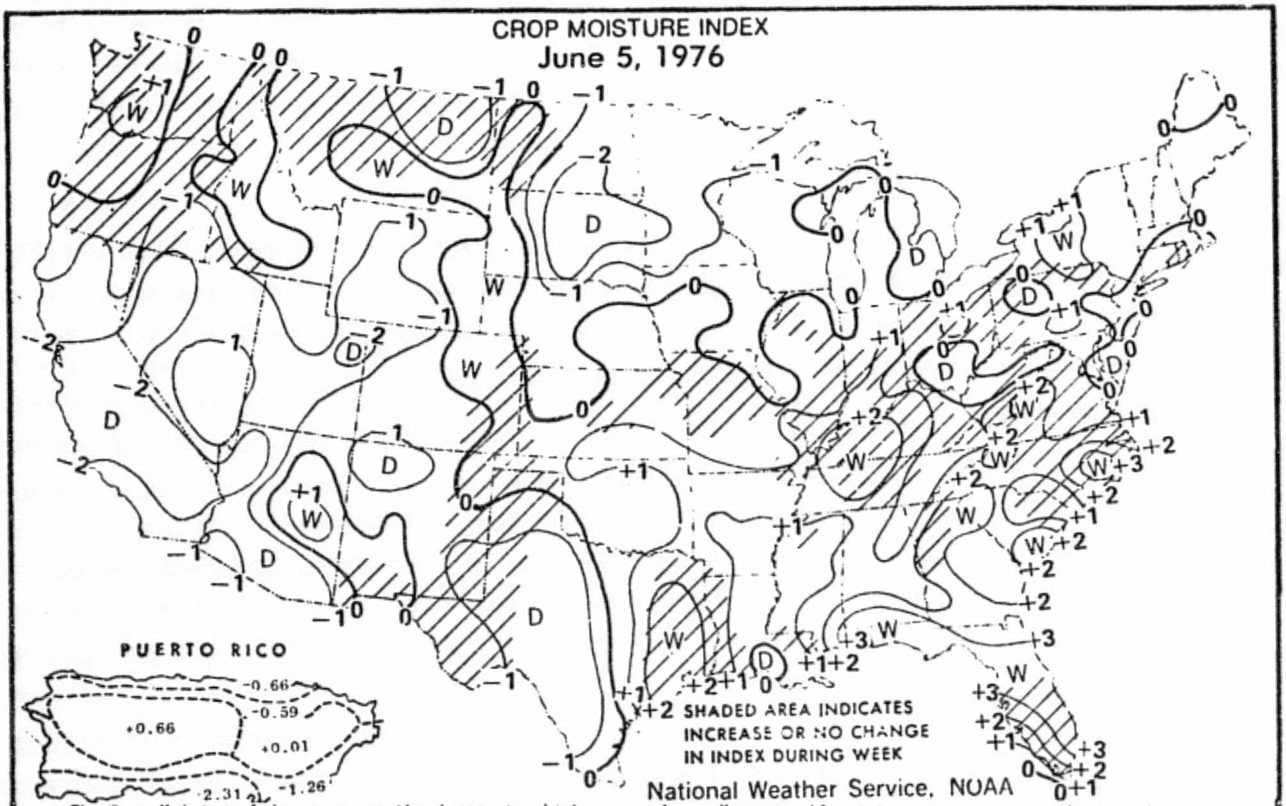

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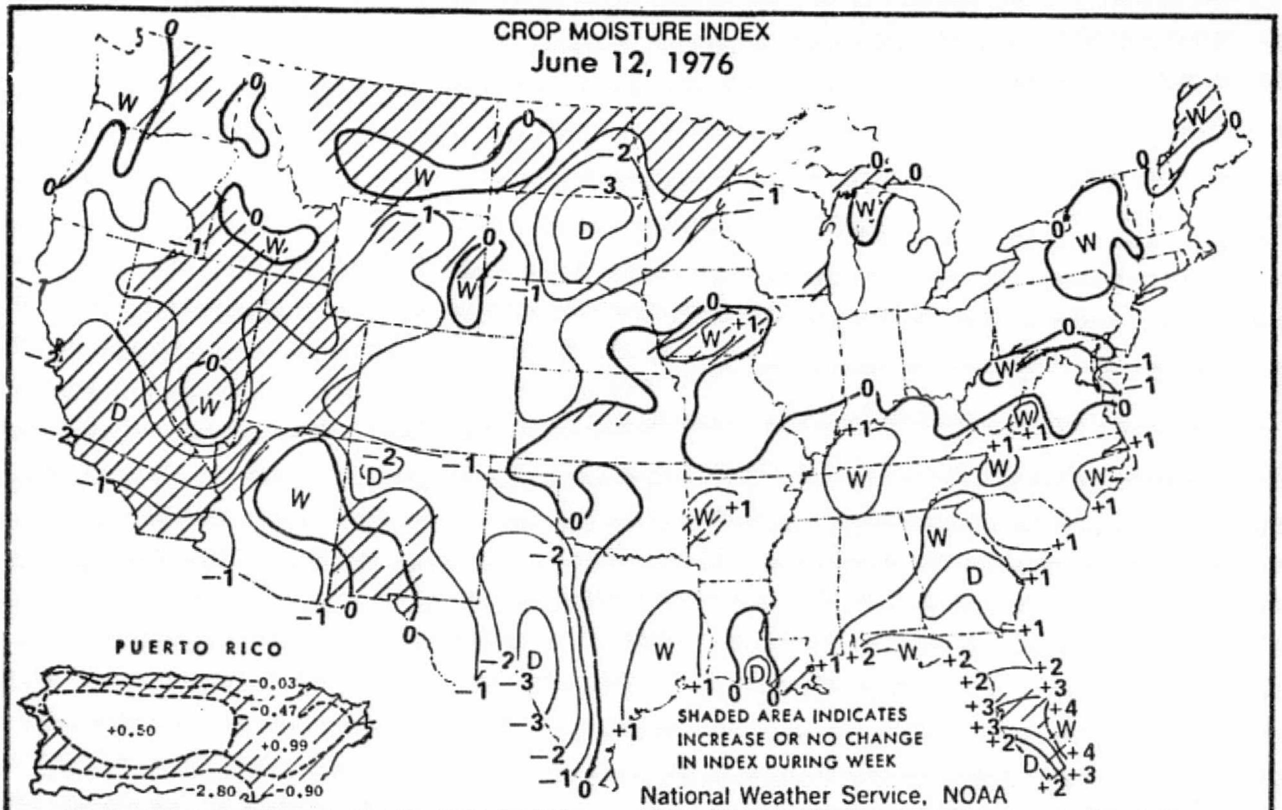
Figure 13. Crop Moisture Index for June 5, 1976.



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0 to	-1.0	TOPSOIL MOISTURE SHORT GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
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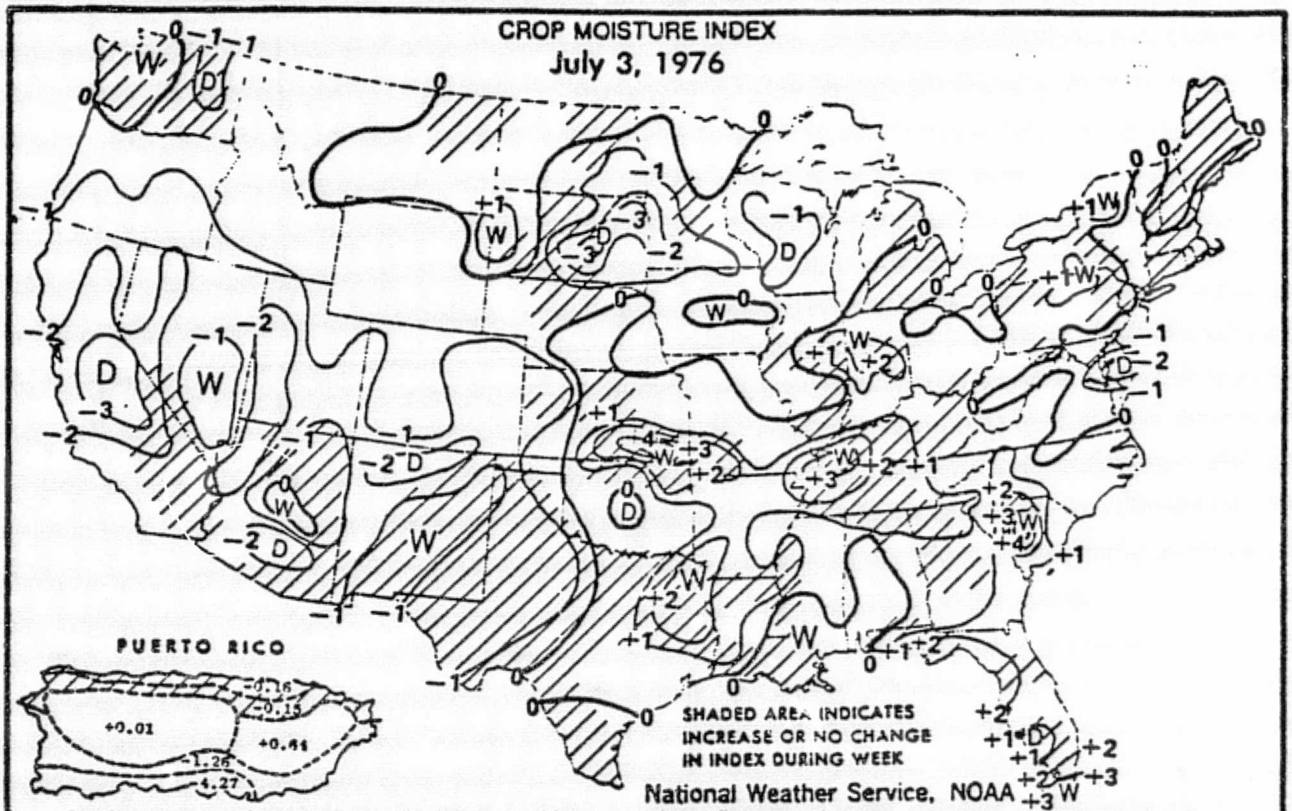
-3.0 to	-4.0	POTENTIAL YIELDS SEVERELY CUT BY DROUGHT
BELOW	-4.0	EXTREMELY DRY, MOST CROPS RUINED

SHADED AREA: INDEX INCREASED OR DID NOT CHANGE		
ABOVE	3.0	EXCESSIVELY WET, SOME FIELDS FLOODED
2.0 to	3.0	TOO WET, SOME STANDING WATER
1.0 to	2.0	PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0	MOISTURE ADEQUATE FOR PRESENT NEEDS
0 to	-1.0	PROSPECTS IMPROVED BUT RAIN STILL NEEDED
-1.0 to	-2.0	SOME IMPROVEMENT BUT STILL TOO DRY
-2.0 to	-3.0	DROUGHT EASED BUT STILL SERIOUS
-3.0 to	-4.0	DROUGHT CONTINUES, RAIN URGENTLY NEEDED
BELOW	-4.0	NOT ENOUGH RAIN, STILL EXTREMELY DRY

Figure 14. Crop Moisture Index for June 12, 1976.



The Crop Moisture Index measures the degree to which moisture requirements of growing crops were met during the previous week. The index is computed from average weekly values of temperature and precipitation. These values are used to calculate the potential moisture demand. Taking into account the previous soil moisture condition and current rainfall, the actual moisture loss is determined.

If the potential moisture demand, or potential evapotranspiration, exceeds available moisture supplies, actual evapotranspiration is reduced and the CMI gives a negative value. However, if moisture meets or exceeds demand the index is positive.

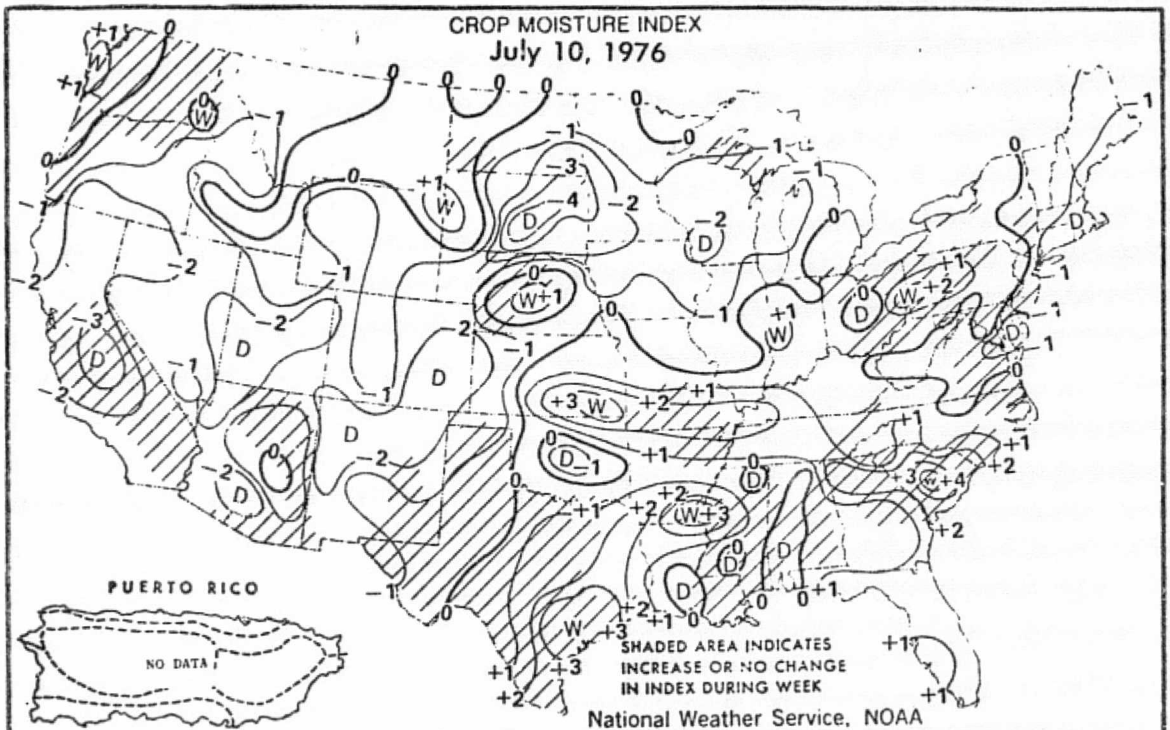
Shaded areas indicate the index was unchanged or increased from the previous week's value; soils dried in the unshaded areas. Centers of positive and negative areas are identified by W for wet and D for dry.

Local moisture conditions may vary because of differences in rainfall distribution or soil types. The type of agriculture and stage of crop development must be considered when assessing the impact of moisture conditions based on the Crop Moisture Index. Some general guidelines follow.

UNSHADED AREAS: INDEX DECREASED		
ABOVE	3.0	SOME DRYING BUT STILL EXCESSIVELY WET
2.0 to	3.0	MORE DRY WEATHER NEEDED, WORK DELAYED
1.0 to	2.0	FAVORABLE, EXCEPT STILL TOO WET IN SPOTS
0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0	TOPSOIL MOISTURE SHORT GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
-2.0 to	-3.0	TOO DRY, YIELD PROSPECTS REDUCED
-3.0 to	-4.0	POTENTIAL YIELDS SEVERELY CUT BY DROUGHT
BELOW	-4.0	EXTREMELY DRY, MOST CROPS RUINED

SHADED AREA: INDEX INCREASED OR DID NOT CHANGS		
ABOVE	3.0	EXCESSIVELY WET, SOME FIELDS FLOODED
2.0 to	3.0	TOO WET, SOME STANDING WATER
1.0 to	2.0	PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0	MOISTURE ADEQUATE FOR PRESENT NEEDS
0 to	-1.0	PROSPECTS IMPROVED BUT RAIN STILL NEEDED
-1.0 to	-2.0	SOME IMPROVEMENT BUT STILL TOO DRY
-2.0 to	-3.0	DROUGHT EASED BUT STILL SERIOUS
-3.0 to	-4.0	DROUGHT CONTINUES, RAIN URGENTLY NEEDED
BELOW	-4.0	NOT ENOUGH RAIN, STILL EXTREMELY DRY

Figure 15. Crop Moisture Index for July 3, 1976.



The Crop Moisture Index measures the degree to which moisture requirements of growing crops were met during the previous week. The index is computed from average weekly values of temperature and precipitation. These values are used to calculate the potential moisture demand. Taking into account the previous soil moisture condition and current rainfall, the actual moisture loss is determined.

If the potential moisture demand, or potential evapotranspiration, exceeds available moisture supplies, actual evapotranspiration is reduced and the CMI gives a negative value. However, if moisture meets or exceeds demand the index is positive.

Shaded areas indicate the index was unchanged or increased from the previous week's value; soils dried in the unshaded areas. Centers of positive and negative areas are identified by W for wet and D for dry.

Local moisture conditions may vary because of differences in rainfall distribution or soil types. The type of agriculture and stage of crop development must be considered when assessing the impact of moisture conditions based on the Crop Moisture Index. Some general guidelines follow.

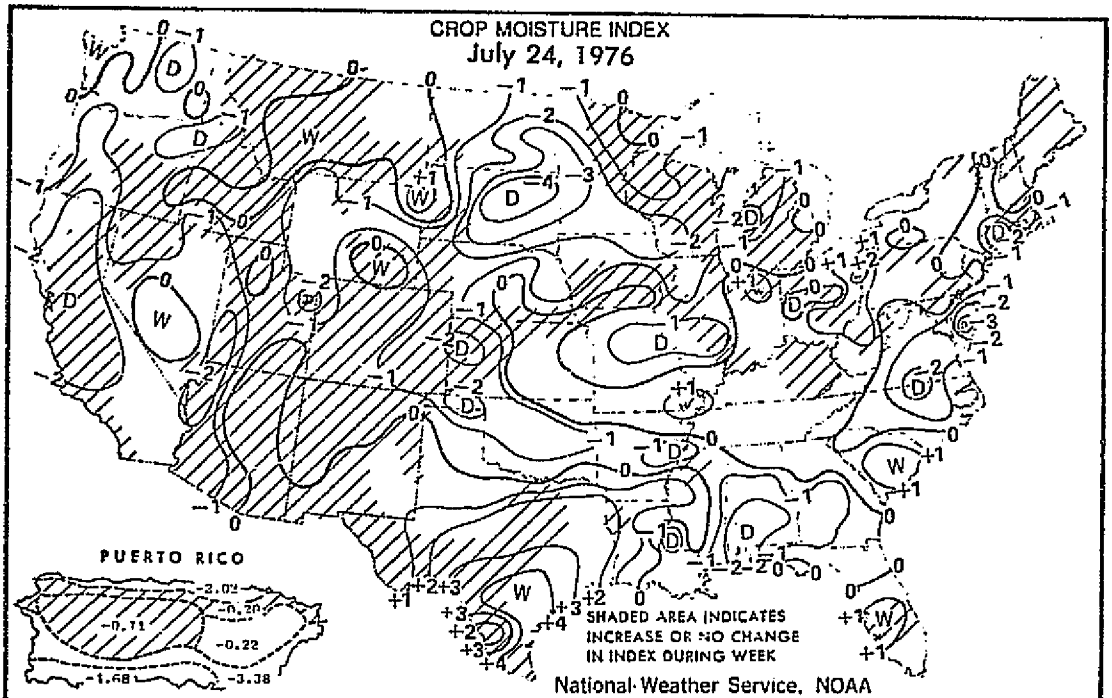
UNSHADED AREAS: INDEX DECREASED

ABOVE	3.0	SOME DRYING BUT STILL EXCESSIVELY WET
2.0 to	3.0	MORE DRY WEATHER NEEDED, WORK DELAYED
1.0 to	2.0	FAVORABLE, EXCEPT STILL TOO WET IN SPOTS
0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0	TOPSOIL MOISTURE SHORT GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
-2.0 to	-3.0	TOO DRY, YIELD PROSPECTS REDUCED
-3.0 to	-4.0	POTENTIAL YIELDS SEVERELY CUT BY DROUGHT
BELOW	-4.0	EXTREMELY DRY, MOST CROPS RUINED

SHADED AREA: INDEX INCREASED OR DID NOT CHANGE

ABOVE	3.0	EXCESSIVELY WET, SOME FIELDS FLOODED
2.0 to	3.0	TOO WET, SOME STANDING WATER
1.0 to	2.0	PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0	MOISTURE ADEQUATE FOR PRESENT NEEDS
0 to	-1.0	PROSPECTS IMPROVED BUT RAIN STILL NEEDED
-1.0 to	-2.0	SOME IMPROVEMENT BUT STILL TOO DRY
-2.0 to	-3.0	DROUGHT EASED BUT STILL SERIOUS
-3.0 to	-4.0	DROUGHT CONTINUES, RAIN URGENTLY NEEDED
BELOW	-4.0	NOT ENOUGH RAIN, STILL EXTREMELY DRY

Figure 16. Crop Moisture Index for July 10, 1976.



The Crop Moisture Index measures the degree to which moisture requirements of growing crops were met during the previous week. The index is computed from average weekly values of temperature and precipitation. These values are used to calculate the potential moisture demand. Taking into account the previous soil moisture condition and current rainfall, the actual moisture loss is determined.

If the potential moisture demand, or potential evapotranspiration, exceeds available moisture supplies, actual evapotranspiration is reduced and the CMI gives a negative value. However, if moisture meets or exceeds demand the index is positive.

Shaded areas indicate the index was unchanged or increased from the previous week's value, soils dried in the unshaded areas. Centers of positive and negative areas are identified by W for wet and D for dry.

Local moisture conditions may vary because of differences in rainfall distribution or soil types. The type of agriculture and stage of crop development must be considered when assessing the impact of moisture conditions based on the Crop Moisture Index. Some general guidelines follow.

UNSHADED AREAS: INDEX DECREASED

ABOVE	3.0	SOME DRYING BUT STILL EXCESSIVELY WET
2.0 to	3.0	MORE DRY WEATHER NEEDED, WORK DELAYED
1.0 to	2.0	FAVORABLE, EXCEPT STILL TOO WET IN SPOTS
0 to	1.0	FAVORABLE FOR NORMAL GROWTH AND FIELDWORK
0 to	-1.0	TOPSOIL MOISTURE SHORT GERMINATION SLOW
-1.0 to	-2.0	ABNORMALLY DRY, PROSPECTS DETERIORATING
-2.0 to	-3.0	TOO DRY, YIELD PROSPECTS REDUCED
-3.0 to	-4.0	POTENTIAL YIELDS SEVERELY CUT BY DROUGHT
BELOW	-4.0	EXTREMELY DRY, MOST CROPS RUINED

SHADED AREA: INDEX INCREASED OR DID NOT CHANGE

ABOVE	3.0	EXCESSIVELY WET, SOME FIELDS FLOODED
2.0 to	3.0	TOO WET, SOME STANDING WATER
1.0 to	2.0	PROSPECTS ABOVE NORMAL, SOME FIELDS TOO WET
0 to	1.0	MOISTURE ADEQUATE FOR PRESENT NEEDS
0 to	-1.0	PROSPECTS IMPROVED BUT RAIN STILL NEEDED
-1.0 to	-2.0	SOME IMPROVEMENT BUT STILL TOO DRY
-2.0 to	-3.0	DROUGHT EASED BUT STILL SERIOUS
-3.0 to	-4.0	DROUGHT CONTINUES, RAIN URGENTLY NEEDED
BELOW	-4.0	NOT ENOUGH RAIN, STILL EXTREMELY DRY

Figure 17. Crop Moisture Index for July 24, 1976.

The CMI for July 24 (figure 17) shows the southeastern corner of North Dakota still affected.

It appears that the areal extent of drought from Landsat full frame analysis is in general agreement with the Crop Moisture Index. The Crop Moisture Index is not designed to give precise locations of moisture stress and thus an exact correlation between the CMI and Landsat derived drought areas would not be expected.

A report was released by the Crop Quality Council, Minneapolis, Minnesota based on personal observations made during the period July 11 to 19, 1976. This period corresponds to the areal extent determined from Landsat acquired July 8-11 and July 17-20 (figure 7). They reported that the "drought in central and north eastern counties has been the most severe in years" for South Dakota. This corresponds to the area determined using Landsat. They also reported that "prospects are good for North Dakota spring wheat and durum despite drought damage in northeastern sections." This also reported that "In southern and south central counties in an area bounded by Ellendale, Napoleon, Linton and Strasburg, fields become progressively poor with a yield prospect of 12-14 bushels in earlier portions, and 8-10 bushels along the Linton-Strasburg line." This area is bounded by the area determined from Landsat as being drought affected in North Dakota (figure 7).

2.3 SUMMARY OF AREAL EXTENT ANALYSIS

The use of Landsat full frame color transparencies for delineation of areal extent for drought damage agrees with other sources of indicating drought. Landsat analysis appear to provide a more accurate indication of drought damage than the CMI. The area delineated from Landsat compares with a ground survey made during the Landsat overpass.

3.0 AUTOMATIC PROCESS FOR DROUGHT DETECTION AND MONITORING

During the southern Great Plains drought analysis, it appears that by measuring the amount of green vegetation present, a method of detecting drought could be devised using Landsat digital data. Kauth and Thomas (LARS Symposium Proceedings, pp 4B-41-51, 1976) suggested a linear combination of Landsat channels which changes the four Landsat channel values to four other values with agricultural interpretation. These agricultural related values are called brightness, greenness, yellowness and none such. If the greenness and brightness values are plotted (figure 18), bare soil lies in a plane with green vegetation above the soil line. The theory was proposed during the southern Great Plains drought, that by measuring the amount of greenness above the soil line, drought stress could be detected. The greenness coordinate of a pixel minus the minimum greenness (or soil line greenness) is the green number. The percent of pixels above a threshold t is called the Green Index Number or GIN(t). Because of the lack of data in the southern Great Plains, this theory could not be proven conclusively. The South Dakota drought provided an opportunity to monitor drought stress as it became progressively worse. Good data was available for the 1975-76 crop year and also for selected sample segments in 1974-75 crop year.

In order to identify a segment as drought or not drought affected, certain assumptions were made. They were: (1) during winter the

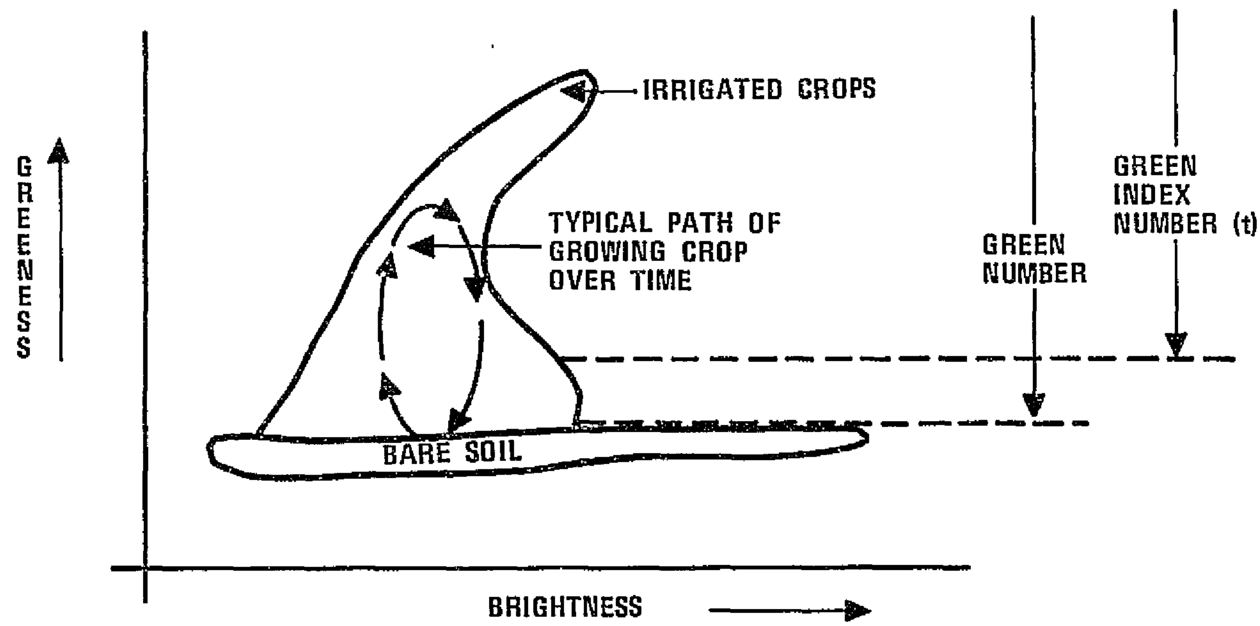


Figure 18. Sketch of the region occupied by typical agricultural data and the location of the green number.

segment (5 x 6 nm) is not green, (2) in spring, the segment becomes green at some measurable rate, (3) later in the season, the segment reaches and holds some high green level, (4) at harvest, the segment browns, possibly very quickly, and (5) with drought, the segment is not as green as normal.

Using the above assumptions, observations and calculations indicated that normal segments increase in the very green percent (percent of pixels in a segment with green index number greater than 15) at the rate of about 1 percent per day. Normal South Dakota segments level out with 30 to 50 percent of the pixels in the segment having a green index number greater than 15. Normal segments fall very quickly about 80 days after the beginning of green up. To detect adverse conditions, a scheme was derived whereby a green up rate less than 1/2% per day, a level very green percent of less than 20,and total time to browning less than 70 days would indicate drought conditions. This scheme was tested on all available 1975 and 1976 South Dakota data. The results were compared to a classification based on the Crop Moisture Index for Crop Reporting Districts. The agreement of these classifications is given below:

GIN CLASSIFICATION

		Wet	Dry	Total
CMI Classification	Wet	9	4	13
	Dry	2	7	9
	Total	11	11	22

X^2 - 4.70 1DF

5% level = 3.84

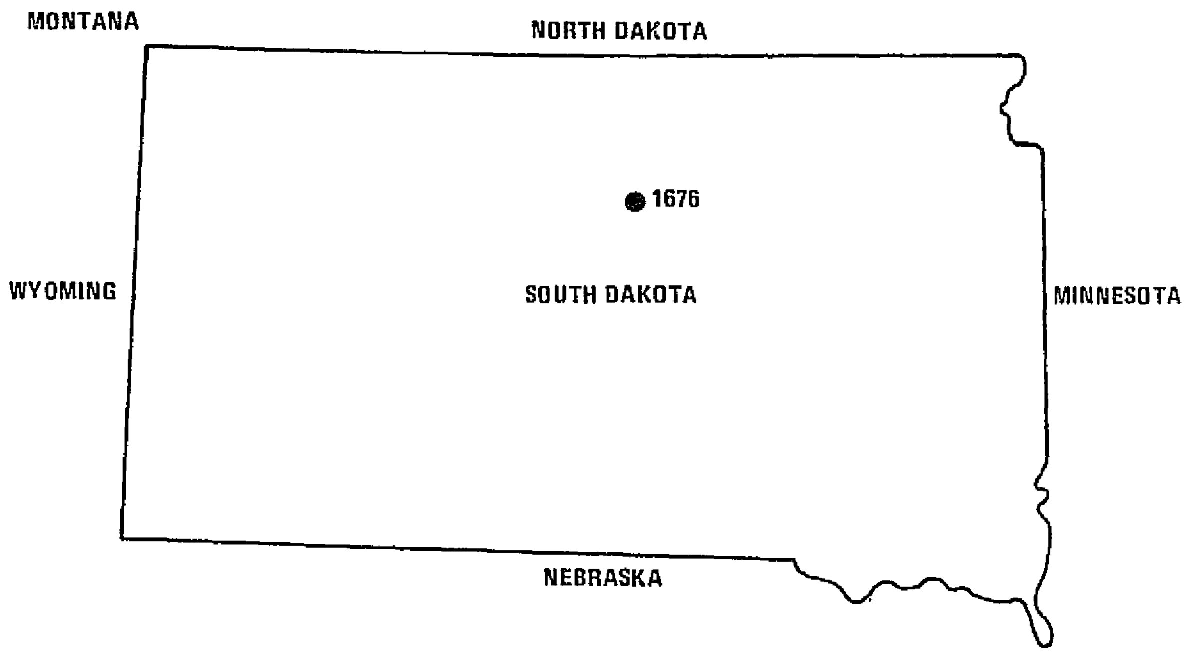
This is significant at the 5% level, meaning that the agreement is better than would be expected more than 1 time in 20 if there were no relation between the classification techniques. Regarding the errors, the four classified as dry, which were actually wet, were all predominantly rangeland, less than 5% agriculture. The two classified as wet by GIN and dry by CMI are located on the edge of their Crop Reporting Districts, and from full frame imagery, it appears that the CMI is in error.

If individual segments are examined for 1975 and 1976 crop years, and compared to the CMI, it is possible to determine if GIN detected drought stress occurred at the same time indicated by the CMI at CRD level. CMI data was available for CRD's starting May 17 for 1976 and April 7 for 1975. Since the 1976 crop calendar was earlier than 1975, the drought GIN starting point is earlier than 1975. On figures 19, 20, 21, and 22, only the location of the 1976 drought GIN bounds is shown. For 1975, the drought GIN bounds would be shifted to approximately 10 days later. Also the crop calendar would in actuality be later the further north the segment is located and the starting point for the drought GIN bounds would reflect this difference.

From figure 19, the GIN indicated that year 1975 was normal for the entire crop season for segment 1676 when compared to the year 1975 CMI, however, in year 1976 the GIN indicated that between May 26 and June 12, there was drought stress. The CMI for 1976 on May 26 was +.57

and -3.45 for June 12. This indicates that the GIN detected drought stress at the same time as the CMI was indicating a change. Segment 1686 also shows correlation with the GIN and CMI for both years. However, on segment 1676 (figure 19) drought stress did not hit until June 12 on both the GIN and CMI, segment 1686 (figure 20) was under drought stress on May 24 as indicated by both the GIN and CMI numbers. Segment 1690 (figure 21) provides the same correlation as segment 1686. Segment 1694 (figure 22) shows drought stress for both crop years. This is indicated by the GIN and CMI numbers.

It appears that the GIN can be used to detect when drought stress occurs by monitoring the 5 x 6 nm sample segments. A correlation exists between when the GIN indicates drought and the CMI at Crop Reporting Districts levels indicates drought. It appears that the GIN can detect when drought stress occurs earlier than the subjective evaluations from Landsat full frame imagery. It was not until the June 11-14 overpass that areal extent of the drought could be detected on full frame (figure 3, p. 7). The GIN indicated that part of the area (segment 1686, 1690, 1694) were affected as early as May 24.



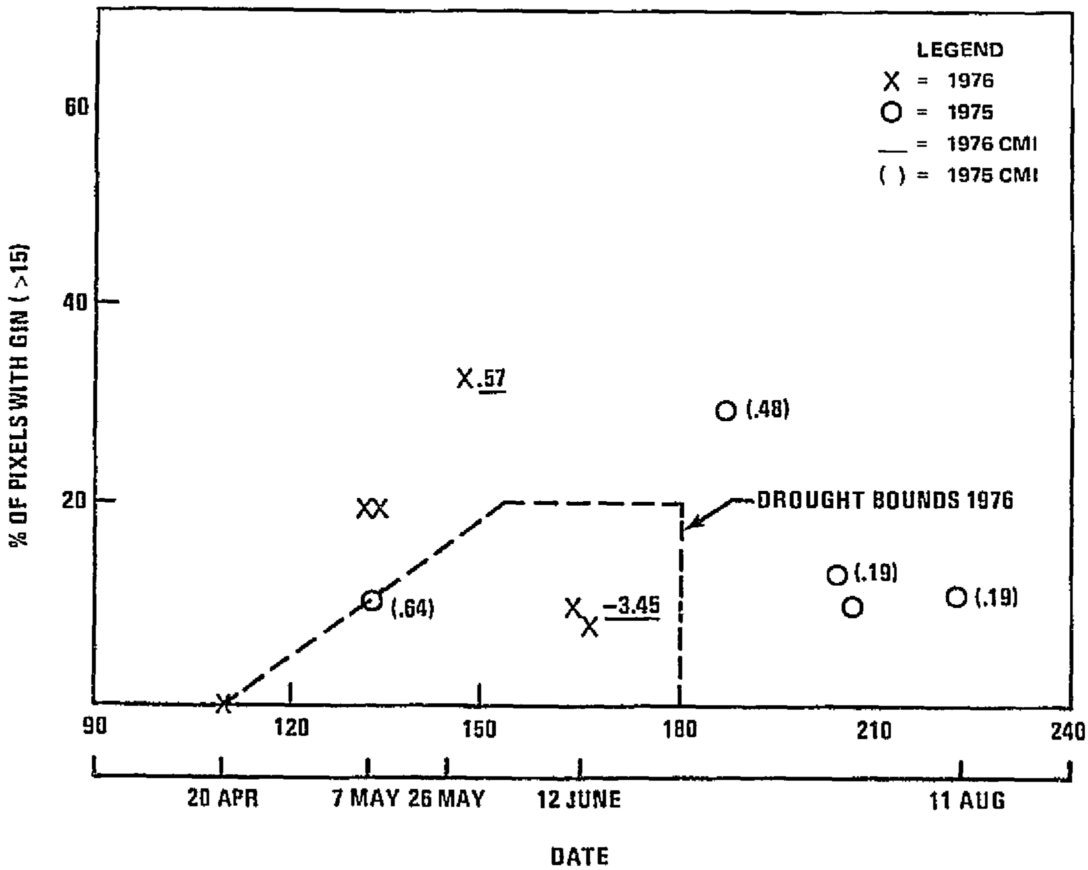


Figure 19. Drought on segment 1676 as indicated by GIN and verified by CMI.

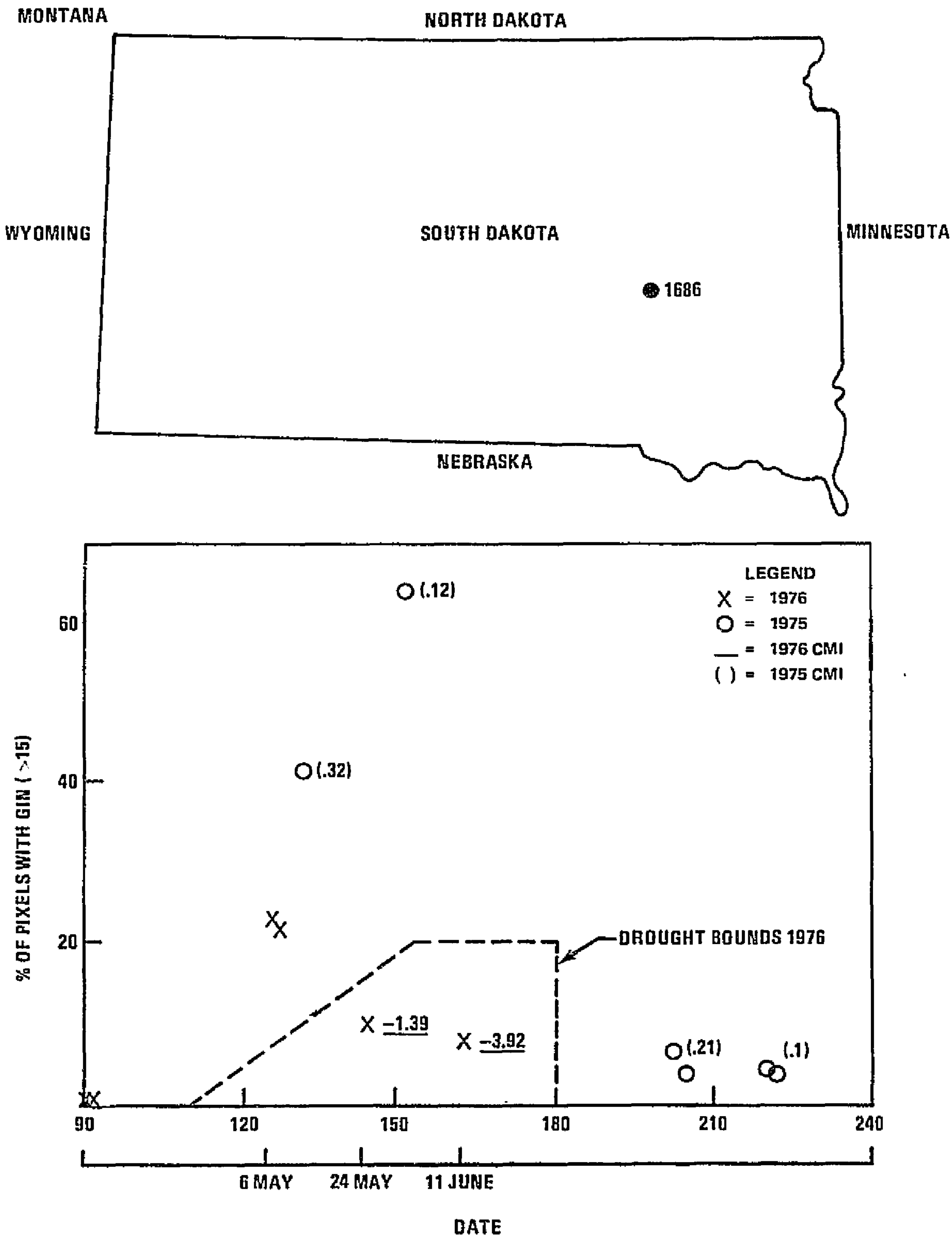
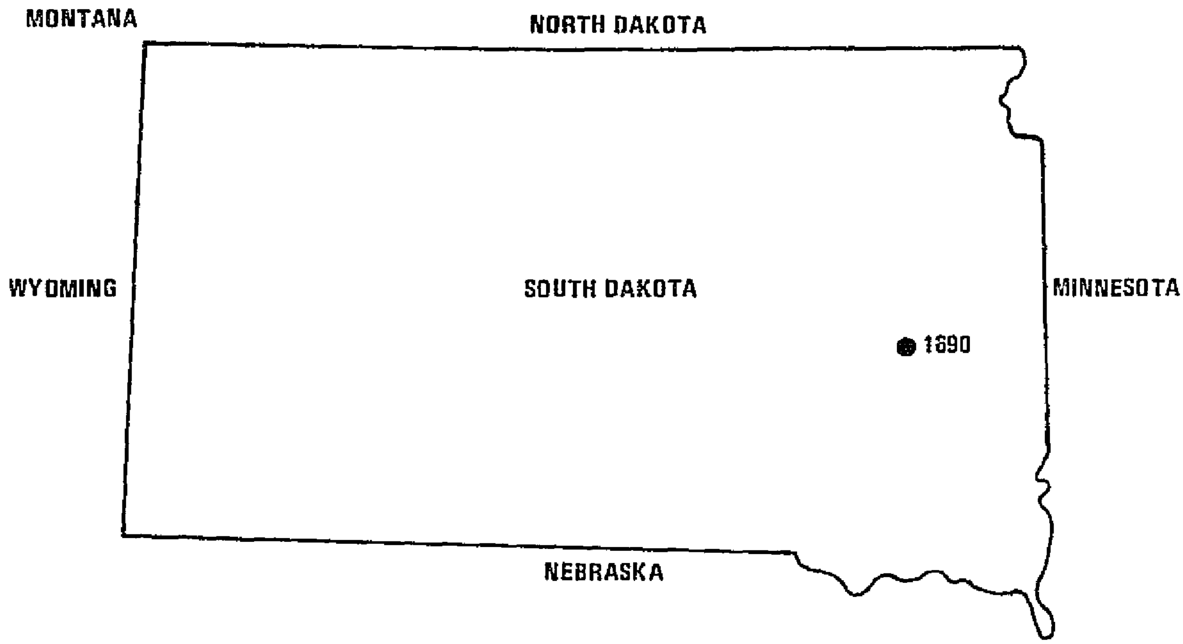


Figure 20. Drought on segment 1686 as indicated by GIN and verified by CMI.



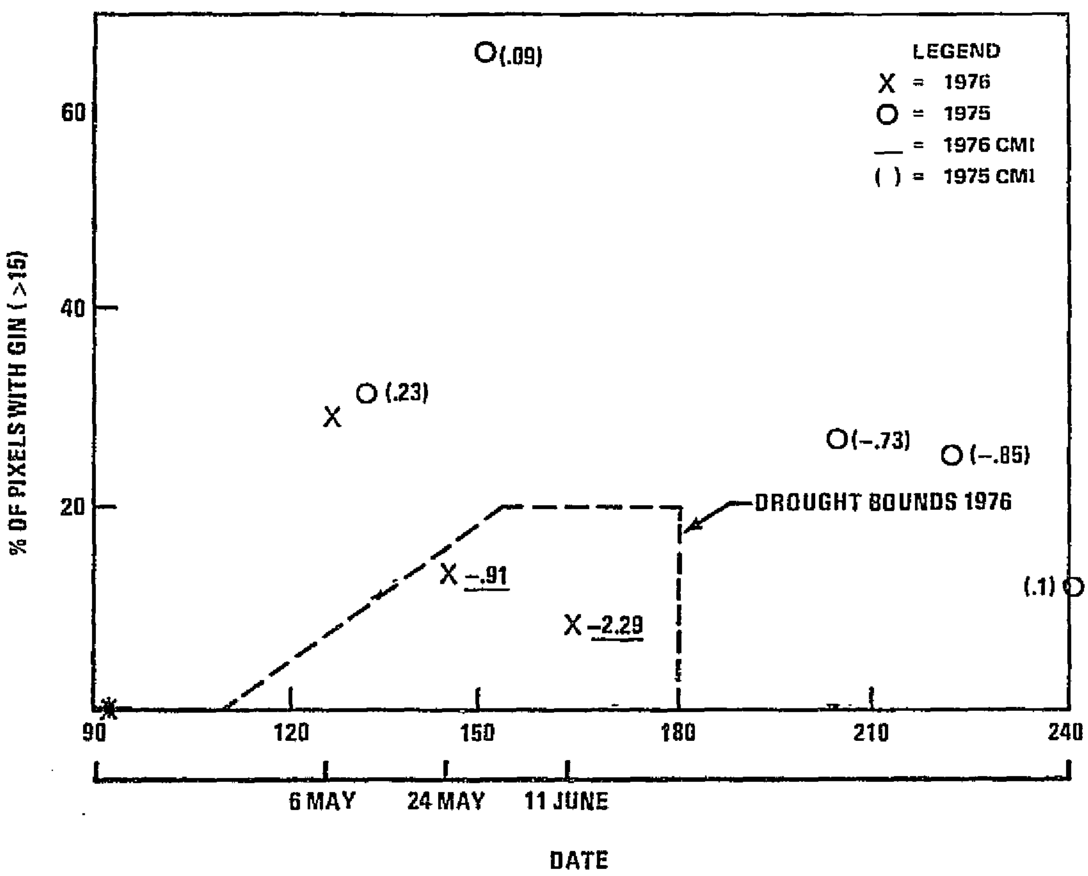


Figure 21. Drought on segment 1690 as indicated by GIN and verified by CMI.

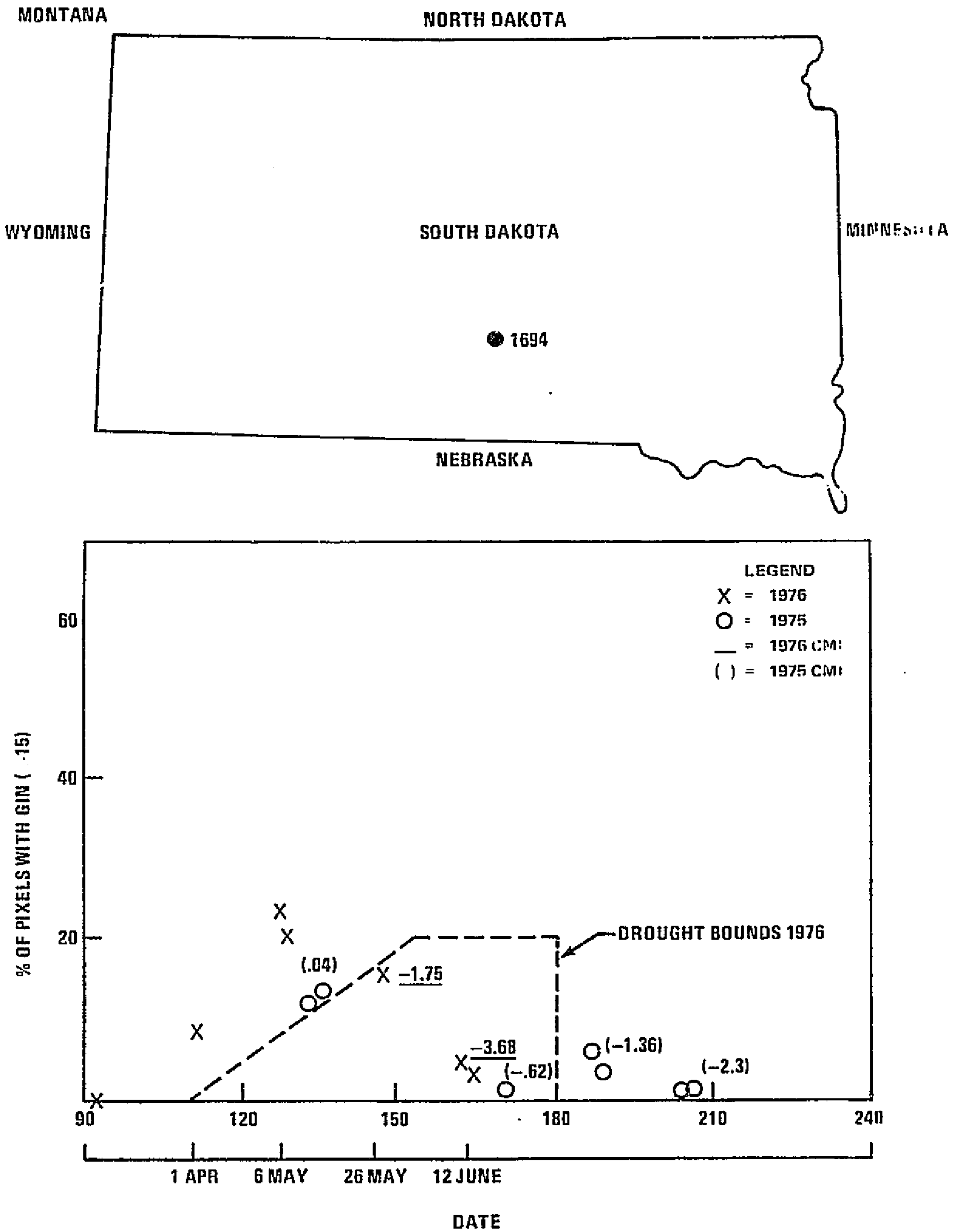


Figure 22. Drought on segment 1694 as indicated by GIN and verified by CMI.

4.0 YIELD AND ACREAGE RESULTS

Yield and acreage results will be reported and discussed in a separate report on how well LACIE performed in both the southern Great Plains and South Dakota droughts.

5.0 SUMMARY AND CONCLUSIONS

The technical approach developed in the southern Great Plains for detecting and monitoring drought was used successfully in the South Dakota drought. Landsat full frame images were used to outline and monitor the areal extent of the drought. This areal extent agreed with other sources of indicating drought. A scheme using Landsat digital data was developed for identifying 5 x 6 nm segments as drought affected or not affected. This scheme agreed with the Crop Moisture Index as when the area was under drought stress. This scheme (GIN) also provides an aid to analyst interpreters for indicating changes that are occurring before these changes are detected on color infrared images.

LACIE has developed and validated in the 1975-76 droughts in the U.S. Great Plains, a procedure whereby drought can be detected and monitored using remote sensing based criteria (Landsat). This capability will provide the ability to detect potential drought in areas of the world where ground information is not available or reliable.