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A COMPARISON OF CROP YIELDS USING EL NINO AND NON-EL NINO CLIMATOLOGICAL DATA IN A CROP MODEL

by

Kenneth J. DeMoyse

1990 Thesis/~~Dissertation~~

A Comparison of Crop Yields Using El Nino and Non-El Nino Climatological Data In a Crop Model

Kenneth J. Demoyse

AFIT Student at: Utah State University

AFIT/CI/CIA -90-113

AFIT/CI
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A COMPARISON OF CROP YIELDS USING

EL NINO AND NON-EL NINO

CLIMATOLOGICAL DATA

IN A CROP MODEL

by

Kenneth J. DeMoyse

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Soil Science and Biometeorology

Approved:

Major Professor	Committee Member
Committee Member	Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1990

ACKNOWLEDGEMENTS

My special thanks to Dr. Gail Bingham for taking me under his wing, allowing me to pursue my interests, and guiding me along my academic path.

I would also like to thank the Air Force Institute of Technology (AFIT) for sending me for my masters degree and the other members of my committee, Drs. Don Sisson and Jim Richards, for their classes and questions, which forced me to think. Additionally, a note of thanks to Drs. Larry Hipps and Bruce Bugbee for their courses, which rounded out my education in agricultural meteorology.

A special and well-deserved thanks to Greg McCurdy, without whose help I never would have gotten this paper done.

Finally, a thank-you note to my wife, Hellen, and son, Jim, who were always there for me during my time at Utah State.

Ken DeMoyse

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ABSTRACT

A Comparison of Crop Yields Using El Nino
and Non-El Nino Climatological Data
in a Crop Model

by

Kenneth J. DeMoyse, Master of Science

Utah State University, 1990

Major Professor: Dr. Gail E. Bingham
Department: Plant, Soils, and Biometeorology

During a 38-year period (1950-1987), daily climatological data for the five largest corn-producing states in the Midwest (Illinois, Indiana, Iowa, Nebraska, and Minnesota) were averaged to obtain climatological data sets for both El Nino and non-El Nino years. These data bases were then used in the crop yield model, CERES Maize, to determine if the El Nino climate resulted in any differences in yield for each state.

After running the model with the two data sets for the five different states, the results showed no significant difference in the simulated corn yields between El Nino and non-El Nino years.

(104 pages)

INTRODUCTION

The periodic warming of the normally cold waters off the coast of Peru is called "El Nino" (also known as El Nino-Southern Oscillation and hereafter referred to as ENSO). This phenomenon has been documented by ice cores (Thompson and Mosley-Thompson, 1986), alluvial flood deposits (Wells, 1986; Craig and Shimada, 1986), beach ridges (Sandweiss, 1986), and fossil mollusks (DeVries, 1986) to have existed along the Peruvian coast for at least several millenia (Nicholls, 1989). Quinn et al. (1978) presents a detailed chronology of ENSO events beginning in 1541. These events affect the interannual fluctuations of the climate over much of the globe (Rasmusson and Carpenter, 1982, 1983; Ropelewski and Halpert, 1986, 1987). The weather anomalies associated with these events range from droughts in areas that usually have seasonal monsoon rains (Ropelewski and Halpert, 1987) to flooding in arid regions to extremely severe and numerous hurricanes and typhoons to above- and below-average temperatures in various parts of the world. More importantly, they bring warmer than usual ocean water to the South American coast, where there is normally an upwelling of cold water. This warming of the ocean waters causes the food cycle of the area to be severely disrupted. The natural food chain (plankton-sardines-seabirds-etc.) is upset, causing economic chaos in the area (Cane and Zebiak, 1986).

Even though the exact cause or causes for the initiation of an ENSO event are still not known, we do know enough about its formation to be able to detect its onset during the early stages of development, usually 6 to 9 months before it reaches the coast of the Americas (Cane and Zebiak, 1986).

Initially, it was the hope of this research project that advance knowledge of an upcoming ENSO event could be used to give corn producers a better idea of how their corn yields might be modified by expected differences in precipitation and temperatures resulting from an ENSO event. Corn was used in this project because it is a very important cash crop in the Midwest. If it could be shown that yields during an ENSO are a certain percentage above or below normal, the farmers could take appropriate steps when alerted that an ENSO was imminent. Depending on how production was affected, these steps could mean adding additional acreage if the yields were improved, or planning additional expenditures for irrigation and fertilizer to help improve yields if it were shown that they decrease during ENSO periods.

If it could be shown that ENSO events indeed affect the climatology of our largest Midwestern corn-producing states (Illinois, Indiana, Iowa, Nebraska, and Minnesota) and their subsequent crop yields, then perhaps this knowledge could be applied to other crops in other parts of the world as well.

OBJECTIVES

The main objective of this project was to compare the results of a crop yield model using ENSO and non-ENSO climatological data sets for the five largest midwestern corn-producing states (Figure 1) to see if the modelled yields differ significantly. If so, it would mean that the climatological conditions during an ENSO event are different than those deemed normal (derived from non-ENSO years), and this may help to explain some of the dramatic peaks and valleys observed in smoothed crop yields over the past 38 years (Figures 2a-f).

To achieve this objective, two tasks first had to be accomplished. The first was to examine the sea surface temperatures of the Pacific Ocean. Averaging them over time and space allowed the determination of a set of years representing the ENSO events between 1950 and 1987. This period was chosen because of the availability of a comprehensive data base for both sea surface temperatures and daily climatic observations. This set of ENSO years was then used to compare climatic parameters and crop yields.

The second task was to compile a climatic data base for both ENSO and non-ENSO years from the daily weather records of all reporting stations in each state for the past 38 years. The overall averages of precipitation and temperature maximums and minimums of these years (after

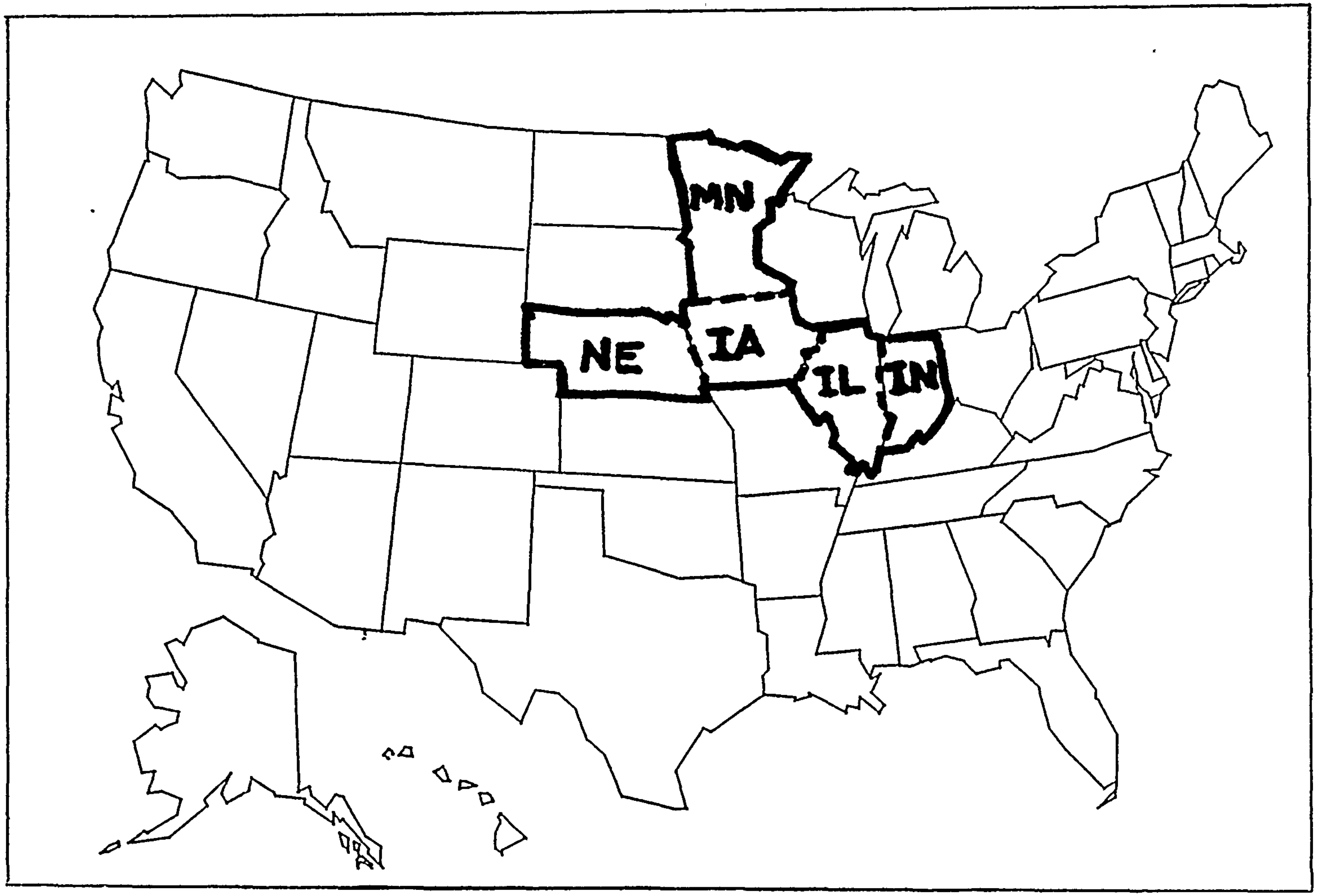
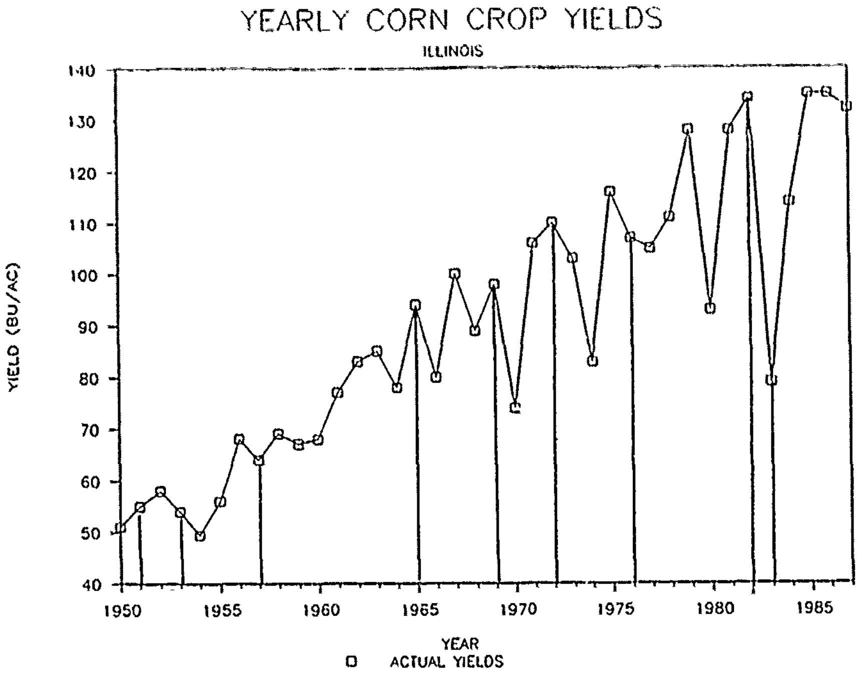


Figure 1. Five midwestern states of interest.

a. Illinois



b. Indiana

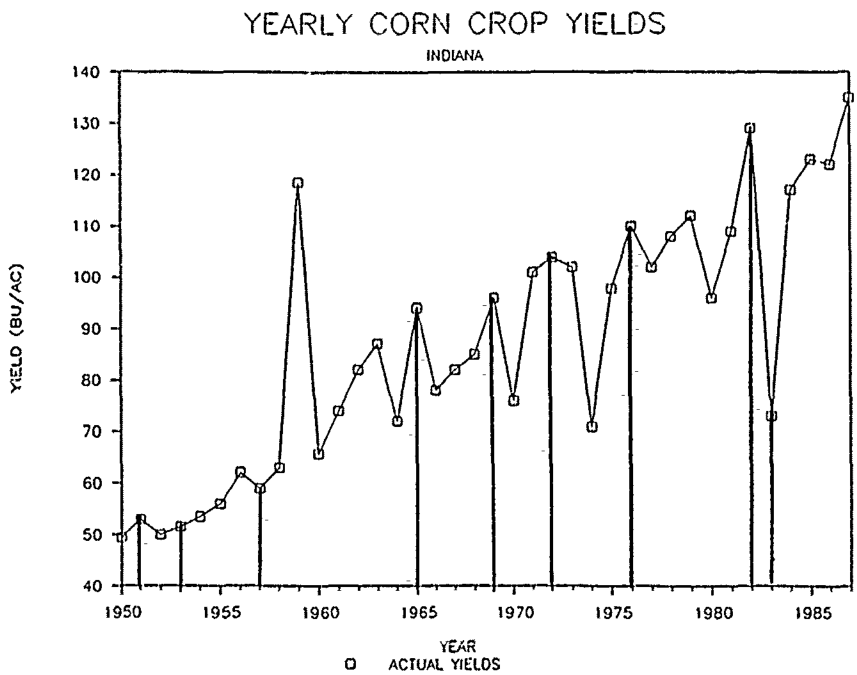
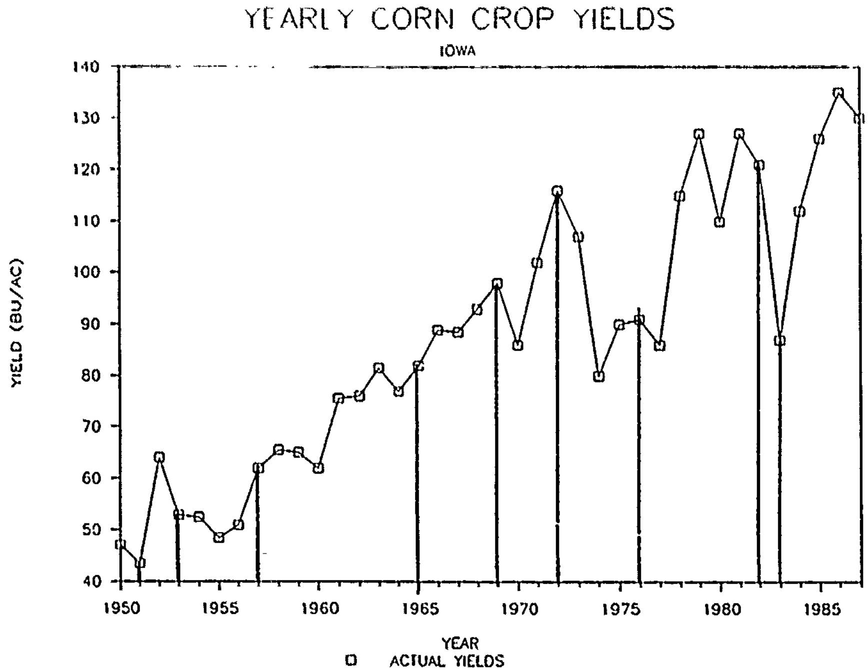


Figure 2. Average corn crop yields (1950-1987).
Dark lines represent El Nino events.

c. Iowa



d. Minnesota

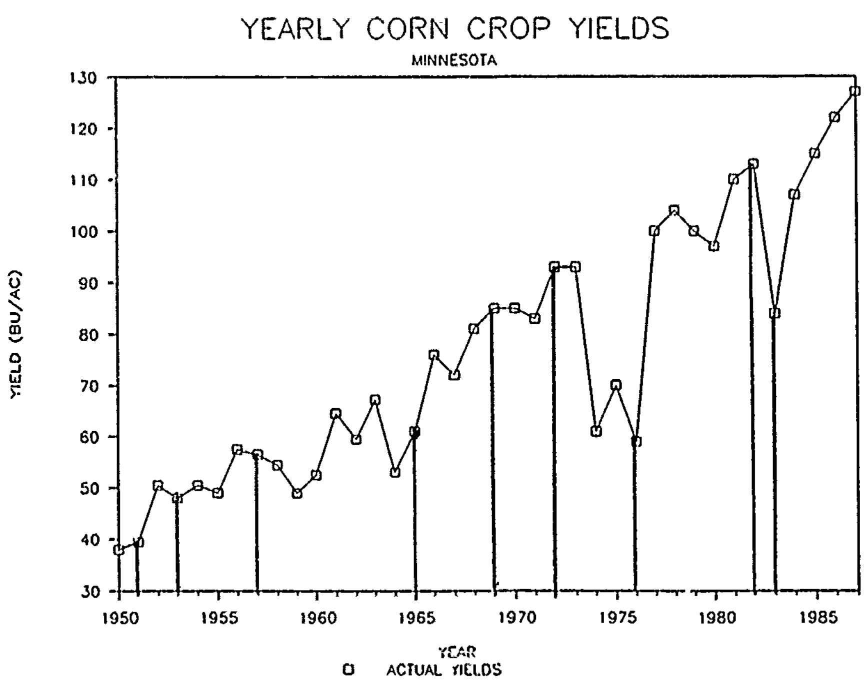
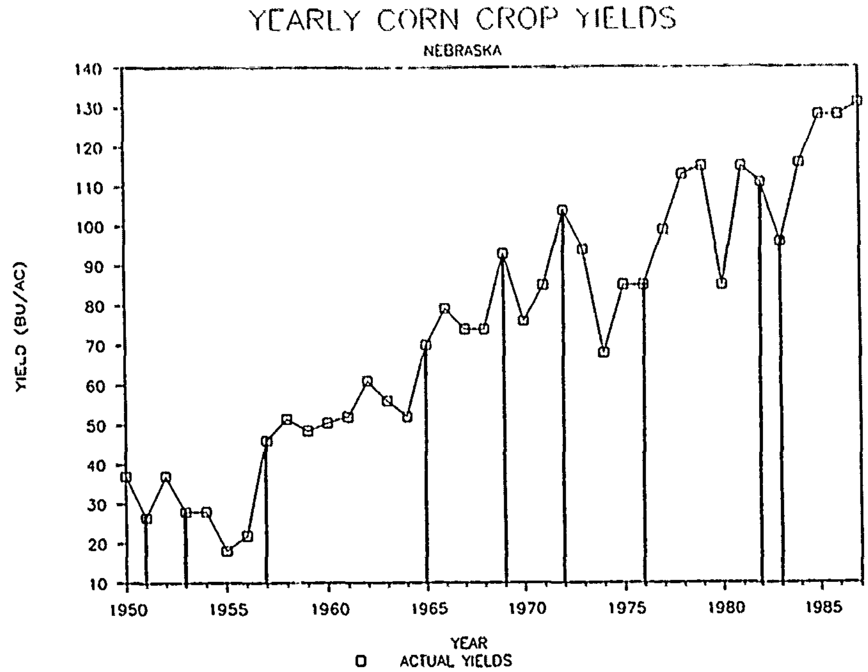


Figure 2. (continued)

e. Nebraska



f. U. S. Average

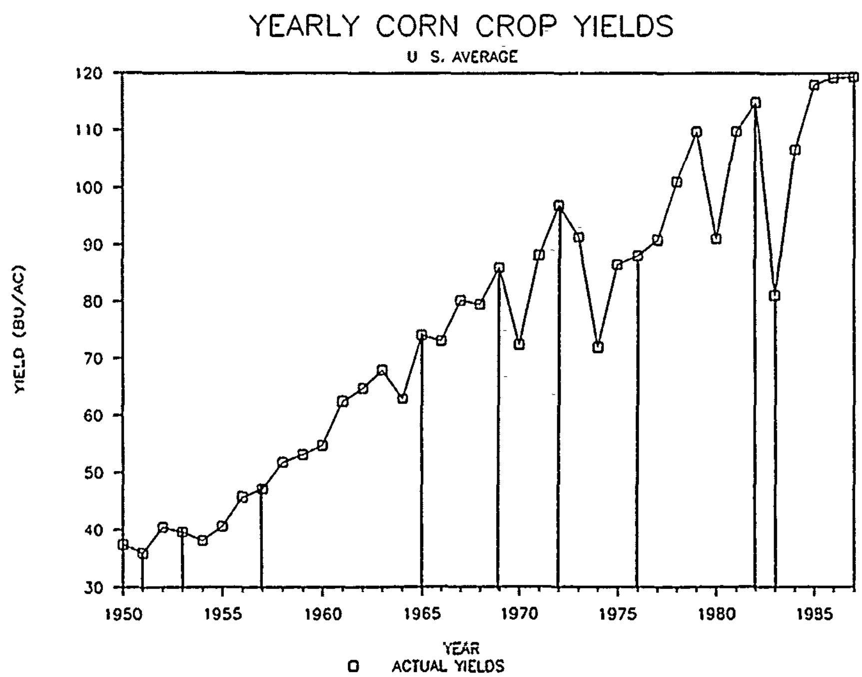


Figure 2. (continued)

separating them into ENSO and non-ENSO years) formed the composite climatic data sets for each state and was used in running the crop yield models.

Once these two tasks were accomplished, the overall objective was achieved by running the crop yield model using both the ENSO and non-ENSO data sets and comparing the resultant yields. If these yields differ significantly, then one might infer that the climatology of that region during ENSO periods is sufficiently different to affect agricultural production.

REVIEW OF LITERATURE

El Nino

In his book, El Nino, La Nina, and the Southern Oscillation, S. George Philander (1990) quotes Senor Dr. Luis Carranza, 1891 president of the Lima, Peru, Geographical Society, stating that a countercurrent flowing from north to south had been observed between the ports of Paita and Pacasmayo. The sailors had named the current "El Nino" (the child Jesus) because it has been observed to appear right after Christmas. Dr. Carranza goes on to explain that when the countercurrent is observed, the whole weather pattern of the region is altered. Normally barren deserts are deluged with heavy rains and exceptionally warm temperatures, and the normally abundant bird and marine life of the area disappears. This reference to El Nino is one of the earliest on record as to its location and its consequences.

It wasn't until 1969 that J. Bjerknes associated the El Nino with the Southern Oscillation discovered by Sir Gilbert Walker in 1923. These events all seem correlated to major changes in rainfall patterns and wind fields over the tropical Pacific and Indian oceans and with temperature fluctuations in southeastern Africa, southwestern Canada, and the southeastern United States.

El Nino is the phase of the Southern Oscillation when the trade winds are weakened; there is low pressure over the eastern Pacific and high pressure over the western tropical Pacific. The normal east-to-west trade winds weaken, slack off, and then reverse direction. The result is a weakening of the Walker Circulation, and the warmer, western Pacific waters begin to flow eastward. As the waters reach the eastern edge of the ocean, they overwhelm the normally cold, nutrient-rich waters upwelled off the coast of South America. This weakening of Walker Circulation allows the convective zone of rainfall that usually exists in the extreme western Pacific to move eastward, changing the pattern of the monsoon rains in that part of the world.

Several authors (Rasmusson and Wallace, 1983; Horel et al, 1986; Berlage, 1966; Horel and Wallace, 1981; Namias, 1969; Dickson and Namias, 1976) have shown that during an ENSO event, the Hadley Circulation strengthens with the appearance of upper-level easterly wind anomalies near the equator. On the poleward flanks, the subtropical jet streams are intensified and displaced equatorward (especially during November, December, and January). The resultant impact on the weather regimes in the Americas is severe wind and rain storms that occur along the coast of California, heavy snows that fall in the mountains of the western United States, and extremely heavy rains that fall in Brazil, Paraguay, and northern Argentina. Although the correlation is not extremly high, the authors do show some correspondence between ENSO events and the severe winter (summer) weather found in the western U.S. (South America).

It is this teleconnection and its effect on the climate of the midwestern portion of the U. S. that was explored in this project.

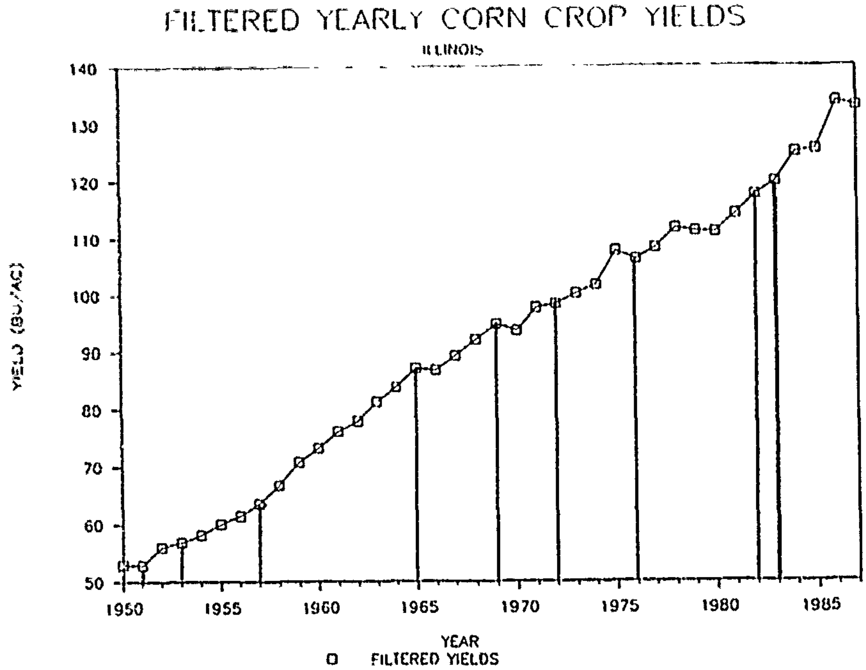
Corn Yield Predictions

As shown in Figures 2a-f and 3a-f, the crop yield over the past 38 years shows tremendous variability, even after using a 9-year smoothing technique on the values (Kogan, 1987). These figures show this variability and the impressive increase in yield due to technological advancements over the 38-year period.

Over the past few decades, management of some of the major factors influencing crop production (soil fertility, insect and weed pressure, and crop genetics) has improved. However, the effect of the most uncontrollable factor in crop production, weather, and its interactions with other factors has not changed and has not even been carefully investigated (Andresen et al, 1987). Two of the most important climatic factors--precipitation and temperature (maximum and minimum)--are examined here for their roles in estimating crop yields (Andresen et al, 1987; Carlson and Gage, 1987; Liverman et al, 1986; Skaggs and Baker, 1985). Changnon et al. (1989) shows that increasing rainfall by as much as 25 percent has a positive effect on crop yields when all other climatic conditions are near normal. During other times, increased rainfall tends to decrease yield.

Rosenzweig (1989) shows that temperature is the single

a. Illinois



b. Indiana

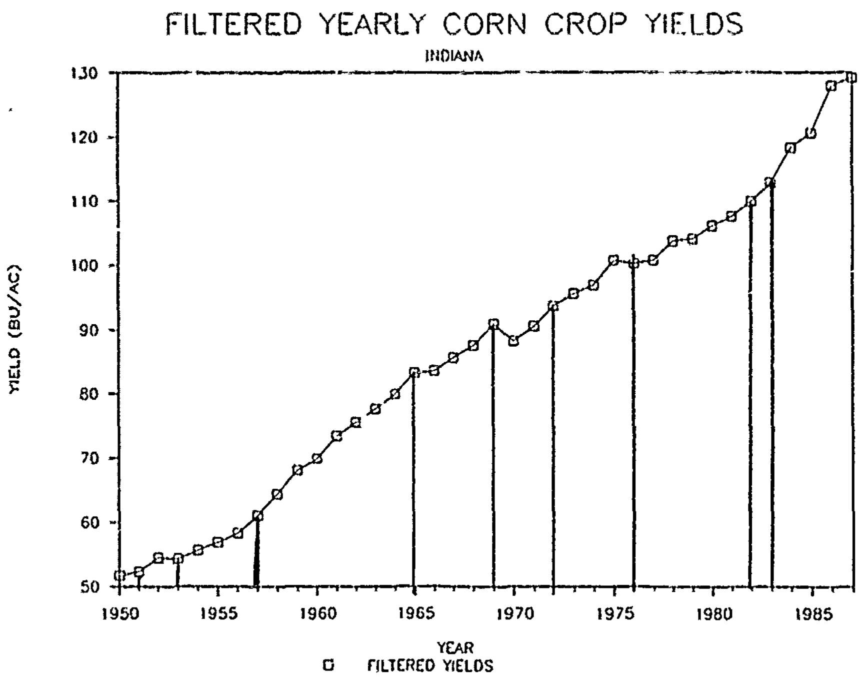
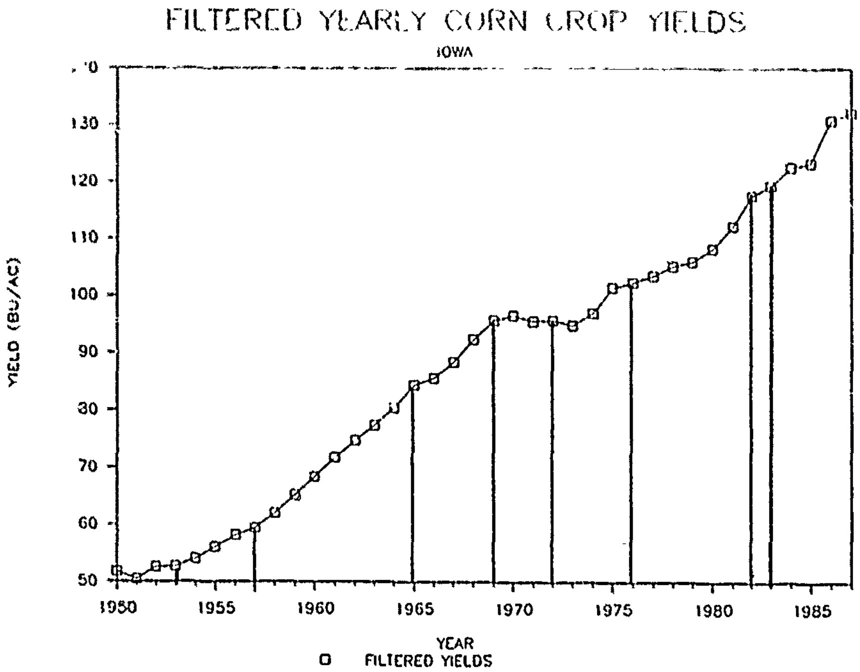


Figure 3. Average corn crop yields after a 9-year smoothing technique (1950-1987). Dark lines repesent El Nino events.

c. Iowa



d. Minnesota

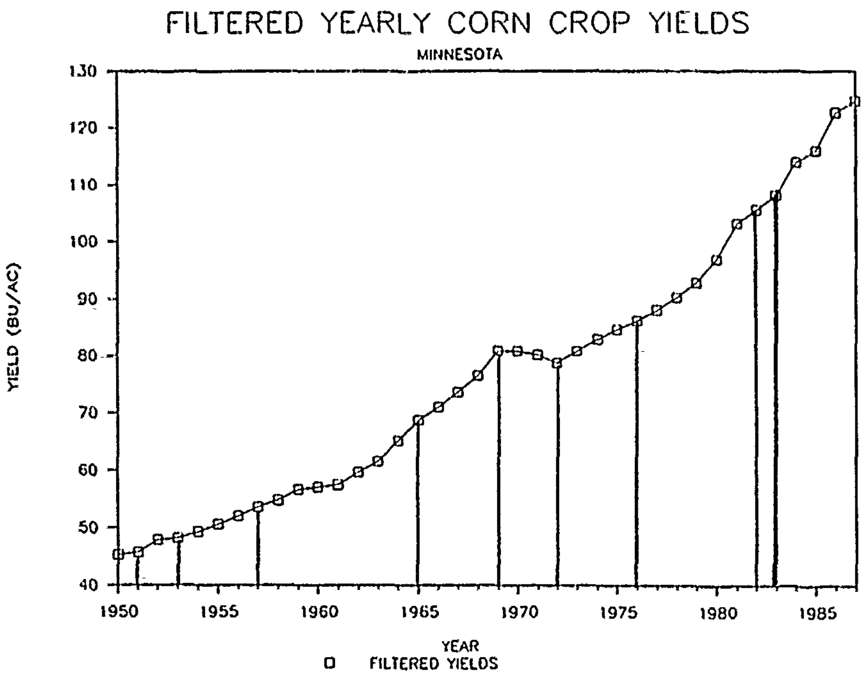
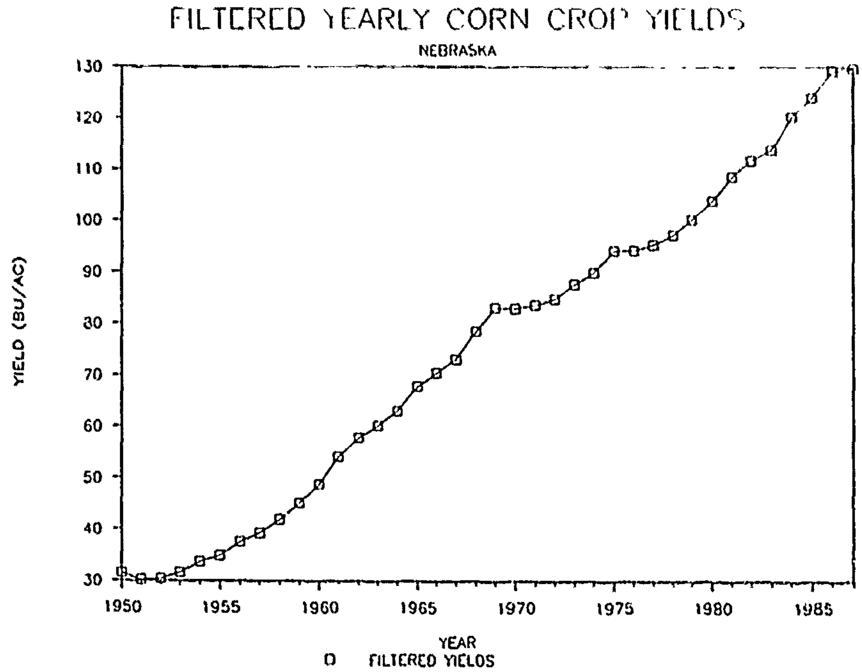


Figure 3. (continued)

e. Nebraska



f. U. S. Average

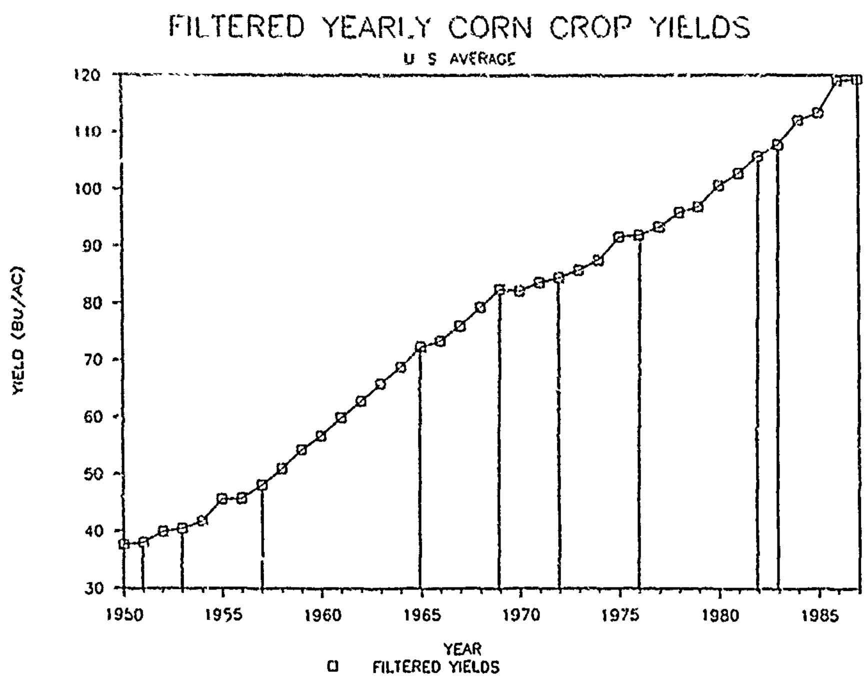


Figure 3. (continued)

most important factor in determining increases or decreases in yields. It is especially critical in terms of stress degree days (Sdd=number of days where the maximum temperature is above 90^{o} F) during the silking period (10 July through 20 August). The more Sdds during this period, the lower the yield (Newman and Scheeringa, 1985). Although it has not been shown that ENSO events cause average temperatures to rise or fall, we can expect the yields to follow the results of climatological averages.

Attempts have been made to tie corn crop yields to volcanic eruptions and increased aerosols. Handler and O'Neill (1987) tried to prove that increased aerosols (due to low-latitude [<30^{o}N/S] volcanic eruptions) reduce solar radiation, which in turn is responsible for an increase in the corn yields. The problem with their logic is that most crop yield models show <u>decreasing</u> yields with <u>decreasing</u> solar radiation values. They also use the growing season yields immediately after an eruption (i.e., April 1982 eruption and 1982 yield data) to prove their theory, when it would probably take 6-12 months for the aerosols to spread poleward in the stratosphere sufficiently to reduce incoming radiation in the corn-growing regions.

Still, it has been shown that changes in precipitation and temperature have an effect on both actual and modelled results. It is hoped that the climatic changes in the midwestern states (if any) will be shown to lead to these same yield changes.

PROCEDURE

Determination of El Nino Years

A set of sea-surface temperatures (SSTs) and temperature anomalies for the Pacific Ocean was obtained from the Scripps Oceanographic Institution for the period of 1950 to the present. This data set gives the average monthly temperatures (and deviations from the mean) for 5^{o} grid points in the Pacific Ocean. This data was averaged for the nine values found within the El Nino box (Figure 4): 0^{o} to 10^{o} S by 80^{o} to 90^{o} W (Flueck and Brown, 1987); the values are presented in Appendix B. These monthly averages were then grouped by frequency to determine the median and percentile levels. Based on the fact that moderate to strong ENSO events had SSTs averaged within the El Nino box that fell outside the 88th percentile (Flueck and Brown, 1987), the median was calculated to be 22.0^{o} C and the 88th percentile began at 23.4^{o} C. Using these criteria, the following eight years were picked as moderate to strong ENSO events: 1951, 1953, 1957, 1965, 1969, 1972, 1976, and 1982-83 (Figure 5). The moderate to severe events were chosen so that their effects (if any) on the climatology of the region would be more pronounced and more easily demonstrated. Although most authors don't agree on the same ENSO events due to the manner in which they are chosen (i.e., sea-level pressure differences between Darwin and Tahiti, sea-surface temperatures, vulcanism, etc.), the ENSO set chosen for this

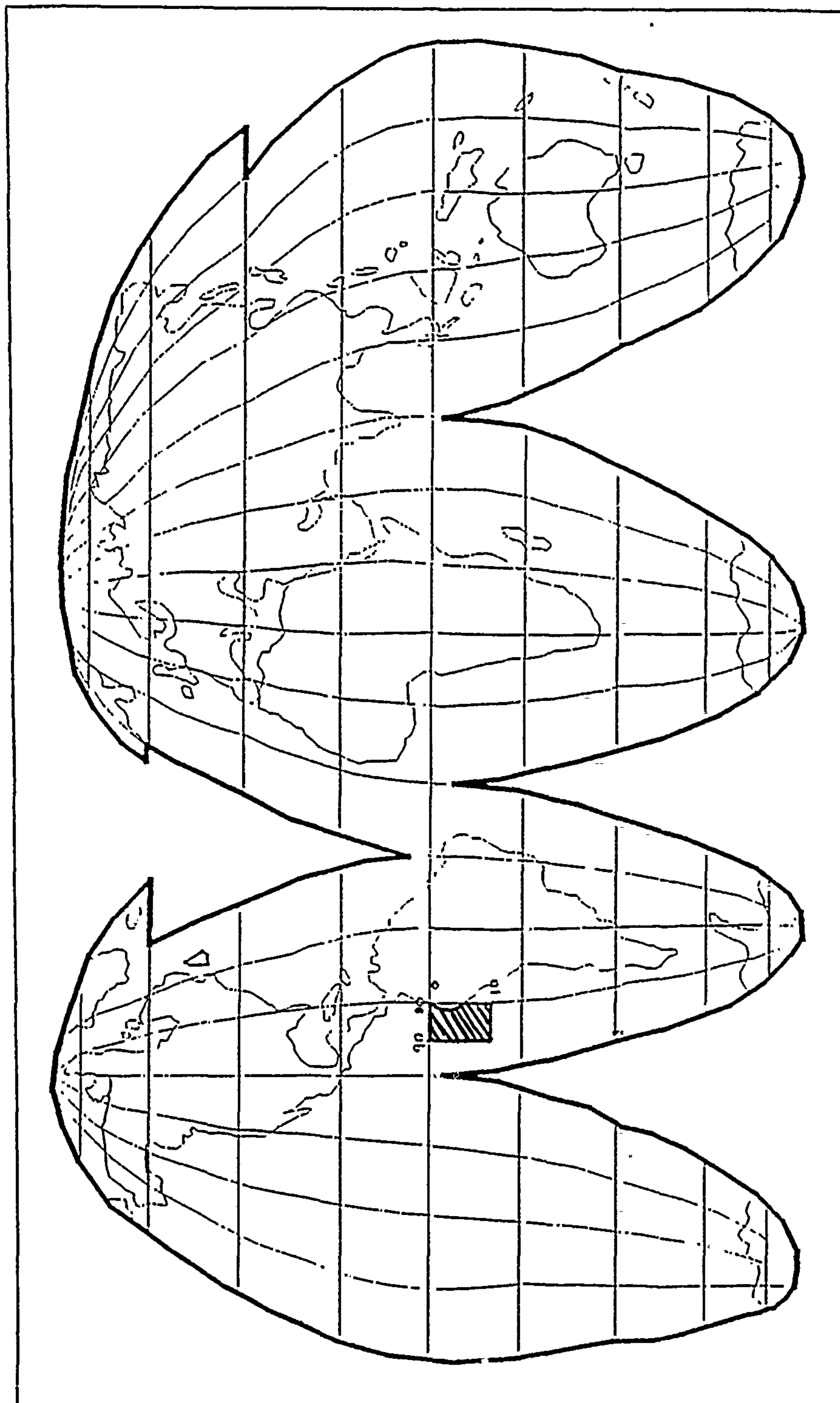


Figure 4. Map of the El Nino Box. 0 - 10° S by 80 - 90° W.

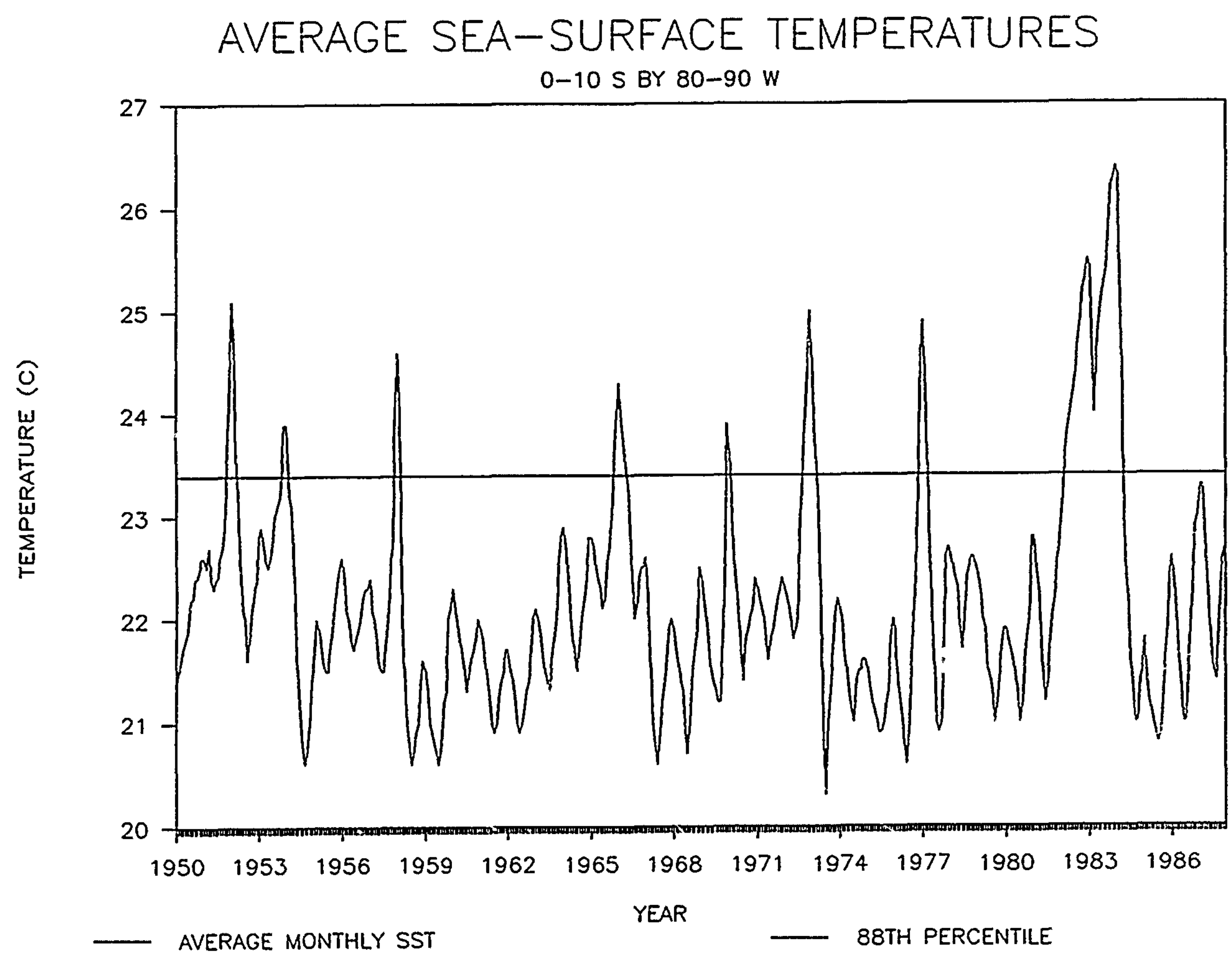


Figure 5. Average Sea-Surface Temperatures. Averaged over the El Nino box by month (° C).

TABLE 1. Various sets of El Ninos determined by various authors

AUTHOR	51	52	53	57	63	65	66	67	68	69	72	76	78	79	82	83	86
Quinn et al. (1978)	X		X	X		X				X	X	X			X	X	
Rasmusson and Carpenter (1982)	X		X	X	X	X				X	X						
Flueck and Brown (1987)	X			X							X	X			X	X	
Rogers (1987)			X	X	X	X				X	X	X	X				
Schreiber and Schreiber (1987)				X	X						X				X	X	
Handler (1984)	X	X			X		X	X	X		X			X	X		X
DeMoyse (1990)	X		X	X		X				X	X	X			X	X	

project is in fairly good agreement with others (Table 1). It should also be noted that even though the 88th percentile was chosen as the demarcation line for moderate and stronger ENSO events based on Flueck and Brown's work, a slight change in the percentile rank used would not make any difference in the years chosen.

Once an ENSO set was determined, the growing season immediately following it (called ENSO+1) was used as the year in which crop yields and climatic variables were examined to make up the "ENSO" set.

Climatic Composite Construction

The daily weather records of the reporting stations in each of the five states for the period of 1950 through 1987 were obtained from the Department of the Air Force, OL-A, Environmental Technical Applications Center (ETAC), Asheville, N. C. Depending on the state, the year, and the variable being examined, the total number of these reporting stations varied from a low of 86 (minimum temperatures/Indiana) to a high of 253 (precipitation/ Nebraska). These variables were averaged (precipitation, maximum and minimum temperatures) by day and by year for each state. From this record, the eight ENSO periods were averaged together to form an ENSO climatological data set for each state. The remaining 30 years were then averaged together to form the non-ENSO climatological data set for each state.

Examination of Climatic Values

Before these data files were used in the crop models, the Palmer Drought Severity Index (PDSI) for each year and each region of the states was examined to see if there was any apparent correlation between ENSO+1 years and drought. The PDSI was prepared using the Moisture Anomaly Review System (MARS) available from the National Climatic Data Center, Asheville, N. C. The results were mixed; some of the ENSO+1 years showed evidence of being in a drought situation while other ENSO+1 years showed no indication of a drought. These inconsistent results were found in all regions and in all five states (Appendix F).

The monthly averages for each variable were then calculated for each state for both ENSO and non-ENSO years to see if they were significantly different. Using a t-test with a significance level of 95 percent, the means of the ENSO years were compared to the means of the non-ENSO years. Out of the 125 possible cases (5 months times 5 states times 3 variables), only one case showed a statistically significant difference between ENSO and non-ENSO years. This was found in the averages for Indiana/Precipitation/May. Generally speaking however, no difference was shown between the mean values for the variables in ENSO years and those of non-ENSO years.

The Model

The crop yield model, CERES Maize, was used for estimating crop yields in this project. It was developed at the University of Hawaii in conjunction with Michigan State University, the International Fertilizer Development Center, Muscle Shoals, Alabama, and the International Benchmark Sites Network for Agrotechnology Transfer. The model, which has been throughly documented (Jones and Kiniry, 1986) and widely tested (Singh, 1985), simulates crop responses to major factors that affect crop yields: climate, soils, and management. It employs simplified functions to predict the phenological development; apical development related to morphogenesis of vegetative and reproductive structures; extension growth of leaves and stems; senescence of leaves;

biomass production and partitioning; root system dynamics; and the effects of soil-water deficit on the photosynthesis and photosynthate partitioning in the plant.

Model Input

Once the averaged daily precipitation and temperature values were obtained for each state, data files were created for each of the states to be used in the crop yield model. The CERES Maize model required daily precipitation, maximum and minimum temperatures, and solar radiation values as input. Precipitation and temperature values came from the climatological data bases; the solar radiation values were calculated using the tables of solar radiation at the earth's surface (Jensen, 1973) and the equation

$$Rs = (0.35 + 0.61S) Rso$$

where Rs is the solar radiation value needed in the crop model, S is the ratio of actual to possible sunshine, and Rso is the solar incident on the earth's surface on cloudless days. Through experimentation with the model, the value for S was set at .07 to simulate the increased cloudiness due to the fact that the composite climatological sets have some precipitation occurring every day.

In addition to precipitation, solar radiation values, and temperatures, a representative latitude for each state was entered into the data file as well. This value was later used by the model for calculations of evapotranspiration and growth phases.

Model Use

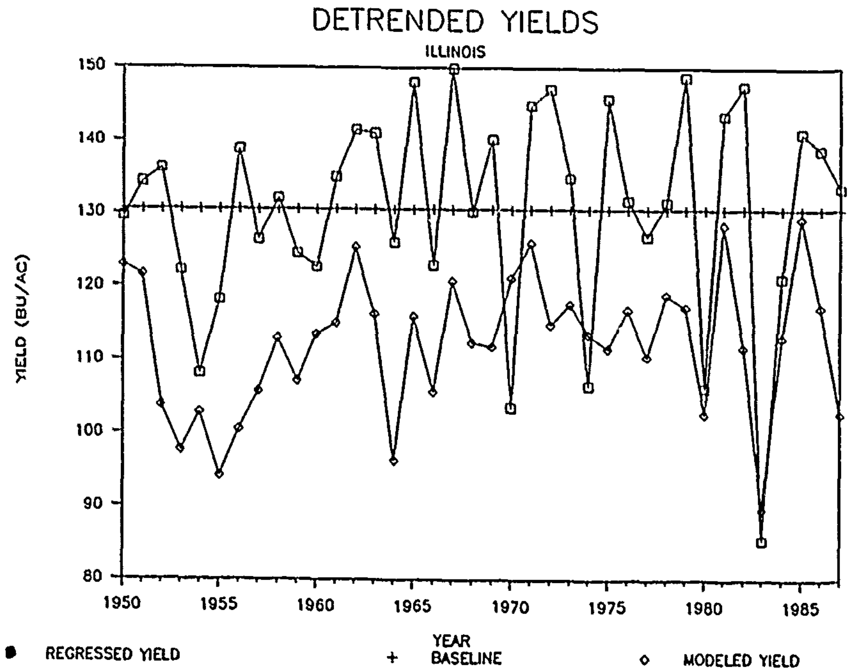
Before running the crop model with the composite climatological data sets, the model had to be initialized with certain variable values specifically for the Midwest. The program requires the initial planting date, set to May 15 for all states. There is also an option to change the soil type and crop variety; these were set to medium texture silt loam (Terjung et al., 1984) and CP170 (a variety that fills fast and is sensitive to the changes in the photoperiod) (Terjung et al., 1984). The program was set for rainfed only (no irrigation), and all runs had adequate fertilization at the start and were fertilized twice during the growing cycle (see Appendix E for a sample printout of a model run).

The model was then validated by obtaining estimated yields using the averaged monthly climatic data for each year in each state. These results were later used for comparison with the yields obtained using the composite climatic data sets to determine if the differences were statistically significant at the 95th percentile level.

Determination of Significance

To test the ENSO and non-ENSO yield results for a significant difference, the significance level had to first be decided upon (95%), and the model had to be run through all the years and all the states to obtain an average and standard deviation that could then be used for comparison

a. Illinois



b. Indiana

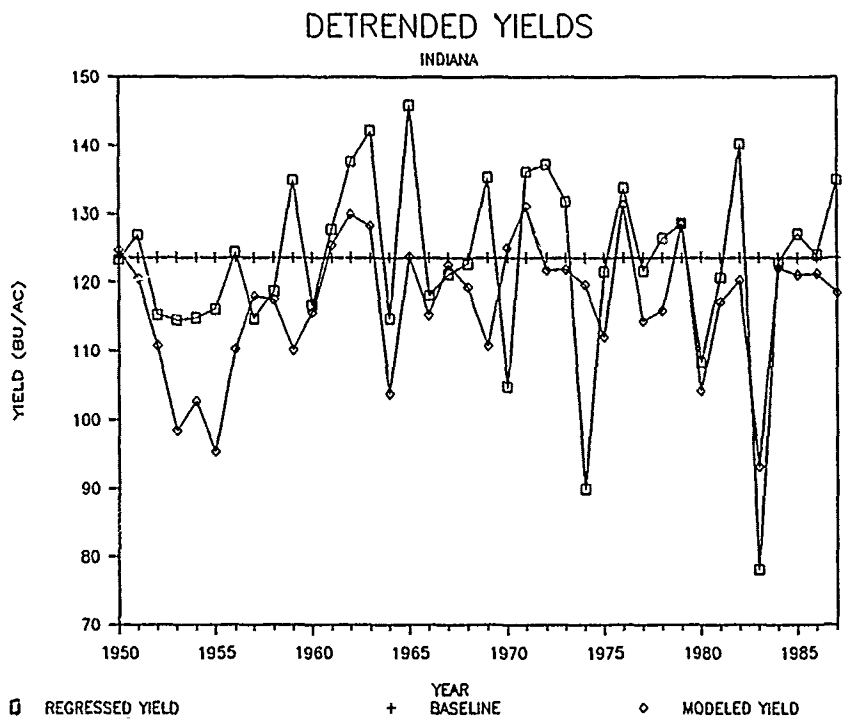
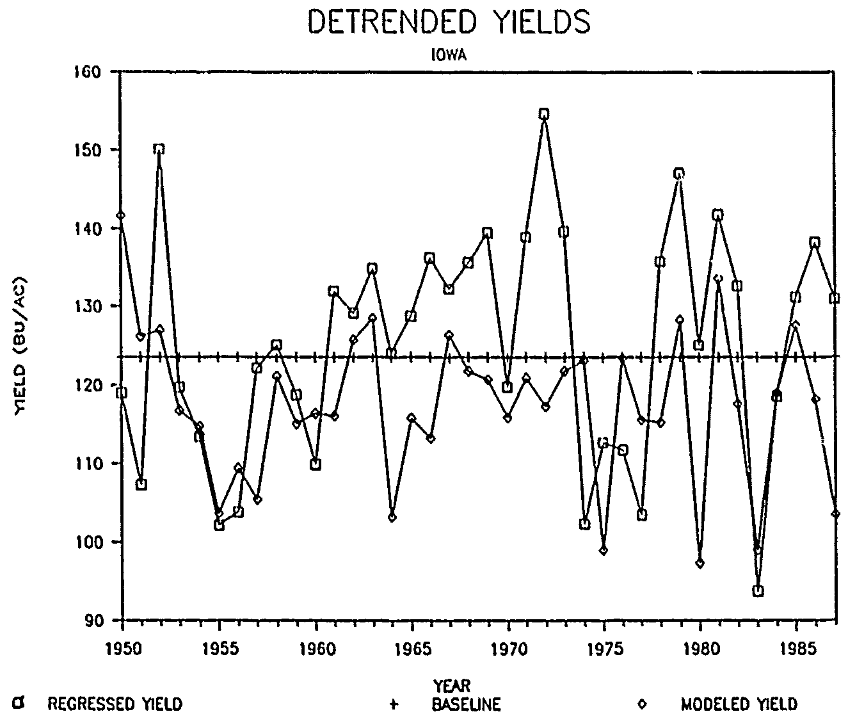


Figure 6. Detrended yields. Actual yields by state after being detrended using a regression equation and setting the previous values against a baseline. Modelled results are also given for purposes of comparison.

c. Iowa



d. Minnesota

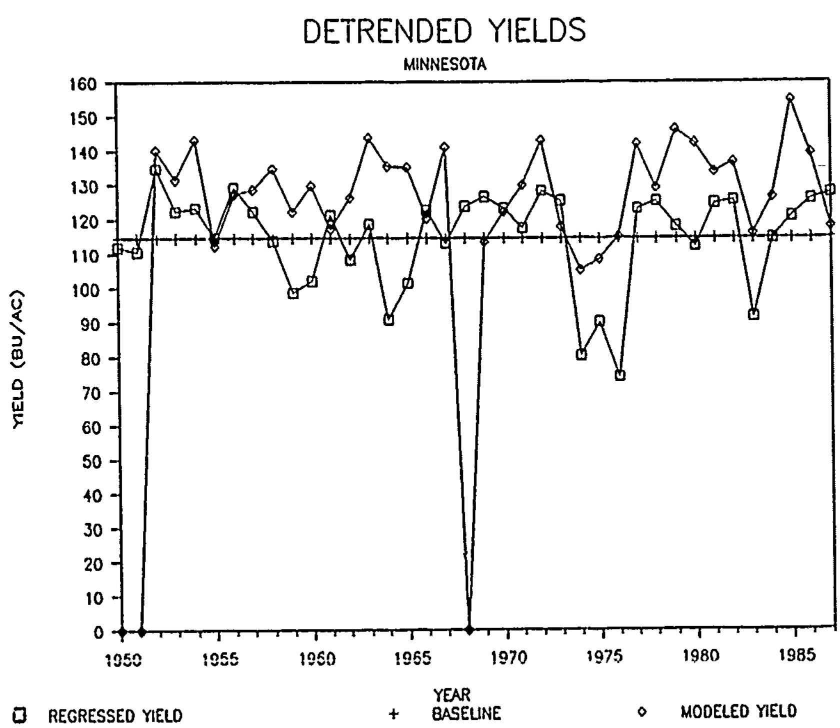


Figure 6. (continued)

e. Nebraska

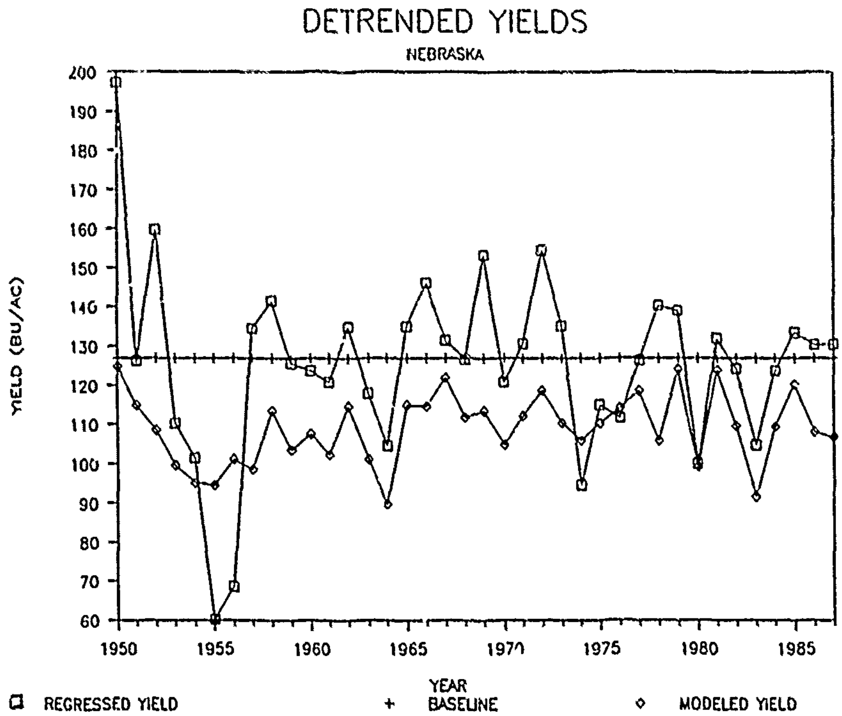


Figure 6. (continued)

purposes. To do this, the yields of each state were first smoothed out using the 9-year smoothing technique (Figures 3a-f). These yields were then run through a regression model to get a regression equation. Since this line removed most of the variability due to weather and left in the increasing trend due to technological advancements, the yields had to be detrended using a baseline value obtained for 1987. The actual yields were then adjusted against this baseline and the regression equation (Figures 6a-e). Once these new detrended values were determined, they were grouped together according to whether they were an ENSO or a non-ENSO year and averaged. Using a 95 percentile significance level, a confidence interval was computed for each state for the actual non-ENSO yields. The ENSO yields determined from the composite climatological data sets were then compared to see if they fell within the 95th percentile C. I.

RESULTS

After testing the weather parameters obtained from averaging the two separate groups, comparing their means for statistical differences, and finding none, it was no surprise when the crop yield results using the CERES Maize model showed little difference between ENSO and non-ENSO years for each of the states. Table 2 shows the yields per state and the percent difference from non-ENSO years as compared to ENSO years.

Table 2. Model yield results and differences

STATE	NON-ENSO YEARS	ENSO YEARS	% DIFFERENCE
Illinois	110.3 bu/ac	110.4 bu/ac	+0.091%
Indiana	116.6	114.8	-1.568%
Iowa	116.5	118.8	+1.936%
Minnesota	142.4	139.7	-1.933%
Nebraska	121.4	108.3	-12.096%

The only state that showed something of a difference was Nebraska. These yields are predicted based on a composite climatological data base in which there was precipitation every day, and the temperatures did not show any of the extremes that naturally occur. The abnormally high yields in Minnesota could also be accounted for by the fact that the growing season in the model had to be extended to allow for maturity of the corn. This allowed the model to predict unusually high yields for an area that doesn't normally achieve these. Even though the expected yields themselves should be looked at with some suspicion, the differences between the two sets of data are valid and were shown to exist. Even when the solar radiation values were increased and the yields became unreasonable, the percent difference between the two sets of data for each of the states remained about the same. Another interesting result is the fact that the sign of the difference did not stay the same for the five states.

The differences between the two modeled yields were then compared to the standard deviations found in each state using the actual weather data and yields. As expected, there was no significant difference (at the 95% level) found between the expected yields using ENSO climatology and the yields using non-ENSO climatology.

CONCLUSIONS

While it was originally hoped that some of the dramatic yearly differences might result from the effect of El Ninos on the climate and the subsequent yields, it immediately becaome apparent that yields in the year directly after an ENSO event did not coincide with either the peaks or the valleys in the history of crop yields (Figures 1a-f).

This was further evidenced by the fact that even though temperature and precipitation have a direct impact on crop growth and yield, the compiled climatological data bases for both ENSO and non-ENSO years showed no real statistical difference between the values for ENSO and non-ENSO years in any of the variables in any of the states, with the exception of only one case. When these climatological parameters were inserted into the crop yield models, the resultant yields should not have shown any major differences between the different data sets. Even though not significant, the 12 percent difference between ENSO and non-ENSO yields for Nebraska, when the monthly averages showed no significant difference, may have resulted from the fact that the model uses daily values in the input; even though the monthly averages were very close, the daily values that went into that average may have been different enough at different times of the growing season to yield this difference. This sensitivity of the model to daily changes in temperatures and precipitation is something that was expected despite the small difference between the averaged climatic inputs.

Stated another way, Nebraska may indeed exhibit a climatic difference, but further investigation and more years of data are needed to support this outcome. While there was no significant difference between the monthly means for precipitation and maximum and minimum temperatures for Nebraska at the 95 percent level, during a number of months the various variables came very close to being significantly different. This may have had a cumulative effect in the crop model, resulting in the yield difference.

The overall conclusion is that ENSO events are not associated with any significant impacts on the climatological parameters investigated in this study. The climatological data bases do not show any significant difference between ENSO and non-ENSO years, and the results from a crop yield model confirm this lack of yield-affecting difference.

RECOMMENDATIONS FOR FURTHER STUDY

A number of areas are indicated where further study may uncover connections between the ENSO events and changes in crop yield, among them to:

- investigate only those states that seem to have their jet stream altered during an ENSO event.
- extend the period of investigation.
- examine the yield responses of other crops.
- assemble a composite climatic base more representative of the actual weather.

Jet Stream Alteration

Examining the weather maps for the Midwest (or any other area of interest), can indicate the normal upper-level flow of air. By comparing this pattern to one established during ENSO events, areas can be chosen that show an upper-level flow changed during the ENSO. The nature of the change may mean cooler than normal temperatures (if troughing develops), warmer than normal temperatures (if high pressure builds up and ridging occurs), more or less persistent rain, or a change in the timing of delivery of the precipitation (convective storms giving large amounts all at once versus stable, cumuloform rain). These changes in the weather pattern may have a noticeable impact on crop yields.

Period of Investigation

Because this study traced data back to 1950, only eight moderate to strong ENSO events were chosen. If the period of investigation were extended to the turn of the century (or longer), more ENSO events could be used to develop the climatic data base and also to develop the non-ENSO data base. Using a period of 80-100 years would give about 20-25 ENSO events, which in turn could give a very representative climatic base.

Other Crops

This study only looked at corn; other crops (like wheat, soybean, or alfafa), might show some correlation between the minor climate changes during an ENSO period and the yields given by these crops. Other crops may prove to be more sensitive to subtle changes in the temperature and precipitation than corn; if this is the case, then maybe their expected yields would show the difference between ENSO years and non-ENSO years.

More Representative Climatic Base

Due to the way this data base was constructed, precipitation was found to occur ever day, even though amounts were small, this is not what happens in nature. Although partly accounted for by not using irrigation and by using a constant solar value for each entire month, periods of drought or excessive rain may exist in either the ENSO or non-ENSO years that are lost in the composite data base.

The composite also reduces periods of extreme cold and hot weather due to its averaging. These periods may have extreme impact on overall yields and need to be examined.

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APPENDICES

Appendix A. Pascal Program
Used to Average SSTs.

The monthly values for the grid points within the El Nino box were read off the sea-surface temperature data reels and averaged together to obtain a monthly value for that area.

```
(       Program to read Blendedsst.dat file
        and get averages by long. and lat.
                I = lat, J = long.
)
        PROGRAM BSST (INPUT,OUTPUT);

        CONST
             N = 91;
             M = 180;

        VAR
           SST                : REAL;
           iflag              : string[255];
           IDA,IMO,IYR,IY     : INTEGER;
           I,J,K,COUNTER      : INTEGER;
           SUM,AVG            : REAL;
           file_in            : string[30];
           file_out           :string[30];
           IN_FILE            : TEXT;
           OUT_FILE           : TEXT;

        BEGIN
(
        Open files
)
        write ('Enter Input Filename --> ');
        readln (file_in);
        ASSIGN(IN_FILE,file_in);
        RESET (IN_FILE);
        write ('Enter Output Filename --> ');
        readln (file_out);
        ASSIGN (OUT_FILE,file_out);
        REWRITE(OUT_FILE);
(
        START READING FILE
)
        WHILE NOT EOF(IN_FILE) DO
        BEGIN
            READLN(IN_FILE,IDA,IMO,IYR,IY);
            WRITELN (IDA,' ',IMO,' ',IYR,' ',IY);
            WRITELN(OUT_FILE,IDA,'',IMO,'',IYR,'',IY);
            COUNTER := 1;
            SUM := 0.0;
            FOR I := 1 TO 91 DO
            BEGIN
                FOR J := 1 TO 180 DO
                BEGIN
                     READ(IN_FILE,SST);
                     SUM := SUM + SST;
```

```
        END;
        AVG := SUM / 180.0;
        WRITELN (OUT_FILE,I,' ',AVG);
        WRITELN ('*******',I);
    END;
    FOR I := 1 TO 206 DO
    begin
         READLN(IN_FILE,iflag);
         WRITELN(iflag);
    end;
  end;
   CLOSE(IN_FILE);
END.
```

Appendix B. Averaged Sea-Surface Temperatures (SSTs) for the El Nino Box. (0-10S by 80-90W) (^{o} C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1950	21.4	21.5	21.6	21.7	21.8	21.9
1951	22.6	22.5	22.7	22.4	22.3	22.4
1952	25.1	24.8	23.6	23.1	22.4	22.1
1953	22.8	22.9	22.7	22.6	22.5	22.6
1954	23.9	23.2	23.1	22.7	22.0	21.5
1955	21.6	22.0	21.9	21.8	21.6	21.5
1956	22.6	22.4	22.1	22.0	21.8	21.7
1957	22.4	22.1	22.0	21.8	21.6	21.5
1958	24.6	24.0	22.0	21.5	21.0	20.8
1959	21.5	21.3	21.0	20.9	20.8	20.7
1960	22.3	22.1	22.0	21.8	21.7	21.5
1961	21.9	21.8	21.6	21.4	21.2	21.0
1962	21.7	21.5	21.4	21.2	21.0	20.9
1963	22.1	22.0	21.9	21.7	21.5	21.4
1964	22.9	22.7	22.5	22.1	21.8	21.7
1965	22.8	22.7	22.5	22.4	22.3	22.1
1966	24.3	24.0	23.8	23.5	23.3	23.0
1967	22.6	22.1	21.5	21.0	20.8	20.6
1968	21.9	21.7	21.6	21.4	21.3	21.0
1969	22.4	22.2	22.0	21.8	21.5	21.4
1970	23.6	23.0	22.6	22.3	22.0	21.7
1971	22.3	22.2	22.1	22.0	21.8	21.6
1972	22.3	22.2	22.1	22.0	21.8	21.9
1973	24.5	24.0	23.5	23.0	22.0	21.0
1974	22.1	22.0	21.7	21.5	21.3	21.1
1975	21.5	21.3	21.2	21.1	21.0	20.9
1976	21.9	21.4	21.2	21.0	20.8	20.6
1977	24.9	24.2	23.6	22.7	22.0	21.5
1978	22.6	22.5	22.4	22.3	22.0	21.7
1979	22.4	22.2	22.0	21.9	21.5	21.4
1980	21.9	21.8	21.7	21.6	21.4	21.3
1981	22.8	22.5	22.3	22.0	21.5	21.2
1982	23.0	23.4	23.7	23.9	24.1	24.2
1983	25.4	24.8	24.0	24.6	24.9	25.1
1984	26.3	25.3	24.5	23.0	22.4	22.1
1985	21.8	21.4	21.2	21.1	21.0	20.9
1986	22.6	22.3	22.0	21.7	21.3	21.0
1987	23.5	23.3	23.0	22.5	22.0	21.8

YEAR	JUL	AUG	SEP	OCT	NOV	DEC
1950	22.2	22.2	22.4	22.4	22.5	22.6
1951	22.4	22.6	22.7	22.9	23.5	24.1
1952	22.0	21.6	21.8	22.1	22.3	22.4
1953	22.8	23.0	23.1	23.2	23.4	23.9
1954	21.0	20.8	20.6	20.7	21.0	21.4
1955	21.5	21.7	21.9	22.2	22.4	22.5
1956	21.8	21.9	22.0	22.2	22.3	22.3
1957	21.5	21.8	22.0	22.5	22.8	24.0
1958	20.6	20.7	20.9	21.0	21.4	21.6
1959	20.6	20.8	21.2	21.3	22.0	22.1
1960	21.3	21.5	21.6	21.7	21.8	22.0
1961	20.9	21.0	21.3	21.4	21.5	21.7
1962	21.0	21.1	21.3	21.4	21.7	22.0
1963	21.3	21.6	21.8	22.0	22.5	22.8
1964	21.5	21.7	22.0	22.2	22.4	22.8
1965	22.2	22.5	22.7	23.0	23.5	23.9
1966	22.4	22.0	22.1	22.4	22.5	22.5
1967	20.9	21.2	21.4	21.6	21.9	22.0
1968	20.7	21.0	21.5	21.6	21.9	22.5
1969	21.3	21.2	21.2	21.8	22.6	23.9
1970	21.4	21.8	21.9	22.0	22.1	22.4
1971	21.8	21.9	22.0	22.2	22.3	22.4
1972	22.0	23.0	23.5	24.0	24.5	25.0
1973	20.3	21.0	21.3	21.7	22.0	22.2
1974	21.0	21.4	21.5	21.5	21.6	21.6
1975	20.9	21.0	21.2	21.3	21.8	22.0
1976	21.0	21.5	22.0	22.5	23.5	24.5
1977	21.0	20.9	21.0	21.8	22.6	22.7
1978	22.0	22.4	22.5	22.6	22.6	22.5
1979	21.3	21.0	21.2	21.4	21.7	21.9
1980	21.0	21.2	21.5	21.8	22.0	22.8
1981	21.4	21.7	22.0	22.2	22.5	22.7
1982	24.4	24.7	24.9	25.2	25.3	25.5
1983	25.3	25.4	25.8	26.2	26.3	26.4
1984	21.6	21.3	21.0	21.0	21.4	21.5
1985	20.8	20.9	21.2	21.6	21.9	22.4
1986	21.0	21.4	21.9	22.4	22.9	23.0
1987	21.5	21.4	21.9	22.3	22.6	22.7

Appendix C. FORTRAN Program Used to Average Weather Data:

Daily values of precipitation and maximum and minimum temperatures from all reporting stations within a state, are read from a data file and averaged to get one daily value for the state. They were later averaged together to obtain a yearly value.

```
      program average
      include 'avg.common/nolist'

      fcount = 0
      scount = 0              ! increment when year 1950 is found
      call open_files
      do while(.true.)
          call get_header
          if(year .eq. 1950) scount = scount + 1
          call get_month_data
          call process_month_data
      end do
      end

C ------------------------------------------------------------------------
      subroutine process_month_data
      include 'avg.common/nolist'
      integer count

      do count = 1,days
        if( dat(count) .lt. 10000 ) then
            account(count,year-1949)=
     2      account(count,year-1949)+dat(count)
            goodones(count,year-1949) = goodones(count,year-1949) + 1
        end if
      end do
      end
C ------------------------------------------------------------------------
      subroutine get_header
      include 'avg.common/nolist'
   50 read (unit=infile,err=100,end=200,fmt=1000) station,year,days
      if(year .eq. 0) then ! if TRUE probably just blank line
        read (unit=infile,err=100,end=200,fmt=1000) station,year,days
      end if
      return
  100 write(*,fmt='(a27)') 'Error reading input file...'
      stop
  200 call open_next_file
      goto 50
 1000 format(x,t9,[illegible]
      end
C ------------------------------------------------------------------------
      subroutine get_month_data
      include 'avg.common/nolist'
      mondat(1:1) = '1' ! put in the missing 1
   50 read(unit=infile,
     1    err=100,end=200,fmt=1000)(mondat(80*(i-1)+2:80*i+1),i=1,5)
      read(mondat,fmt=1001) (dat(i),i=1,days)
      return
  100 write(*,fmt='(a27)') 'Error reading input file...'
      stop
  200 call open_next_file
      goto 50
 1000 format(4(x,a80/),x,a80)
 1001 format(<days>(6x,i5,x))
      end
```

```
C ------------------------------------------------------------------
      subroutine open_next_file
      include 'avg.common/nolist'
C     are we already in second file? if so.. go do averages
      if(fcount .eq. 1) then
          call do_averages
          stop
      end if
      fcount = 1
      close(infile)

      if(file2 .eq. ' ') call do_averages

      open (
     1 unit=infile, file = file2, access = 'sequential',
     1   organization = 'sequential', err = 1000, status = 'old',
     1   readonly)
      return
 1000 write(*,fmt='(a22)') ' Error opening file...'
      stop
      end
C ------------------------------------------------------------------
      subroutine open_files
      integer stat,context
      include 'avg.common/nolist'
      call lib$get_lun (infile)
      call lib$get_lun (outfile)
      write(*,fmt='(a32)') ' Enter input name (no extention)'
      read(*,fmt='(a15)')file1

      context = 0
      file2 = file1
      file3 = file1
      call      str$trim(file1,file1,l)
      file1(l+1:l+5) = '.1out'
      file2(l+1:l+5) = '.2out'
      file3(l+1:l+5) = '.avg'

      file1 = 'GPXA::DUB6:[DEMOYS2]'//file1
      file2 = 'GPXA::DUB6:[DEMOYS2]'//file2
      file3 = 'GPXA::DUB6:[DEMOYS2]'//file3

      stat = lib$find_file (file1,file1,context)
      if(.not. stat) then
        write(*,fmt='(a18,a50)') ' file not found - ',file1
        stop
      end if

      stat = lib$find_file(file2,file2,context)
      if(.not. stat) then
        file2 = ' '
      end if
```

```
      write(*,fmt='(a15/,2(x,a50/))') ' input file(s):',file1,file2
      write(*,fmt='(a13/,x,a50/)') ' output file:',file3

      open ( unit=infile, file = file1, access = 'sequential',
     1   organization = 'sequential',  status = 'old',
     1   readonly,err = 1000)

      open ( unit=outfile, file = file3, access = 'sequential',
     1   organization = 'sequential',  status = 'new',
     1   err = 1000,recl = 350, carriagecontrol = 'list')
      return

C     error opening some file..  give error and exit
 1000 write(*,fmt='(a22)') ' Error opening file...'
      stop
      end

C ----------------------------------------------------------------
      subroutine do_averages
      include 'avg.common/nolist'

      integer dy,yr,montest

      real count,total(38)

      write(outfile,fmt='(a10,i3,x,a8)')
     1    'processed ',scount,'stations'
      close(infile)

      do i=1,38
        montest = montest + goodones(31,i)
      end do

      if( montest .eq. 0) days = 30  ! change to 30 day month if so

      do yr = 1,38
         do dy = 1,days
            if( goodones(dy,yr) .ne. 0) then
               account(dy,yr) = account(dy,yr)/goodones(dy,yr)
            else
               account(dy,yr) = 0
            end if
            total(yr) = total(yr) + account(dy,yr)
         enddo
      enddo

      write(outfile,fmt=1002) (yr+1949,yr=1,38)
      do dy = 1,days
         write(outfile,fmt=1000) (account(dy,yr),yr=1,38)
      end do
      write(outfile,fmt=1001) (total(yr),yr=1,38)

      close(outfile)
      stop

1000  format(x,38(f7.2,x))
1001  format(//x,38(f7.2,x)///)
1002  format(x,38(i7,x))
      end
```

Appendix D. Sample of Averaged Climatological Values.

PROCESSED 133 STATIONS
IOWA TEMPERATURE MAXIMUMS MAY

	YEAR						
DAY	1950	1951	1952	1953	1954	1955	1956
1	54.62	77.41	85.25	56.27	55.54	80.9	47.96
2	61.39	78.74	85.52	50.06	50.62	85.88	60.35
3	67.6	75.53	86.16	52.41	42.5	83.17	58.51
4	81.55	66.05	89.75	65.54	52.57	76.48	56.47
5	75	60.24	83.43	63.84	59.07	74.02	64.57
6	68.1	57.1	73.28	65.34	62.44	85.73	64.35
7	62.9	67.53	66.43	72.79	54.92	75.07	66.38
8	58.5	73.12	56.91	78.17	54.94	64.42	65.92
9	61.46	68.8	55.59	80.13	58.96	61.8	80.51
10	63.56	59.02	54.42	79.03	66.62	68.58	76.18
11	71.88	66.64	52.99	73.22	69.33	72.87	82.32
12	75.96	73.81	54.08	63.34	69.61	68	88.58
13	76.95	76.3	72.2	52.64	72.18	73.5	86.44
14	79.45	74.89	74.8	61.54	76.41	78.08	70.15
15	74.52	80.93	68.62	73.1	83.36	78.13	66.52
16	68.48	77.25	60.91	70.02	77.87	80.83	74.52
17	76.83	75.48	64.3	67.8	70.4	75.21	74.79
18	74.3	81.16	64.7	70.1	67.91	79.77	87.2
19	69.72	76.77	66.05	76.32	64.98	85.11	76.5
20	72.09	79.76	69.9	78.34	70.06	86.49	82.46
21	67.92	73.46	67.7	71.69	73.86	85.2	83.76
22	79.7	70	67.53	65.56	79.73	81.94	87.02
23	85.92	74.98	73.94	68.14	82.73	85.35	73.42
24	85.05	78.05	71.86	73.41	72.51	75.81	76.08
25	70.46	76.1	78.23	88.23	72.04	71.1	75.86
26	66.92	69.09	81.52	80.52	66.81	73.61	79.32
27	63.98	69.76	74.87	69.24	76.54	73.81	86.33
28	68.78	76.92	63.84	75.8	72.57	69.06	84.12
29	73.47	79.97	68.05	89.22	67.48	65.81	82.88
30	77.33	81.57	73.79	90.19	74.44	73.88	81.35
31	72.63	79.5	72.49	84.49	75.52	76	73.32
AVERAGE BY YEAR	71.19419	73.41709	70.61645	71.17709	67.56516	76.31	74.64967

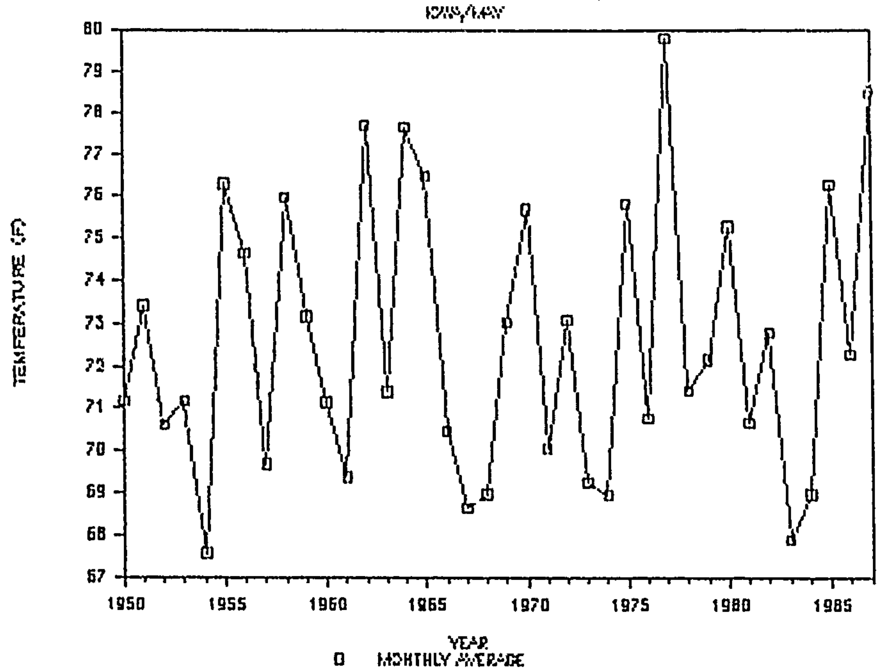
1957	1958	1959	1960	1961	1962	1963	1964
82.52	70.36	85.52	67.41	56.48	68.52	63.98	58.1
77.32	68.7	86.82	74.88	59.3	74.48	66.38	74.29
66.02	71.36	84.76	77.29	62.52	81.62	74.1	78.53
62.02	63.72	85.95	75.01	61.62	84.83	73.95	80.54
69.08	62.12	80.48	69.05	57.36	86.55	68.89	79.84
76.41	65.98	71.33	63.43	68.19	74.78	74.48	77.93
79.99	63.59	61.64	53.78	70.07	73.58	82.55	82.01
81.87	72.66	67.76	57.2	62.74	69.33	88.03	79.27
74.47	76.23	65.32	58.65	59.12	60.19	87.4	70.84
61.39	81.64	75.71	61.1	75.17	67.83	81.45	76.69
60.48	86.37	72.53	64.09	81.27	72.27	61.06	75.37
68.9	83.91	70.78	70.26	84.35	83.24	62.74	68.68
65.98	83.64	62.31	75.96	82.24	86.07	72.05	65.29
68.27	81.76	53.88	81.42	78	85.31	71.2	73.75
61.61	79.02	58.12	82.1	67.43	86.58	67.74	82.37
52.23	78.8	69.2	74.74	65.99	86.52	66.81	83.74
65.52	77.34	69.25	70.88	60.02	86.34	75.19	85.22
58.63	74.47	69.8	67.2	55.81	87.03	72.49	88.2
54.06	74.86	81.62	75.98	60.28	83.48	66.8	85.39
57.91	75.1	80.74	73.47	65.54	81.56	70.58	82.47
76.67	78.79	75.21	67.7	73.26	80.76	59.27	88.67
70.13	75.02	61.81	75.39	70.25	84.04	58.09	89.41
67.71	71.26	64.37	78.99	74.33	73.18	67.15	87.02
75.07	81.25	71.89	77.84	76.43	76.48	69.23	81.42
75.37	80.17	76.04	73.67	71.98	74.41	67.52	83.35
67.68	80.97	80.59	68.72	62.94	70.1	69.49	79.99
70.31	79.91	78.21	66.95	73.06	69.13	70.34	72.44
78.09	74.1	78.61	70.62	77.99	71.45	67.08	67.9
79.8	82.81	77.03	72.29	77.1	75.28	75.98	69.61
75.95	80.35	77.13	78.2	74.37	78.84	81.33	69.71
78.69	78.81	74.13	81.26	85.88	75.22	80.23	69.33
69.68225	75.97	73.17870	71.14612	69.39	77.70967	71.40580	77.65709

1965	1966	1967	1968	1969	1970	1971	1972
85.98	54.26	67.98	82.4	71.86	54.34	61.66	63.13
86.47	67.36	51.87	86.5	78.1	60.13	57.03	59.35
80.61	64.63	48.74	80.57	80.24	75.4	64.13	63.52
80.25	78.55	52.26	65.65	80.02	74.22	70.42	64.13
80.05	86.45	52.02	61.61	78.94	70.42	71.42	66.21
81.73	81.84	55.68	64.53	76.6	68.47	67.57	64.11
83.61	83.62	68.09	62.73	73.68	81.93	63.25	53.94
78.69	74.1	65.17	70.95	65.31	83.98	68.56	57.28
75.7	51.31	68.95	66.24	62.44	79.21	72.78	62.95
68.05	51.83	70.6	66.51	59.8	76.74	72.08	65.43
71.56	47.23	63.11	66.54	58.76	77.68	69.67	67.86
82.68	44.81	54.35	71.07	66.51	76.45	63.2	72.26
84.05	50.56	61.19	75.82	73.97	71.42	76.72	68.67
79.18	65.3	62.02	80.87	76.73	62.26	83.04	65.71
76.73	67.77	63.74	82.87	80.89	58.73	83.63	73.43
69.06	75.66	69.81	69.73	80.84	64.25	82.5	81.37
80.16	75.36	75.85	63.87	68.76	74.6	81.81	84.14
77.1	70.05	88.4	60.25	59.42	84.7	75.42	84.23
73.22	69.8	76.88	60.15	64.25	85.29	63.81	85.77
78.28	69.08	68.32	61.98	65.93	86.89	67.54	86.8
80.59	74.61	72.4	67.69	61.86	88.56	69.91	87.7
74.61	80.11	75.12	65.56	56.07	87.72	67.65	88.35
74.58	76.47	84.99	66.31	63.39	79.88	68.66	85.87
80.9	74.98	87.71	67.84	74.55	81.59	66.91	77.66
82.32	81.1	94.27	64.92	76.38	76.31	56	80.84
74.08	87.33	93.26	57.23	81.37	72.66	57.62	83.89
61.6	85.93	84.92	63.69	87.04	76.58	65.05	82.9
56.49	78.45	70.33	71.85	88.51	78.89	71.06	79.01
61.44	71.62	59.2	68.61	86.03	79.05	75.92	73.8
68.75	71.64	57.43	72.67	84.78	79.09	77.17	66.63
82.8	73.21	63.14	70.84	81.65	79.27	79.94	68.57
76.49419	70.48451	68.63870	68.96935	73.05419	75.70032	70.06870	73.08096

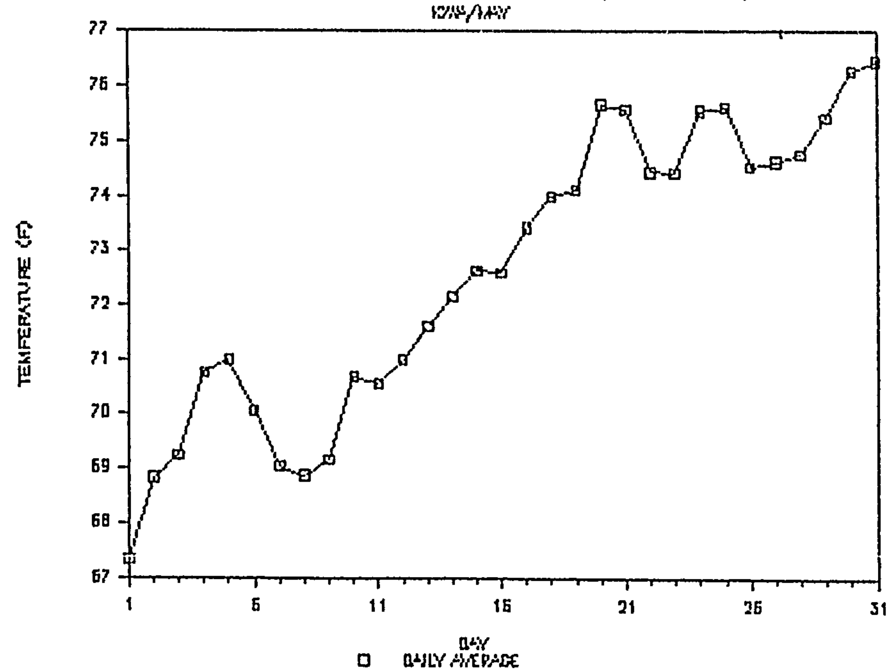
1973	1974	1975	1976	1977	1978	1979	1980
62.49	72.72	64.71	64.63	75.39	59.39	58.88	74.94
56.46	74.47	68.75	60.32	76.4	61.07	59.39	79.67
58.88	71.36	66.86	53.44	72.63	63.6	55.09	82.51
66.81	67.03	72.84	67.36	70.68	60.85	59.95	85.3
67.19	69.18	80.46	72.75	75.76	56.6	69.29	85.09
63.32	65.5	78.15	65.33	74.33	57.44	77.64	78.09
60.66	60.34	69.75	60.92	72.77	54.16	78.31	66.88
72.12	51.74	66.96	69.77	75.61	57.31	78.03	59.59
75.04	54.43	70.74	73.81	73.19	62.4	77.55	68.84
72.11	59.48	75.63	77.86	70.37	76.6	75.49	73.6
69.05	65.24	72.27	76.17	74.24	78.45	62.82	68.24
63.95	64.07	67.87	72.79	79.55	73.77	61.78	67.46
64.08	63.25	70.91	65.89	83.04	66.39	69.29	64.56
61.31	62.96	73.94	67.02	85.3	67.97	69.04	67.16
68.82	62.32	70.9	70.51	85.63	68.13	70.26	70.47
68.31	70.67	74.23	65.96	85.29	67.6	73.96	67.03
67.92	69.85	80.39	64.74	83.93	70.06	83.44	59.25
79	69.1	85.8	69.66	86.8	76.47	82.16	59.61
78.91	67.69	89.82	78.51	86.17	81.85	72.12	67.2
79.45	80	89.94	83.96	81.4	78.74	70.46	73.38
81.02	83.06	85.9	83.01	77.08	72.62	66.73	79.36
77.75	77.88	87.21	76.44	75.11	71.59	74.94	82.65
77.31	73.43	86.95	63.48	80	71.77	73.19	80.92
76	68.4	83.47	66.81	85.16	79.69	67.65	81.27
67.68	68.2	80.31	71.31	86.85	87.68	71.92	85.96
66.43	66.77	75.92	73.88	87.51	89	72.46	85.56
60.95	68.98	76.72	76.54	85.77	86.1	75.12	87.52
65.31	77.25	74.79	78.23	84.65	81.39	81.76	87.73
67.29	80.61	70.82	75.23	83.36	78.08	86.3	86.48
72.49	77.92	67.79	72.42	81.94	78.73	85.9	81.79
78.51	73.36	69.52	75.15	78.64	79.18	75.82	75.85
69.24580	68.94387	75.81677	70.77096	79.82419	71.44129	72.15290	75.28903

1981	1982	1983	1984	1985	1986	1987	AVERAGE BY DAY
65.35	71.36	62.26	56.71	70.61	65.2	81.66	67.33552
71.63	74.95	55.17	60.76	72.12	61.39	81.6	68.83394
76.88	79.83	61.39	57.85	75.89	65.24	69.95	69.24526
70.97	83.66	63.52	57.53	78.44	77.02	65.59	70.76578
65.3	78.35	68.88	64.07	76.09	80.76	67.61	71.00105
62.78	62.07	75.54	64.76	72.61	78.85	76.18	70.05236
63.26	67.32	71.17	59.81	76.46	78.55	78.84	69.03368
62.47	73.32	59.71	54.29	80.62	80.26	80.27	68.86710
62.55	77.68	64.46	62.17	83.81	77.9	84.98	69.17368
59.04	80.92	71.46	71.28	82.39	72.59	87.53	70.67842
64.66	79.2	75.73	73.52	78.58	72.34	86	70.56868
62.93	76.18	74.61	72.96	73.72	78.23	80.22	70.99105
60.25	72.38	71	74.61	68.97	75.63	84.56	71.60421
65.68	71.63	62.89	72.72	70.24	75.54	84.53	72.15657
74.03	72.47	61.28	70.29	64.42	72.48	79.85	72.62631
74.92	76.43	66.99	73.08	60.82	67.8	84.36	72.59421
69.13	76.31	64.22	81.26	67.46	64.28	88.54	73.41842
60.24	76.82	58.43	81.75	76.68	63.86	86.75	73.98605
69.21	80.03	60.11	75.87	81.16	66.75	83.21	74.09736
75.97	78.01	65.84	77.56	77.29	68.12	84.07	75.67052
78.35	66.03	68.1	79.26	72.26	70.48	81	75.56578
77.84	57.86	70.76	75.87	74.51	71.32	65.91	74.43289
76.22	61.06	72.19	72.21	76.91	70.21	63.25	74.41421
72.16	64.63	79.27	76.77	79.61	72.1	63.61	75.55578
72.68	64.78	73.65	72.72	84.27	71.15	67.31	75.60894
75.15	67.35	70.17	64.56	87.85	67.86	76.32	74.53947
78.35	71.93	77.75	61.77	80.87	66.69	77.76	74.61605
80.52	74.14	78.81	59.88	75.12	70.66	78.59	74.74605
81.98	74.88	70.36	64.37	80.07	73.98	79.83	75.42342
79.74	75.39	62.48	70.38	84.08	79.2	81.53	76.27289
80.94	69.19	66.1	77.52	80.64	84.76	82.88	76.44684
							ERR
70.68322	72.77935	67.88064	68.97290	76.27645	72.29677	78.52548	72.59105

TEMPERATURE MAXIMUMS (AVERAGE)



TEMPERATURE MAXIMUMS (AVERAGE)



PROCESSED 133 STATIONS
IOWA TEMPERATURE MINIMUMS MAY

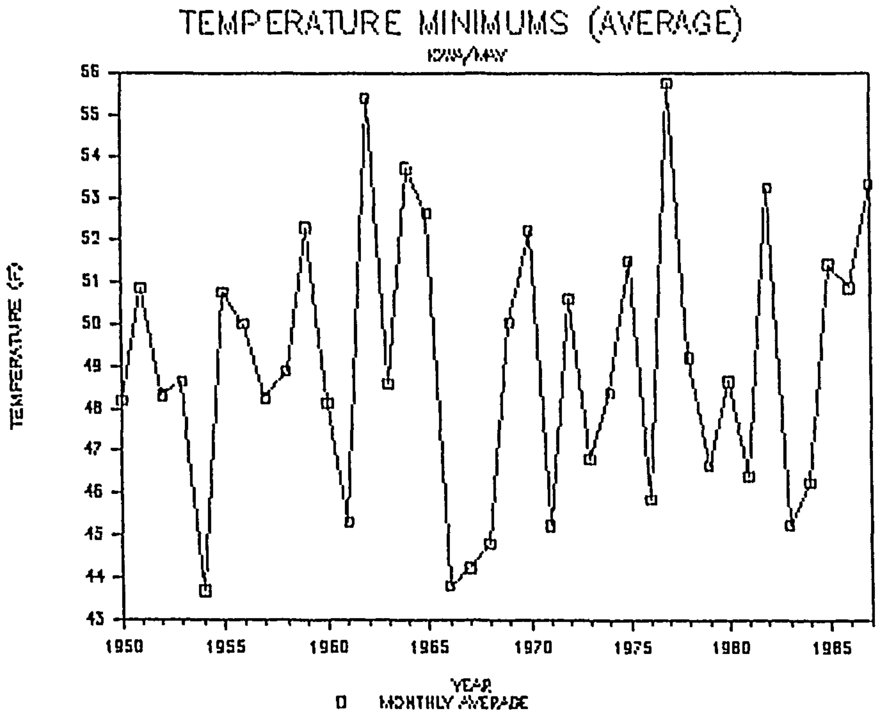
DAY	YEAR 1950	1951	1952	1953	1954	1955	1956
1	28.96	58.09	56.13	43.97	41.14	53.79	37.84
2	37.86	53.54	55.55	41.78	38.06	62.96	40.41
3	48.24	51.73	55.71	40.95	29.47	63.16	39.88
4	56.97	48.05	58.6	39.55	29.02	52.11	34.45
5	43.86	40.24	58.65	45.38	30.6	47.24	44.83
6	42.28	37.77	47.43	45.36	35.57	50.88	46.71
7	38.03	37.64	49.5	42.46	29.45	51.46	40.69
8	39.67	43.18	44.34	45.91	32.99	34.55	41.79
9	44.72	51.91	46.38	52.58	34.02	45.97	55.17
10	41.85	42.17	41.09	56.43	37.98	46.26	55.47
11	42.57	36.29	35.73	45.64	38.54	43.81	56.94
12	48.86	41.37	38.7	38.2	41.42	46.42	61.35
13	50.02	46.7	39.34	32.01	42.76	48.27	55.91
14	49.99	53.57	51.09	38.57	45.39	47.91	44.62
15	46.19	57.54	45.1	43.2	52.56	46.63	47.44
16	49.38	61.75	47.43	48.2	54.69	47.31	34.62
17	44.11	59.88	45.87	50.8	43.84	48.21	48.27
18	50.37	59.77	42.42	47.85	43.12	46.76	44.66
19	51.93	58.66	41.34	41.84	39.66	51.66	46.34
20	48.96	55.82	43.32	55.15	35.89	54.39	51.31
21	51.78	55.27	50.03	47.85	48.52	55.48	57.43
22	47.85	52.36	54.22	47.3	56.47	58.91	58.16
23	59.12	45.44	53.32	47.74	58.02	60.71	47.8
24	62.06	50.7	55.03	52.22	54.74	52.04	47.8
25	54.61	55.87	52.45	66.29	44.18	49.03	49.03
26	51.12	50.22	50.74	57.24	51.27	54.21	57.41
27	50.67	50.27	53.27	52.3	54.76	57.71	61.36
28	51.33	48.2	42.33	53.4	53.46	52.4	63.08
29	54.6	57.04	37.45	63.47	46.52	50.31	63.84
30	57.39	55.22	54.27	69.18	49.14	43.39	63.29
31	48.8	60.71	50.92	55.01	60.27	49.82	52.09
AVERAGE BY YEAR	48.19838	50.87	48.31451	48.63967	43.66193	50.76645	49.99967

1957	1958	1959	1960	1961	1962	1963	1964
51.53	40.88	52.68	32.62	31.34	46.15	31.7	43.91
52.45	47.17	63.06	45.02	28.74	40.7	48.08	47.5
43.49	52.73	61.53	48.93	35.8	45.95	47.7	56.89
32.39	44.13	63.85	54.2	39.06	50.25	54.32	57.64
34.49	34.33	60.96	52.46	44.41	61.55	47.98	60.34
38.57	39.75	48.47	42.32	48.61	49.6	48.83	61.11
48.4	38.48	40.04	35.76	45.12	44.07	55.84	50.85
56.29	39.7	43.53	33.47	46.48	47.41	66.04	56.48
53.22	41.4	49.87	36.71	36.78	43.92	64.26	49.38
46.28	50.14	54.47	36.28	38.56	50.17	52.34	46
43.55	53.37	43.53	36.3	52.83	50.12	44.25	53.88
50.54	54.08	50.38	34.85	53.98	58.16	46.54	48.61
54.95	52.93	44.15	42.09	60.15	66.63	51.02	44.77
54.79	57.9	37.27	48.88	58.52	64.9	47.7	43.33
46.43	56.06	35.12	53.64	47.18	65.84	49.36	53.33
40.85	56.23	39.03	55.73	38.36	66.37	49.01	58.29
45.53	58.93	45.88	48.71	48.05	65.45	53.28	58.46
45.2	52.94	54.27	51.58	45.56	64.02	49.1	63.29
44.69	44.71	56.14	57.26	46.17	61.05	47.82	61.98
44.71	40.94	62.73	55.95	49.75	55.41	38.86	51.2
52.47	44.78	57.05	50.83	45.28	58.67	38.07	56.72
48.84	56.66	50.61	50.7	44.55	61.74	30.81	64.43
44.78	40.35	47.6	53.45	39.43	55.92	32.33	66.71
45.02	49.78	45.33	58.28	44.11	51.54	41.69	57.4
58.53	47.07	58.11	56.21	52.55	54.51	46.66	50.88
51.23	55.83	63.66	54.95	35.34	53.68	52.83	60.99
44.29	54.63	54.26	52.23	39.4	54.03	57.3	51.82
48.52	40.7	59.42	51.91	50.59	58.4	53.9	48.68
56.73	48.4	57.91	56.35	50.59	59.52	48.01	46.7
58.55	59.47	60.72	49.94	48.56	57.41	52.31	48.16
59.03	61.17	59.66	54.26	58.38	54.98	58.41	45.49
48.26903	48.89161	52.29967	48.12483	45.29774	55.42322	48.59193	53.71677

1965	1966	1967	1968	1969	1970	1971	1972
54.72	29.11	38.32	48.98	49.82	37.93	36.07	49.33
57.47	33.71	28.94	51.87	55.33	29.7	34.24	42.62
57.88	35.71	28.64	51.85	55.1	41.06	31.14	41.73
56.88	38.78	32.86	41.35	54.64	45.69	42.36	42.45
58.33	57.85	38.83	32.4	54.87	47.36	47.11	41.51
61.5	49.78	33.[illegible]	43.18	59.23	39.47	47.88	48.06
62.89	49.49	35.76	49.28	51.6	49.47	45.5	42.7
59.63	43.13	43.89	43.99	47.29	57.29	40.81	41.33
56.86	29.58	35.59	41.8	40.16	55.85	40.78	39.49
43.36	29.61	49.82	36.25	37.1	47.09	50.3	40.64
41.94	34.25	42.32	42.13	36.85	55.08	50.44	47.03
46.22	36.83	38.83	38.06	33.33	59.64	34.45	50.1
51.47	37.99	38.58	49.93	46.84	55.1	38.83	51.39
57.22	35.76	44.53	55.42	50.27	49.95	46.35	49.93
59.25	50.3	38.39	53.87	54.09	45.24	53.22	46.05
53.05	41.71	39.8	43.74	57.69	41.15	49.3	51.7
47.83	52.83	43.71	38.07	47.17	43.2	58.3	55.94
54.97	46.6	54.71	39.45	45.24	55.43	55.91	56.27
42.52	44.49	47.85	39.06	45.54	59.43	45.1	56.48
52.25	44.34	38.95	39.65	44.58	60.18	41.71	56.67
60.78	46.58	42.88	39.62	43.3	66.23	47.69	58.19
54.83	52.23	40.02	43.96	41.15	63.46	50.83	60.76
53.14	54.16	54.94	46.07	42.54	60.6	53.65	59.34
59.31	44.26	53.5	42.72	45.38	60.03	51.39	58.12
61.94	47.22	61.39	48.65	50.55	54.42	44.75	55.66
55.48	54.29	65.25	48.81	54	44.28	38.87	59.73
41.02	59.8	59.84	45.1	62.9	50.93	36.79	59.35
37.12	48.53	51.38	45.1	64.79	56.79	39.64	61.6
37.83	43.89	49.45	48.59	64.28	61.95	44.63	57.88
42.47	42.9	49.13	45.98	56.08	61.95	49.1	47.9
51.42	42.2	49.22	53.64	59.93	63.32	55.14	39.3
52.63161	43.80354	44.23032	44.79258	50.05290	52.23451	45.23483	50.62096

1973	1974	1975	1976	1977	1978	1979	1980
49.31	40.96	35.66	38.15	52.82	33.21	33.56	43.41
38.61	48.85	45.28	35.7	50.98	30.57	45.56	45.65
34.42	38.83	47.76	29.87	53.53	34.41	37.08	47.75
35.74	41.17	43.13	34.73	56.74	42.87	35.19	47.58
48.07	45.09	50.61	52.56	52.54	38.94	41.85	52.63
52.04	34.16	51.76	37.95	53.62	35.2	48.96	42.98
52.75	40.01	50.91	32.38	48.91	43.4	55.58	35.14
50.01	41.16	49.36	33.94	50.23	45.06	56.98	32.88
53.38	41.02	47.87	44.5	41.47	43.6	53.07	32.21
49.18	41.98	47	47.44	40.19	40.22	50.9	48.55
45.76	48.39	51.82	43.27	45.24	56.59	38.88	40.36
41.87	44.25	45.78	47.41	48.14	51.11	34.5	41.77
38.02	41.79	43.32	47.36	51.63	45.11	41.55	44.48
36.36	46.74	51.02	45.88	56.59	43.21	46.12	37.46
33.9	40.49	42.34	49.29	61.96	44.32	40.38	44.11
44.86	50.39	41.95	51.67	61.74	47.57	46.55	47.85
35.42	53.63	48.07	43.06	61.69	49.79	58.52	49.05
47.61	54.56	55.62	39.17	62.8	49.18	58.41	50.66
51.32	53.96	63.94	47.38	62.4	56.31	48.36	49.19
47.65	59.53	67.92	57.35	60.07	53.62	49.95	47.69
58.38	64.47	62.23	58.75	58.07	45.91	38.98	48.39
58.16	56.08	62.39	54.04	58.19	49.74	46.66	50.85
47.65	48.57	64.81	49.44	55.67	55.95	47.54	53.64
53.09	44.66	57.46	43.98	59.42	57.78	39.6	56.95
48.86	45.78	59.66	43.12	61.77	64	40.17	57.77
48.25	51.16	55.28	46.29	63.11	66.18	48.58	61.34
52.65	51.49	46.08	51.08	61.69	[illegible]4.75	46.11	60.39
51.23	59.2	54.12	52.19	59.93	[illegible].55	48.27	61.13
49.06	61.67	57.87	54.84	60.39	60.07	57.6	64.2
46.48	58.16	51.9	55.17	59.33	56.27	58.4	59.11
51.39	51.48	43.96	54.13	58.12	58.17	52.64	53.84
46.82193	48.37677	51.51225	45.87387	55.77354	49.21483	46.66129	48.67774

1981	1982	1983	1984	1985	1986	1987	AVERAGE BY DAY
41.32	40.88	44.59	33.79	51.16	43.49	45.22	42.69842
39.55	42.71	42.32	40.95	41.92	35.46	53.68	44.06710
51.87	49.45	41.39	41.73	43.65	41.52	50.77	44.98157
55.51	58	41.65	38.22	51.98	51.61	45.07	46.02078
47.8	54.22	41.13	39.14	56.04	58.67	41.99	47.54894
40.44	44.94	51.99	45.91	48.81	52.22	42.97	46.05605
35.13	40.08	46.26	43.21	48.74	49.06	44.96	44.76315
44.65	46.21	34.17	34.53	47.26	56.87	44.82	45.19263
44.85	53.19	37.57	37.21	54.59	56.41	53.46	45.81052
32.83	58.55	43.86	43.97	59.09	57.48	60.72	46.09526
32.3	58.6	49.06	50.09	59.7	56.61	61.96	46.47421
38.7	58.69	54.09	44.76	54.32	56.02	47.75	46.31789
44.3	59.74	48.9	52.1	46.53	53.63	48.66	47.60394
42.96	58.64	41.89	43.7	51.5	48.31	59.77	48.52657
40.95	54.62	35.18	47.29	49.46	55.16	48.84	48.27157
47.22	55.25	40.27	48.13	49.66	50.69	51.15	48.95631
50.5	58.17	44.01	52.87	46.63	49.23	56.46	50.24789
44.78	55.05	47.84	59.02	46.05	44.41	60.63	51.19157
39.51	56.54	49.81	59.11	51.62	43.98	58.24	50.61552
39.2	57.44	45.86	53.97	51.9	43.46	62.25	50.54157
44.75	45.87	47.49	55.31	43.91	42.41	58.49	51.28710
55.23	48.67	51.87	56.27	46.35	44.58	44.18	51.95026
58.28	50.32	42.6	46.63	50.61	48.54	44.43	51.10105
49.63	51.61	49.29	53.47	51.83	50.28	48.58	51.31789
49.14	55.05	47.33	49.85	53.7	51.7	51.69	52.63552
52.2	56.31	41.17	42.51	61	51.76	57.98	53.27763
53.98	56.01	51.21	47.2	55.44	56.13	62.59	53.17973
58.08	55.72	54.24	44	51.38	56.56	62.52	52.95763
59.11	60.31	47.43	39.12	54.08	58.31	63.71	54.045
54.11	56.55	42.98	42.14	59.69	54.63	60.98	53.64236
49.79	53.44	45.19	·8.48	56.23	58.46	59.24	53.62447
							ERR
46.40870	53.25258	45.24645	46.28	51.44612	50.89193	53.34709	49.06452


TEMPERATURE MINIMUMS (AVERAGE)
IOWA/MAY
TEMPERATURE (F)
56
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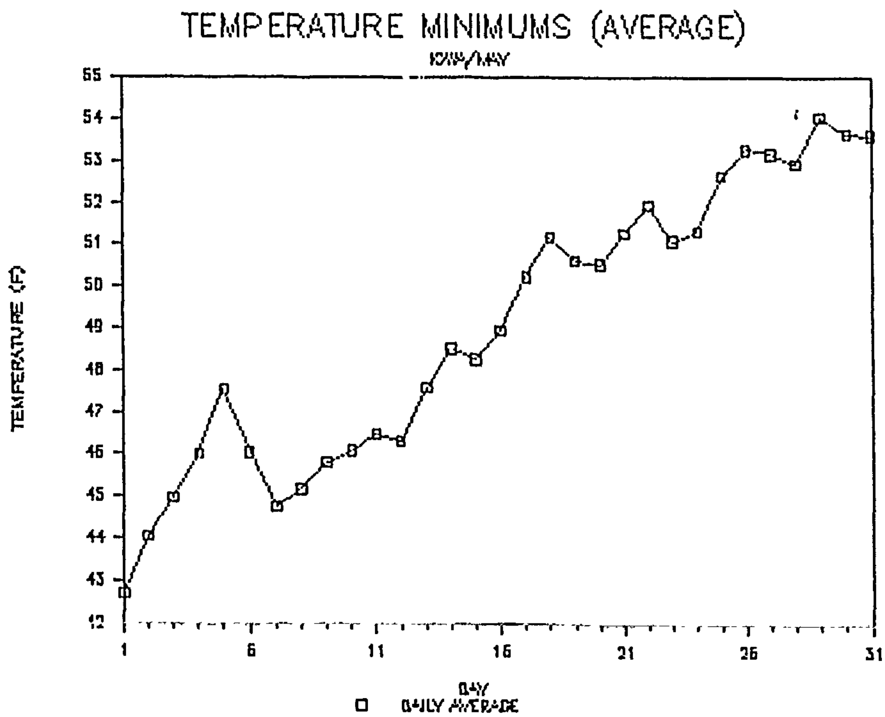
46
45
44
43
1950
1955
1960
1965
1970
1975
1980
1985
YEAR
MONTHLY AVERAGE


TEMPERATURE MINIMUMS (AVERAGE)
IOWA/MAY
TEMPERATURE (F)
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31
DAY
DAILY AVERAGE

PROCESSED 212 STATIONS
IOWA PRECIPITATION MAY

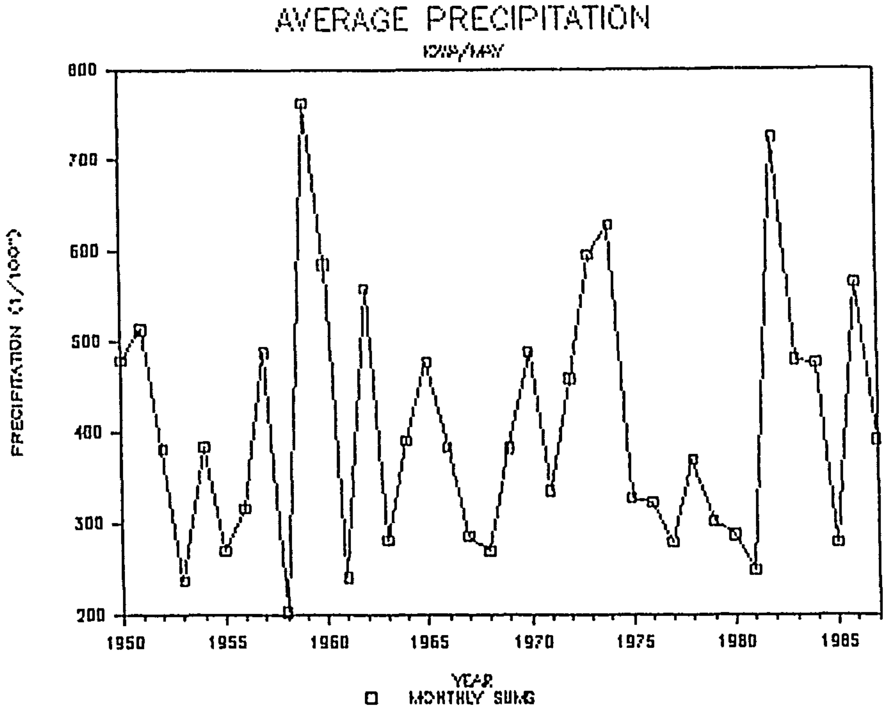
DAY	1950	1951	1952	1953	1954	1955	YEAR 1956
1	0.16	70.92	1.52	20.35	41.46	1.95	16.84
2	0.74	8.98	3.98	9.7	69.15	1.82	25.28
3	1.56	1.83	8.23	7.2	16.69	4.85	18.54
4	24.88	2.3	0.1	1.62	0.24	13.69	7.68
5	48.4	3.98	0.46	5.21	0.02	0	17.45
6	1.23	9.78	0.69	7.2	0.08	2.35	7.82
7	0.08	0.15	51.21	0.22	0.07	9.67	0.19
8	65.11	0.14	18.32	0	0.69	0.06	0.02
9	125.01	48.72	38.31	0	0.62	47.41	5.59
10	0.32	73.47	7.74	15.89	0.01	33.69	21.06
11	0.1	9.51	1.92	7.16	0.17	0	30.44
12	3.23	0	0.98	0.28	0	5.9	0.6
13	3.6	0	0.01	0.03	0	14.32	26.11
14	0.13	11.87	4.3	0.13	0	0.1	1.62
15	0.81	6.11	2.91	0.05	1.32	0	0.03
16	18.41	12.44	43.24	4.73	1.86	0	0.83
17	4.31	17.04	14.18	13.02	0.43	0	1.88
18	6.48	8.05	0.1	5.55	3.78	0	1.13
19	16.72	21.05	0	0.72	2.18	0	2.21
20	16.12	7.91	1.61	7.39	0.24	0.06	0.78
21	43.9	12.3	16.79	37.63	0	0.09	1.38
22	4.38	18.36	68.22	42.51	1.69	3.66	2.99
23	2.32	1.65	48.63	0.88	21.4	13.62	4.51
24	16.63	1.58	3.54	32.2	11.17	17.92	0
25	37.35	41.2	1.87	8.8	0.11	2.27	0.55
26	4.27	46.75	0.17	1.58	14.58	27.44	0.82
27	6.71	1.95	24.55	2.79	46.06	31.47	7.63
28	4.16	0.12	6.1	2.35	81.35	26.57	29.4
29	14.91	2.61	0.79	0.12	4.18	9.38	46.27
30	5.42	1.59	3.36	0.58	2.55	0.55	36.08
31	1.5	70.89	7.89	0	61.9	0.46	0.45
MONTHLY SUM BY YEAR	478.95	513.25	381.72	235.89	384	269.3	316.18

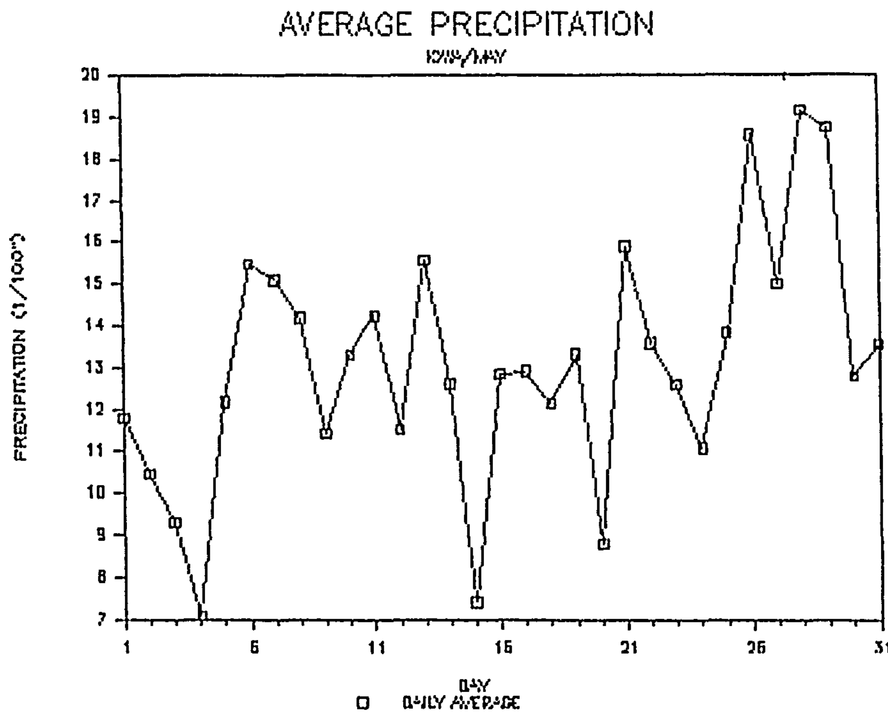
1957	1958	1959	1960	1961	1962	1963	1964
0.01	0.03	0.02	2.49	0	3.98	0.36	13.49
0.01	5.94	5.06	3.46	0	0.16	5.7	10.38
0.04	13.8	38.47	3.76	0	0	10.67	4.92
0	19.96	8.68	7.24	8.75	0.04	34.25	13.28
0	4.11	65.98	32.28	32.55	10.24	0.56	6.45
0	0.1	46.3	112.21	13.35	31.42	0.27	33.71
0.01	6.57	2.57	45.76	6.35	14.96	0.2	13.15
1.06	8.55	0.53	3.79	11.06	48.24	0	49.87
17.72	0	26.55	0.04	0.12	2.2	4.3	4.19
74.17	0	50	2.16	0	4.6	29.36	0.32
12.99	0.05	27.58	3.02	0	20.08	16.17	4.11
27.13	0.24	4.45	0	0	26.03	54.26	43.91
43.36	0.17	4.27	0	0.44	0.69	29.4	28.01
62.79	9.37	0.18	0	11.84	1.39	3.21	0.49
7.79	3.75	0.74	1.21	20.2	0.1	26.29	3.99
8.68	5.48	0.03	86.04	5.97	1.12	3.75	11.9
21.79	28.87	0.19	15.16	46.42	3.38	10.01	1.91
2.28	14.41	19.03	18.58	18.51	12.75	0.65	1.57
2.16	0.03	40.68	31.67	0.12	22.83	0.49	1.81
9.88	0.39	48.32	44.31	1.57	1.05	1.11	0.81
50.57	0.72	75.72	55.63	0.38	35.53	3.46	0.01
5.8	5.23	9.39	5.58	0.02	23.08	0	0.54
3.91	0.81	10.46	0.72	0	20.57	0	15.37
0.46	1.19	0.08	18.29	0.17	0.72	0.46	69.73
26.84	2.12	0.53	66.29	22.76	3.46	1.44	3.88
15.46	2.07	8.77	17.42	3.56	62.56	1.91	51.14
0.05	7.67	9.51	3.76	0	15.94	22.33	1.67
1.01	0	47.12	0.81	1.07	62.15	17.87	0.07
29.08	0.08	87.53	1.12	0.35	121.15	1.54	0
46.96	12.76	53.51	0.86	13.16	7.62	0.14	0.08
15.36	48.18	72.15	1.74	21.4	1.1	1	0.48
487.37	202.65	764.4	585.4	240.12	559.14	281.16	391.24

1965	1966	1967	1968	1969	1970	1971	1972
0.2	0.02	9.33	0.01	4.38	27.73	6.51	69.96
0.19	0	1.22	0.14	9.95	0.17	3.01	21.25
0.22	0.86	2.62	3.04	12.23	0.14	0.16	3.63
3.93	0.02	3.43	0.25	2.29	0.95	4.59	3.23
24.6	0.07	6.88	0.58	6.39	1.25	7.82	13.34
7.54	0	5.21	6.32	46.33	0.44	17.64	61.04
4.71	3.99	2.95	25.6	27.23	0	25.74	45.38
44.37	9.15	3.8	16.9	40.64	0.04	12.23	24.2
16.91	3.55	0.13	0.32	2.36	12.34	0.23	1.3
0.21	1.94	30.81	0	19.63	17.68	7.79	0.82
0.01	79.71	59.94	0.09	3.01	25.77	12.55	4.58
0.01	53.99	0.18	0	1.34	36.79	1.18	12.5
1.61	8.59	0.08	8.27	7.19	101.79	0	35.08
5.01	2.91	0.24	35.31	1.7	81.7	0	14
31.69	32.53	0.32	9.65	0.07	10.14	0.1	4.89
24.36	9.29	1.15	23.57	21.52	1.58	0.31	0.83
0.7	40.36	0.56	0.17	40.34	0	5.7	0.88
11.57	1.41	1.43	8.13	7.65	0	63.89	0.99
0.07	1.47	5.02	6.66	7.59	0	61.66	0
0.12	10.71	0	0.89	12.1	0	1.72	0
22.5	10.61	0.01	0.27	54.11	0.11	0.77	0
52.99	1.11	0.04	4.26	35.88	4.1	0.89	0.27
34.4	75.05	1.42	9.57	0.05	30.45	22.33	22.69
16.44	35.34	0	1.07	1.53	27	44.94	27.42
39.83	0	0.02	16.44	4.97	23.57	7.84	5.77
93.85	0	0.01	49.86	3.94	0.03	0.08	10.68
11.01	0.05	7.05	7	0.16	8.24	0	16.78
0.55	0.01	49.48	7.63	0.1	22.45	0	17.91
14.86	0.08	13.65	11.99	1.23	20.6	0	28.01
8.46	0.57	49.29	0.84	0	17.23	1.59	11.32
3.15	0	28.78	14.74	6.34	16.22	24.42	0.27
476.07	383.39	[illegible]85.05	269.57	382.25	488.51	335.69	459.02

1973	1974	1975	1976	1977	1978	1979	1980
84.35	0	0.33	1.6	0.75	0.16	4.05	0.07
61.1	0.7	3.75	8.93	2.99	0	40.6	0.03
0.79	7.99	12.18	0.61	12.99	0	50.76	0.16
0	0.01	0.73	0	30.91	1.33	0	0.04
2.02	0.01	2.01	2.64	48.39	10.34	0	0.24
23.29	0.01	6.25	19.89	13.31	9.25	0	0.04
67.98	25.49	23.23	1.73	9.19	64.96	0	0
48.8	38.4	23.21	0	3.49	32.16	12.71	0
5.51	1.45	0.24	0	1.88	2.47	14.11	0.08
11.9	10.42	0.27	0.11	0	0.32	16.25	7.64
0.26	66.86	33.28	0.07	0	4.08	29.5	10.5
1.21	4.72	14.92	7.09	0.09	28.08	0.78	1.86
0.25	30.74	0.2	28.1	0	87.26	5.28	19.13
1.17	56.19	1.46	7.97	0.14	4.66	6.81	2.82
0.03	1.07	2.56	11.93	5.79	0.96	4.09	4.25
0	41.72	0	54.93	9.36	0.02	0.02	8.84
0	50.68	0	16.05	5.53	0	0.57	38.34
0.14	73.44	0.48	0	3.2	0.03	22.9	18.59
0.23	32.7	0.25	0	7.6	2.43	48.98	6.44
0.48	9.77	0.46	0.42	23.87	16.09	0.32	0.05
6.82	14.7	18.28	3.1	26.05	0.01	0.08	0.07
16.34	18.75	8.94	47.3	21.55	2.17	0.86	0
0.74	0.66	11.59	48.65	2.23	11.12	1.62	0.33
6.28	1.35	5.53	6.85	0.2	0.52	0.01	0.53
14.41	2.38	11.05	0.06	1.39	0.62	0.17	0.09
26.74	30.09	20.71	0	4.51	3.08	8.23	3.32
130.76	11.64	0.53	0.79	16.2	11.12	10.49	8.63
78.14	29.93	38.48	5.75	12.57	29.89	0.25	9.62
5.96	37.64	44.73	35.59	5.61	26.51	3.84	46.64
0.69	13.01	35.86	11.49	5.83	9.41	5.25	84.16
0	15.66	6.2	0.81	2.17	10.44	13.92	14.29
596.39	628.18	327.71	322.46	277.79	369.49	302.45	286.8

1981	1982	1983	1984	1985	1986	1987	AVERAGE BY DAY
0.87	0.04	30.23	1.37	16.87	15.48	0.22	11.79236
0.2	0	68.88	11.79	2.44	0.36	9.68	10.46684
8.26	0	31.89	34.91	0	3.59	35.63	9.295263
41.07	9.44	0.92	13.42	0	0.01	10.28	7.093684
12.17	75.69	1.56	6.85	7.84	2.33	1.49	12.16315
0	61.91	9.69	9.57	20.36	2.79	0.85	15.48
0	23.51	41.44	17.96	0.68	10.73	0	15.09631
1.32	4.55	3.71	0.14	0.19	11.27	0	14.17684
3.89	2.09	0.28	0.02	0.06	43.91	0.48	11.43131
4.49	3.87	0.06	2.47	0.71	53.65	1.51	13.29842
1.47	18.17	1.44	6.61	16.66	30.2	2.88	14.23526
6.67	38.68	18.88	2	31.89	6.94	0.85	11.51736
16.44	24.28	23.87	11.87	7.7	22.12	1.78	15.58
21.51	30.39	12.01	0.11	55.09	24.53	6.23	12.61526
3.44	29.79	6.6	0.33	20.57	25.43	0.19	7.413684
0.13	18.44	0.16	1.51	5.34	60.49	0	12.84342
9	25.72	6.72	1.17	1.34	68.29	0.17	12.91789
23.38	22.7	38.19	17.81	0.03	21.38	10.69	12.12894
4.1	16.45	77.69	54.39	3.17	0.01	26.4	13.31526
0	23.25	2.33	21.23	28.05	0	41	8.800263
0.06	61.06	12.34	1.81	0.93	0	36.1	15.89210
6.54	36.83	23.76	40.22	0.04	0.11	1.57	13.57815
38.08	2.96	1.85	10.58	5.05	1.41	0.35	12.57973
26.81	18.21	3.45	5.57	8.99	4.75	4.88	11.10026
0.01	17.84	11.77	95.68	0.01	24.26	27.8	13.82763
0.4	61.32	0.96	3.91	0.68	52.99	72.35	18.58526
1.2	24.18	10.6	18.86	10.49	36.77	45.54	15.00473
6.87	10.34	19.1	77.32	2.12	18.66	11.26	19.17315
9.99	30.39	11.73	6.6	6.63	16.16	14.84	18.74710
0.22	16.84	3.34	0	11.8	6.13	7.64	12.79447
0	15.9	4.59	0	10.27	0	18.74	13.53710
							ERR
248.59	724.84	480.04	476.08	79	564.75	391.4	406.4813


AVERAGE PRECIPITATION
FRECIPITATION (1/100")
YEAR
MOHTHLY SUMG


AVERAGE PRECIPITATION
FRECIPITATION (1/100")
DAY
DAILY AVERAGE

Appendix E. Sample Printout from CERES-Maize

```
Welcome to the C E R E S  M A I Z E Model Version 2.10.
Version 2.10 incorporates new menu structure, supports
multi-year  and  multi-treatment simulation,  and also
provides output support for IBSNAT graphics and DSSAT.

Please press "Enter" to continue



                                                  INST.  SITE  EXPT.
   LIST OF EXPERIMENTS TO BE SIMULATED             ID     ID    NO    YEAR
   ----------------------------------             ----   ----  ----   ----
 1)  N X VAR WAPIO, IBSNAT EXP.1983-4              IB     WA    01    1983
 2)  N X IRRIGATION, GAINESVILLE                   UF     GA    01    1982
 3)  N X IRRIG., S.C. (CERES MAIZE BK)             FL     SC    01    1981
 4)  MULTI-YEAR TEST,  SITIUNG                     IB     SI    01    1980

 1]  <=== CURRENT EXPERIMENT SELECTION.
     <--- NEW SELECTION?
3
2J


TRT                                               INST.  SITE  EXPT.
NO.  N X IRRIG., S.C. (CERES MAIZE BK)             ID     ID    NO    YEAR
---  ----------------------------------------------------   ----  ----   ----
 1)  Pio 3382 200 kg N/ha IRR                      FL     SC    01    1981
 2)  Pio 3382 200 kg N/ha NO IRR                   FL     SC    01    1981
 3)  Run all treatments without keyboard inputs

 1]  <=== CURRENT TREATMENT SELECTION.
     <--- NEW SELECTION?
2
2J



 RUN-TIME OPTIONS?

 0)   RUN SIMULATION
 1)   SELECT SIMULATION OUTPUT FREQUENCY
 2)   MODIFY SELECTED MODEL VARIABLES INTERACTIVELY.


 <=== CHOICE? [ DEFAULT = 0 ]
2
2J
```

```
MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

              VARIABLES TO BE MODIFIED

          1.  Planting Date, Simulation Date and Seeding Depth
          2.  Plant Population
          3.  Nitrogen Non-Limiting
          4.  Irrigation Inputs and Water Balance Switch
          5.  Fertilizer Inputs
          6.  Select New Variety
          7.  Soil Profile Inputs (Water Balance,Root Preference,DMOD)
          8.  Select Weather Data
          9.  Initial Soil Fertility and Water,
               and Crop Residue Parameters
         10.  Display Echo
         11.  End of Changes
         12.  Abandon all Changes and Return to Experiment Menu

        ENTER NUMBER OF MODIFICATION : 1

         Do you want to
       1. Change Planting Date ?
       2. Change Simulation Date ?
       3. Change Seeding Depth (cm) ?
       4. Return to main menu ?

     Enter number of choice : 1

Existing Planting Date is  97 .

  Input New Planting Date : 135

         Do you want to
       1. Change Planting Date ?
       2. Change Simulation Date ?
       3. Change Seeding Depth (cm) ?
       4. Return to main menu ?

     Enter number of choice : 2
  Input New Date to Begin Simulation : 135
```

```
        Do you want to
     1. Change Planting Date ?
     2. Change Simulation Date ?
     3. Change Seeding Depth (cm) ?
     4. Return to main menu ?

   Enter number of choice : 4

MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

             VARIABLES TO BE MODIFIED

              1.  Planting Date, Simulation Date and Seeding Depth
              2.  Plant Population
              3.  Nitrogen Non-Limiting
              4.  Irrigation Inputs and Water Balance Switch
              5.  Fertilizer Inputs
              6.  Select New Variety
              7.  Soil Profile Inputs (Water Balance,Root Preference.DMOD)
              8.  Select Weather Data
              9.  Initial Soil Fertility and Water,
                   and Crop Residue Parameters
             10.  Display Echo
             11.  End of Changes
             12.  Abandon all Changes and Return to Experiment Menu


       ENTER NUMBER OF MODIFICATION : 6


                         ==========================
                          VARIETIES IN THE DATA BASE
                         ==========================

The current variety is   12 .
```

NO.	VARIETY NAME	P1	P2	P5	G2	G3
1	CORNL281	110.00	.3000	685.00	825.40	6.600
2	CP170	120.00	.0000	685.00	825.40	10.000
3	LG11	125.00	.0000	685.00	825.40	10.000
4	F7 X F2	125.00	.0000	685.00	825.40	10.000
5	PIO 3995	130.00	.3000	685.00	825.40	8.600
6	INRA	135.00	.0000	685.00	825.40	10.000
7	EDO	135.00	.3000	685.00	825.40	10.400
8	A654 X F2	135.00	.0000	685.00	825.40	10.000
9	DEKALB XL71	140.00	.3000	685.00	825.40	10.500
10	F478 X W705A	140.00	.0000	685.00	825.40	10.000
11	DEKALBXL45	150.00	.4000	685.00	825.40	10.150
12	PIO 3382	160.00	.7000	890.00	750.00	8.500
13	B59*OH43	162.00	.8000	685.00	784.00	6.900
14	F16 X F19	165.00	.0000	685.00	825.40	10.000

```
PRESS <Enter> TO CONTINUE LISTING.
```

NO.	VARIETY NAME	P1	P2	P5	G2	G3
43	PIO 511A	220.00	.3000	685.00	645.00	10.500
44	W69A X F546	240.00	.3000	685.00	825.40	10.000
45	A632 X VA26	240.00	.3000	685.00	825.40	10.000
46	W64A X W117	245.00	.0000	685.00	825.40	8.000
47	PIO 3147	255.00	.7600	685.00	834.00	10.000
48	WF9*B37	260.00	.8000	710.00	825.40	6.500
49	NEB 611	260.00	.3000	720.00	825.00	9.000
50	PV82S	260.00	.5000	750.00	600.00	8.500
51	PV76S	260.00	.5000	750.00	600.00	8.500
52	PIO 3183	260.00	.5000	750.00	600.00	8.500
53	CEEDA-25	260.00	.5000	669.00	780.00	7.100
54	B14*OH43	265.00	.8000	665.00	780.00	6.900
55	MCCURDY 6714	265.00	.3000	825.00	825.40	9.200
56	FM 6	276.00	.5200	867.00	616.00	10.700

PRESS <Enter> TO CONTINUE LISTING.

NO.	VARIETY NAME	P1	P2	P5	G2	G3
57	TOCORON-3	276.00	.5200	867.00	600.00	8.120
58	NC+59	280.00	.3000	750.00	825.00	10.000
59	H6	310.00	.3000	685.00	825.40	10.000
60	H610(UH)	300.00	.5200	920.00	580.00	6.400
61	FE 6	300.00	.5200	990.00	400.00	7.000
62	B56*C131A	318.00	.5000	700.00	805.00	6.400
63	PIO X 304C	320.00	.5200	940.00	625.00	6.000
64	H.OBREGON	360.00	.8000	685.00	825.40	10.150
65	SUWAN-1	380.00	.6000	780.00	750.00	7.000

```
The current variety is  12 .

          Do you want to

     1. Select a new variety ?
     2. Create a new variety ?
     3. Modify current genetic coefficients ?
     4. View the varieties again ?
     5. Return to the main menu ?

    Enter number of choice : 1

New Variety : 2
```

NO.	VARIETY NAME	P1	P2	P5	G2	G3
43	PIO 511A	220.00	.3000	685.00	645.00	10.500
44	W69A X F546	240.00	.3000	685.00	825.40	10.000
45	A632 X VA26	240.00	.3000	685.00	825.40	10.000
46	W64A X W117	245.00	.0000	685.00	825.40	8.000
47	PIO 3147	255.00	.7600	685.00	834.00	10.000
48	WF9*B37	260.00	.8000	710.00	825.40	6.500
49	NEB 611	260.00	.3000	720.00	825.00	9.000
50	PV82S	260.00	.5000	750.00	600.00	8.500
51	PV76S	260.00	.5000	750.00	600.00	8.500
52	PIO 3183	260.00	.5000	750.00	600.00	8.500
53	CESDA-28	260.00	.5000	669.00	780.00	7.100
54	B14*OH43	265.00	.8000	665.00	780.00	6.900
55	MCCURDY 6714	265.00	.3000	825.00	825.40	9.200
56	FM 6	276.00	.5200	867.00	616.00	10.700

PRESS <Enter> TO CONTINUE LISTING.

NO.	VARIETY NAME	P1	P2	P5	G2	G3
57	TOCORON-3	276.00	.5200	867.00	600.00	8.120
58	NC+59	280.00	.3000	750.00	825.00	10.000
59	H6	310.00	.3000	685.00	825.40	10.000
60	H610(UH)	300.00	.5200	920.00	580.00	6.400
61	FE 6	300.00	.5200	990.00	400.00	7.000
62	B56*C131A	318.00	.5000	700.00	805.00	6.400
63	PIO X 304C	320.00	.5200	940.00	625.00	6.000
64	H.OBREGON	360.00	.8000	685.00	825.40	10.150
65	SUWAN-1	380.00	.6000	780.00	750.00	7.000

The current variety is 12 .

Do you want to

1. Select a new variety ?
2. Create a new variety ?
3. Modify current genetic coefficients ?
4. View the varieties again ?
5. Return to the main menu ?

Enter number of choice : 1

New Variety : 2

```
                    SOILS IN THE DATA BASE.
REF                 =====================
NO. TAXONOMY NAME                                                 LOCATION
--- ------------------------------------------------------------  -----------
 1) DEEP SILTY CLAY
 2) MEDIUM SILTY CLAY
 3) SHALLOW SILTY CLAY
 4) DEEP SILT LOAM
 5) MEDIUM SILT LOAM
 6) SHALLOW SILT LOAM
 7) DEEP SANDY LOAM
 8) MEDIUM SANDY LOAM
 9) SHALLOW SANDY LOAM
10) DEEP SAND
11) MEDIUM SAND
12) SHALLOW SAND
13) Waipio (Clayey, kaolinitic, isohyperth, Tropeptic Eutrustox)  Waipio, HI
14) Millhopper Fine Sand (Loamy,silic,hyperth Arenic Paleudult)   Gainesville
15) Millhopper Fine Sand (Loamy,silic,hyperth Gross. Paleudults)  Gainesville
16) Lake Fine Sand (Hyperthermic, coated Typic Quartzipsamments)  Gainesville
17) Orangeburg Sandy Loam (F-loamy,silic,thermic Typ Paleudults)  Quincy, FL
18) Haynie (Coarse-silty, mixed,calcareous,mesic Typ Udifluvent)  Manhattan,KS
19) Wood Mountain Loam (Orthic Brown Chernozem)                   Swift, CAN
20) Rothamsted                                                    Rothamsted
21) Tel Hadya (Palexerollic Chromoxerert; high AWC)               Aleppo, SYR
22) Tel Hadya (Palexerollic Chromoxerert; low AWC)                Aleppo, SYR
23) Norfolk Loamy Sand                                            Florence, SC
24) Norfolk Sandy Loam  (F-loamy,silic,thermic Typ Paleudults)    Marianna, FL
25) Norfolk Sandy Clay Loam (F-l,silic.,therm. Typ. Paleudults)   Raleigh, NC
26) Ida Silt Loam                                                 Castana, IO
27) Sitiung ( no subsoil acidity. Ultisol )                       Sumatra, IND
    [illegible]  subsoil acidity, Ultisol )                       Sumatra, IND
29) Patancheru (Alfisol Udic Rhodustalf)                          Hyderabad,IN

The current soil is number 23 .

           Do you want to

        1. Select a new soil ?
        2. Modify or view parameters of current soil ?
        3. View the soils again ?
        4. Return to the main menu ?

      Enter number of choice : 1

Input new soil selection : 5
```

WEATHER DATA SETS AVAILABLE	DATES AVAILABLE FROM	UNTIL	INST ID	WEATHER STATION ID
1) 1983 WAIPIO,HI	11-22-83	04-23-84	IB	WA
2) 1982 GAINESVILLE	01-01-82	12-31-82	UF	GA
3) 1981 FLORENCE	01-01-81	09-30-81	FL	SC
4) 1950 ILLINOIS,USA NON-ENSO YEARS	05-15-50	09-30-50	IL	LI
5) 1950 ILLINOIS,USA ENSO YEARS	05-01-50	09-30-50	IL	LI
6) 1950 INDIANA,USA NON-ENSO YEARS	05-01-50	09-30-50	IN	DI
7) 1950 INDIANA,USA ENSO YEARS	05-01-50	09-30-50	IN	DI
8) 1950 IOWA,USA NON-ENSO YEARS	05-01-50	09-30-50	IO	WA
9) 1950 IOWA,USA ENSO YEARS	05-01-50	09-30-50	IO	WA
10) 1950 MINNESOTA NON-ENSO YEARS	05-01-50	09-30-50	MI	NN
11) 1950 MINNESOTA ENSO YEARS	05-01-50	09-30-50	MI	NN
12) 1950 NEBRASKA NON-ENSO YEARS	05-01-50	09-30-50	NE	BR
13) 1950 NEBRASKA ENSO YEARS	05-01-50	09-30-50	NE	BR
14) 1950 MINNnois actual data	05-01-50	09-30-40	MI	NN
15) 1971 MINNESis actual data	05-01-50	09-30-40	MI	NN
16) 1972 NMINNois actual data	05-01-50	09-30-40	MI	NN
17) 1973 MINNnois actual data	05-01-50	09-30-40	MI	NN
18) 1974 MINNnois actual data	05-01-50	09-30-40	MI	NN
19) 1975 MINNnois actual data	05-01-50	09-30-40	MI	NN
20) 1976 MINNnois actual data	05-01-50	09-30-40	MI	NN
21) 1977 MINNnois actual data	05-01-50	09-30-40	MI	NN
22) 1978 MINNnois actual data	05-01-50	09-30-40	MI	NN
23) 1979 MINNnois actual data	05-01-50	09-30-40	MI	NN
24) 1980 MINNnois actual data	05-01-50	09-30-40	MI	NN
25) 1981 MINNNois actual data	05-01-50	09-30-40	MI	NN
26) 1982 MINNNNis actual data	05-01-50	09-30-40	MI	NN
27) 1983 MINNNNis actual data	05-01-50	09-30-40	MI	NN
28) 1984 MINNNNis actual data	05-01-50	09-30-40	MI	NN
29) 1985 MINNNNis actual data	05-01-50	09-30-40	MI	NN
30) 1986 MINNNNis actual data	05-01-50	09-30-40	MI	NN
31) 1987 MINNNois actual data	05-01-50	09-30-40	MI	NN
32) 1968 MINNnois actual data	05-01-50	09-30-40	MI	NN
33) 1969 MINNNois actual data	05-01-50	09-30-40	MI	NN
34) 1970 MINNNNis actual data	05-01-50	09-30-40	MI	NN

33 <=== CURRENT WEATHER FILE SELECTION.
<--- NEW SELECTION?
4

MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

VARIABLES TO BE MODIFIED

1. Planting Date, Simulation Date and Seeding Depth
2. Plant Population
3. Nitrogen Non-Limiting
4. Irrigation Inputs and Water Balance Switch
5. Fertilizer Inputs
6. Select New Variety
7. Soil Profile Inputs (Water Balance,Root Preference,DMOD)
8. Select Weather Data
9. Initial Soil Fertility and Water, and Crop Residue Parameters
10. Display Echo
11. End of Changes
12. Abandon all Changes and Return to Experiment Menu

ENTER NUMBER OF MODIFICATION : 311\\

```
RUN   1 OUTPUT SUMMARY
INST_ID :FL  SITE_ID: SC   EXPT_NO: 01  YEAR : 1981   TRT_NO:  2
EXP.    :N X IRRIG. S.C. (CERES MAIZE 8R)
TRT.    :S.2 3.96 200 kg N/ha NO IRR
WEATHER :1984 MINNNIS actual data
SOIL    :MEDIUM SILT LOAM
VARIETY :C2120
IRRIG.  :NEVER IRRIGATED, RAINFED.
LATITUDE = 47.00, SOWING DEPTH =  4. CM, PLANT POPULATION =  7.1 PLANTS/SQ METE
GENETIC SPECIFIC CONSTANTS   P1 =120.00  P2 =  .00  P5=685.00
                             G2 =825.40  G3 =10.000

      SOIL PROFILE DATA C LOCATION:            ]
      SOIL ALBEDO=  .12  U=  6.0  SWCON=   .30   RUNOFF CURVE NO.=  79.0
Press "Enter" to continue

 DEPTH-CM      LO LIM UP LIM  SAT SW EXT SW  IN SW    WR    NO3    NH4
                                                            ---mg/kg---
   0.-  10.     .106   .262   .362   .156   .262  1.000    5.0    2.0
  10.-  20.     .105   .252   .352   .150   .252   .818    5.0    2.0
  20.-  40.     .107   .252   .352   .150   .252   .607    5.0    2.0
  40.-  55.     .108   .251   .351   .150   .251   .407    5.0    2.0
  55.-  70.     .108   .251   .351   .150   .251   .407    3.0    1.0
  70.- 100.     .110   .250   .350   .150   .250   .247    2.0    1.0
 100.- 150.     .111   .259   .359   .148   .259   .135    2.0    1.0
 T 0.- 151.     14.1   33.9   46.9   19.8   33.9           59.*   25.*
 * NOTE: Units are in kg / hectare.
FERTILIZER INPUTS
DAY OF YEAR    KG/HA      DEPTH   SOURCE
Press "Enter" to continue
      90       66.70      10.00   UREA
     130       66.70      10.00   UREA
     153       66.70      10.00   UREA
           THE PROGRAM STARTED ON, 135 DAY OF YEAR

 DATE   CDTT PHENOLOGICAL STAGE         BIOM    LAI  NUPTK   N%    CET  RAIN  PESW
                                        g/m^2        kg/ha         ---mm----   cm
15 May    0. SOWING
19 May    4. GERMINATION                                            5.    3.   20.
29 May   41. EMERGENCE                                             15.   13.   19.
 6 Jun  155. END JUVENILE                 4.    .08    1.5  3.94   41.   53.   20.
10 Jun  201. TASSEL INITIATION            8.    .17    2.7  3.50   56.  115.   20.
19 Jul  606. 75% SILKING                625.   2.33   98.1  2.32  158.  240.   20.
31 Jul  803. BEGIN GRAIN FILL           650.   2.33   98.7  2.35  198.  252.   18.
 9 Sep 1293. END GRAIN FILL            1250.    .92   33.6  1.00  274.  352.   16.
16 Sep 1328. PHYSIOLOGICAL MATURITY    1250.    .92   33.6  1.00  294.  352.   16.
Press "Enter" to continue
YIELD (KG/HA)=  8192. (BU/ACRE)=130.4 FINAL GPSM= 2103. KERNEL WT.(mg)=329.2
ISTAGE       CSD1       CSD2       CNSD1      CNSD2     S T A G E  OF  G R O W T H
   1          .00        .00        .00        .00      EMERG. to END JUVENILE PHASE
   2          .00        .00        .02        .00      END JUV to TASSEL INITIATION
   3          .00        .00        .05        .10      TASSEL INITIATION to SILKING
   4          .00        .00        .05        .40      SILKING to BEGIN GRAIN FILL
   5          .00        .00        .00        .02      GRAIN FILLING PHASE
* NOTE: In the above table, 0.0 represents minimum
   stress and 1.0 represents maximum stress for water (CSD)
   and nitrogen (CNSD), respectively.

NOTE: Data modified by the user.
 Therefore, the  predicted and observed comparison data may not be valid.
                              PREDICTED      OBSERVED
SILKING DATE                      200             0
MATURITY DATE                     259             0
Press "Enter" to continue
GRAIN YIELD (KG/HA)              8192             0
KERNEL WEIGHT (G)                 .329         .000
GRAINS PER SQ METRE              2103.            0
GRAINS PER EAR                  296.14          .00
MAX. LAI                          2.33          .00
BIOMASS (KG/HA)                 12497.           0.
STRAW (KG/HA)                    5575.           0.
GRAIN N%                          1.70          .00
TOT N UPTAKE (KG N/HA)           151.4           .0
STRAW N UPTAKE                    33.6           .0
GRAIN N UPTAKE                   117.8           .0

End of File

Which File do you wish to display
1  No File Display - Return to Simulation Menu
2  Summary Output File
3  Crop Growth Output File
4  Weather and Water Balance File
5  Nitrogen Balance File

Input a number
```

2
2J

```
SUN    1      B:o 3382 200 kg N/ha
INST_ID  :FL  S...IL SC  EXPT_NO: 01  YEAR : 1981  TRT_NO:  2
EXP.     :N X FER G. S.C. (CERES MAIZE BK)
TRT.     :Pio 3382 200 kg N/ha NO IRR
WEATHER  :1981 MIUNNNN'S actual data
SOIL     :MEDIUM SILT LOAM
VARIETY  :CE120
IRRIG.   :NEVER IRRIGATED, RAINFED.
```

DAY CYR	SDTT	BIO g/m2	LN	LAI	ROOT	STEM	GRAIN	LEAF	RTD (cm)	PTF	L1	L3 RCD	L5
					-------	Weight in g	-------	-------					
148	33.	3.	2	.01	.21	.20	.00	.20	18.	.65	.3	.0	.0
155	100.	3.	4	.04	.35	.20	.00	.20	28.	.54	.3	.0	.0
162	5.	8.	6	.10	.82	.20	.00	.88	46.	.58	.4	.1	.0
169	77.	18.	8	.30	2.25	.55	.00	2.50	60.	.55	.7	.3	.0
176	155.	48.	10	.72	4.65	.87	.00	5.82	66.	.55	1.2	.7	.0
183	240.	121.	12	1.44	6.81	4.41	.00	12.65	96.	.71	1.7	1.1	.5

Press "Enter" to continue

190	318.	225.	14	1.86	7.72	16.70	.00	17.42	113.	.81	1.8	1.3	.5
197	418.	371.	16	2.21	8.50	30.03	.00	21.57	[illegible]	.86	1.8	1.4	.5
204	6[illegible].	500.	[illegible]	2.1[illegible]	8.7[illegible]	34.07	.00	21.76	[illegible]	.86	2.0	1.6	.5
211	[illegible]	[illegible]	[illegible]	[illegible]	10.[illegible]	38.[illegible]	.00	18.87	[illegible]	[illegible]	2.1	1.7	[illegible]
218	[illegible]	[illegible]	[illegible]	2.0[illegible]	10.27	40.11	16.54	18.27	[illegible]	.91	2.1	1.7	[illegible]
225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38.47	[illegible]	18.14	[illegible]	[illegible]	2.1	1.7	[illegible]
232	[illegible]	[illegible]	[illegible]	1.7[illegible]	9.5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.1	1.7	[illegible]
239	[illegible]	[illegible]	[illegible]	1.4[illegible]	9.26	[illegible]	71.30	[illegible]	[illegible]	[illegible]	2.1	1.7	[illegible]
246	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.1	1.7	[illegible]
253	657.	1250.	17	.72	8.70	29.81	[illegible]	17.66	132.	.95	2.1	1.7	[illegible]

End of File

Which File do you wish to display
1 No File Display - Return to Simulation Menu
2 Summary Output File
3 Crop Growth Output File
4 Weather and Water Balance File
5 Nitrogen Balance File

Input a number

RUN [illegible] 200 kg N/ha
INST_ID : FL [illegible] ID: SC EXP_NO: 01 YEAR : 1981 TRT_NO: 2
[illegible] MAIZE [illegible]
[illegible] 200 kg N/ha [illegible] IRR
WEATHER : 1984 [illegible] actual data
SOIL : MEDIUM SILT LOAM
VARIETY : C [illegible]
IRRIG. : NEVER IRRIGATED, RAINFED.

* Units are in MJ/square meter

DAY OYR	EP (mm)	ET (mm)	EO (mm)	AVERAGE SR*	MAX C	MIN C	PERIOD PREC (mm)	SW CONTENT SW1	W/DEPTH SW2	SW3	SW4	TOTAL SW5	PESW (cm)
[illegible]	.0	[illegible]	2.8	12.	23.3	8.9	10.80	.24	.25	.25	.26	.26	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	.3	2.9	2.9	[illegible]	[illegible]	13.4	38.50	.30	.30	.30	.30	.30	24.3

Press "Enter" to continue

176	.7	2.9	2.8	13.	25.3	[illegible]	23.60	[illegible]	[illegible]	.28	.29	.29	22.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
253	.6	1.6	1.6	6.	23.0	6.1	10.40	[illegible]	[illegible]	[illegible]	[illegible]	.23	[illegible]

End of File

Which File do you wish to display
1 No File Display - Return to Simulation Menu
2 Summary Output File
3 Crop Growth Output File
4 Weather and Water Balance File
5 Nitrogen Balance File

Input a number

RUN 1 [illegible] 200 kg N/ha
INST_ID :FL SITE_ID: SC EXPT_NO: 01 YEAR : 1981 TRT_NO: 2
[illegible]
NEVER IRRIGATED, RAINFED.

DAY	TOPS N %	NFAC	VEG N	GRAIN N	NO3 1	NO3 2	NO3 3	NO3 4	NO3 5	NH4 1	NH4 2	NH4 3
[illegible]	[illegible]	1.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Press "Enter" to continue

183	3.28	.95	38.4	.0	6.3	11.8	14.7	13.9	10.8	1.5	1.5	1.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1.02	1.00	[illegible]	117.8	1.4	1.5	[illegible]	4.6	4.0	1.4	1.2	1.1

End of File

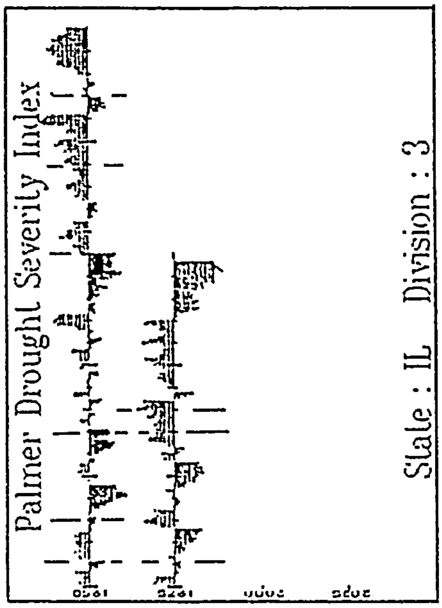
Which File do you wish to display
1 No File Display - Return to Simulation Menu
2 Summary Output File
3 Crop Growth Output File
4 Weather and Water Balance File
5 Nitrogen Balance File

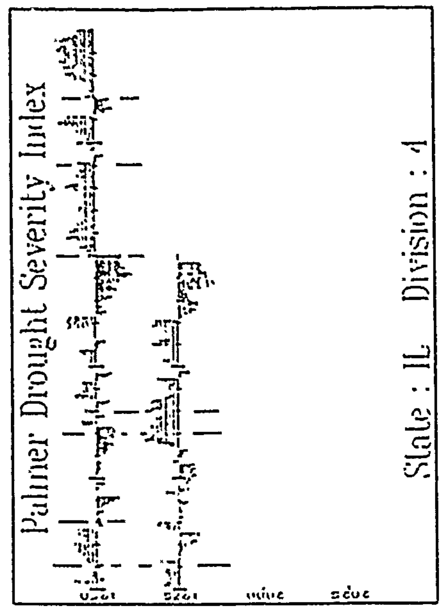
Input a number
1
Simulation complete for this treatment.
Do you want to :
1 Return to Experiment and Treatment Menu
2 Display Detailed Outputs on Screen
3 Quit

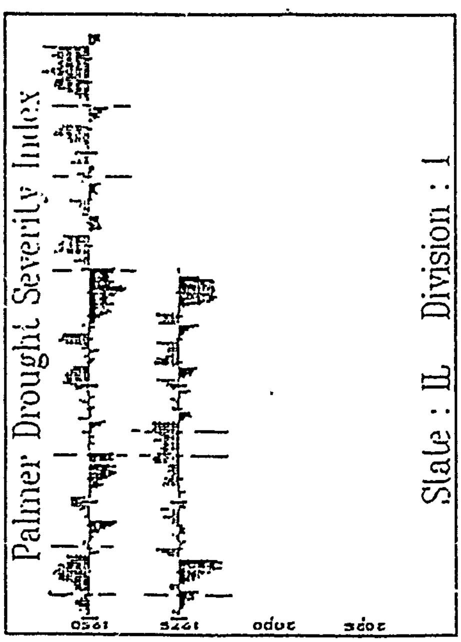
Input a number (default is 1)

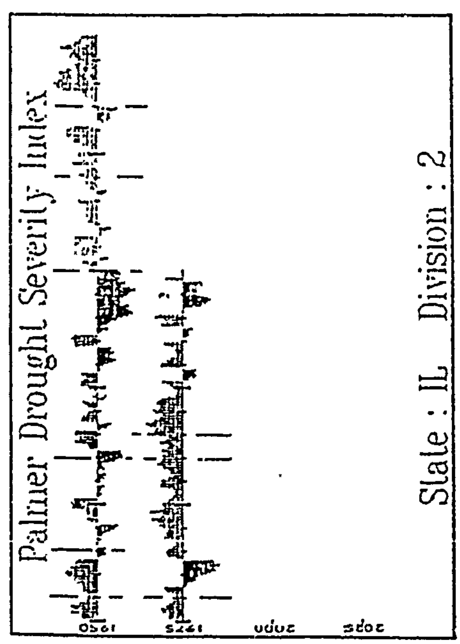
Appendix F. Palmer Drought Severity Index (PDSI):

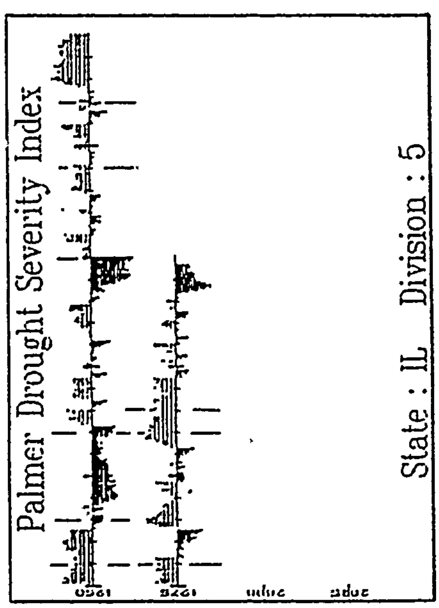
Above the line, the months have moisture surplus, while months below the line are in drought (no units).

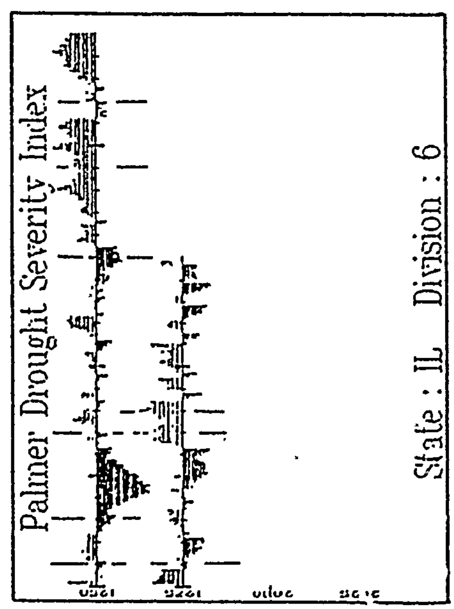


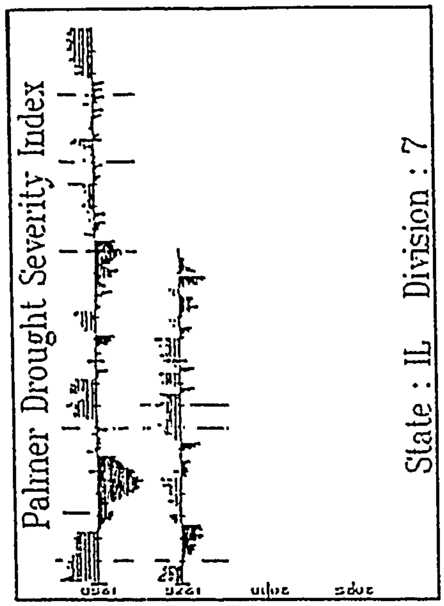


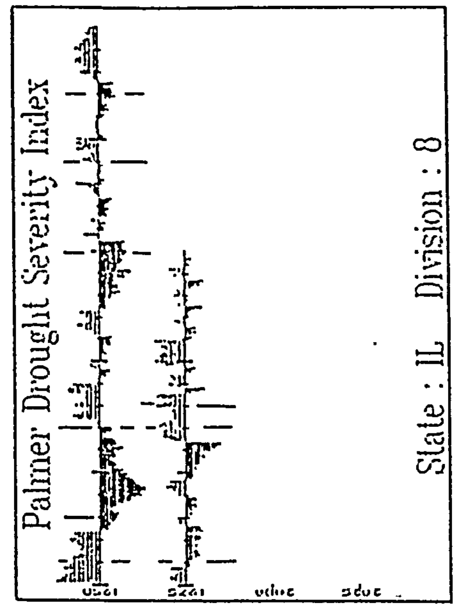


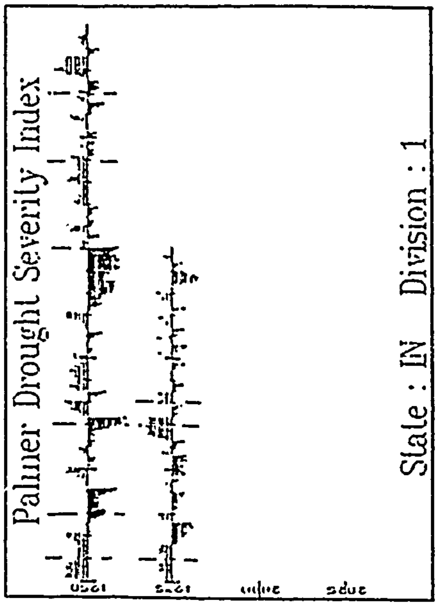


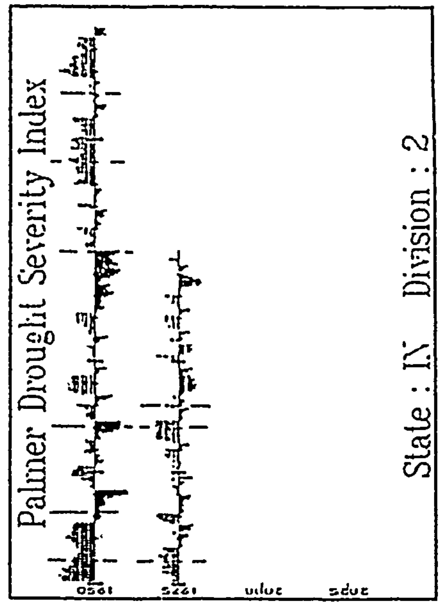

Palmer Drought Severity Index
State : IL Division : 5

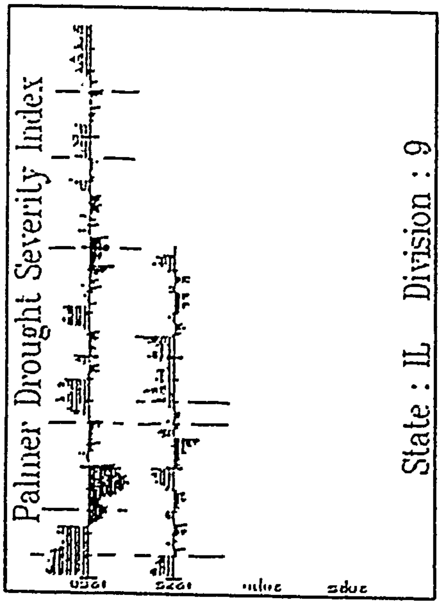

Palmer Drought Severity Index
State : IL Division : 6

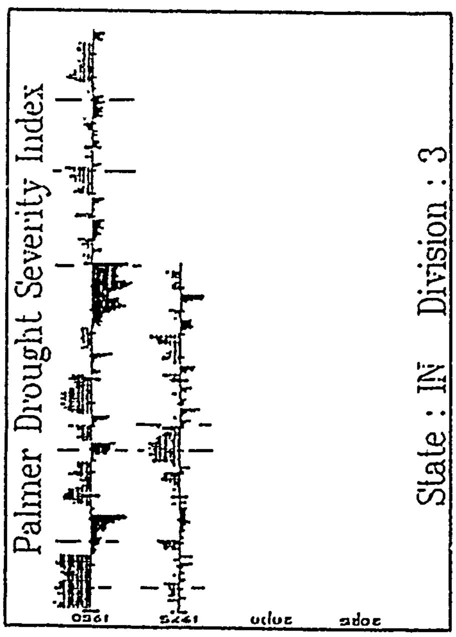

Palmer Drought Severity Index
State : IL Division : 7

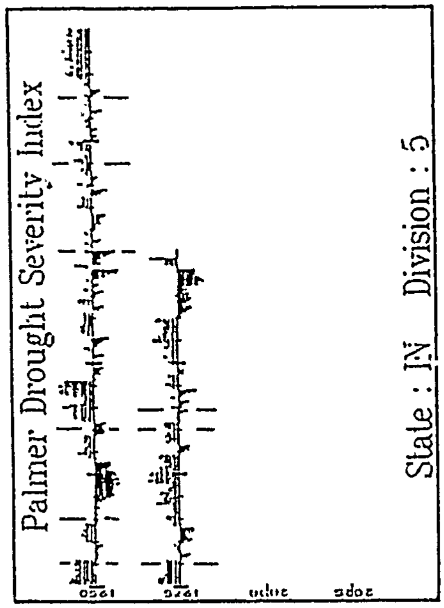

Palmer Drought Severity Index
State : IL Division : 8

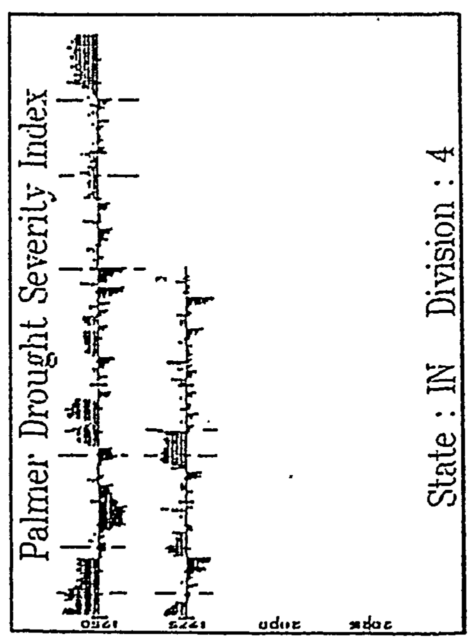

Palmer Drought Severity Index
State : IN Division : 1

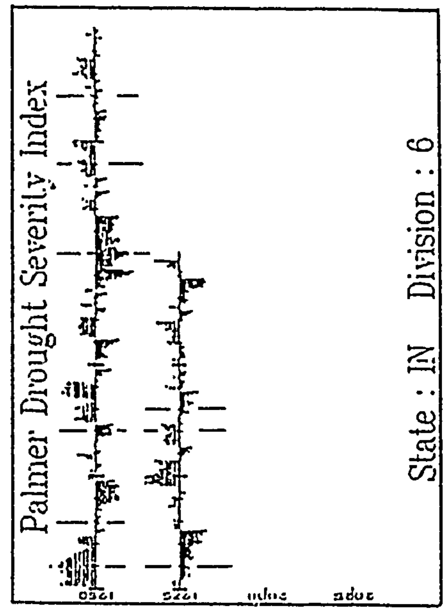

Palmer Drought Severity Index
State : IN Division : 2


Palmer Drought Severity Index
State : IL Division : 9


Palmer Drought Severity Index
State : IN Division : 3


Palmer Drought Severity Index
State : IN Division : 5


Palmer Drought Severity Index
State : IN Division : 4


Palmer Drought Severity Index
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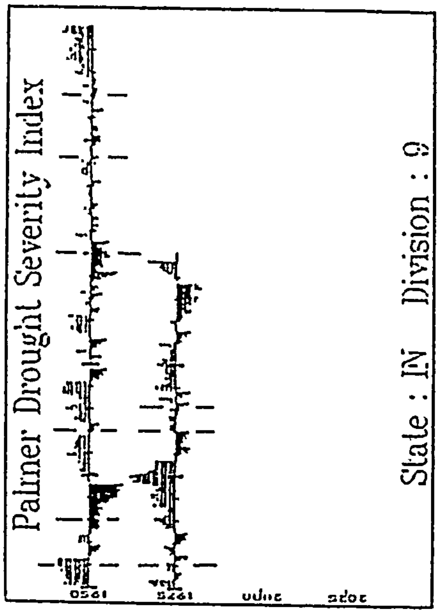
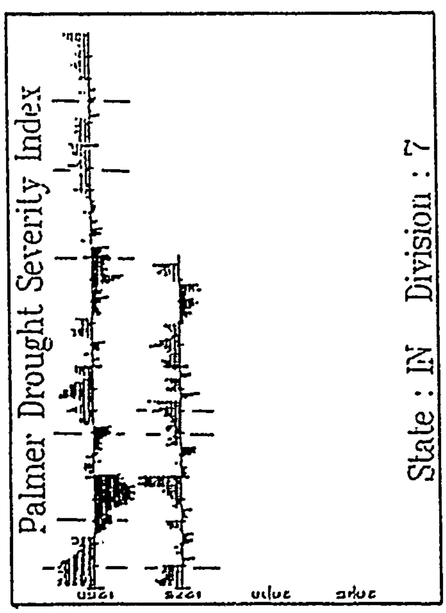

Palmer Drought Severity Index
State : IN Division : 9


Palmer Drought Severity Index
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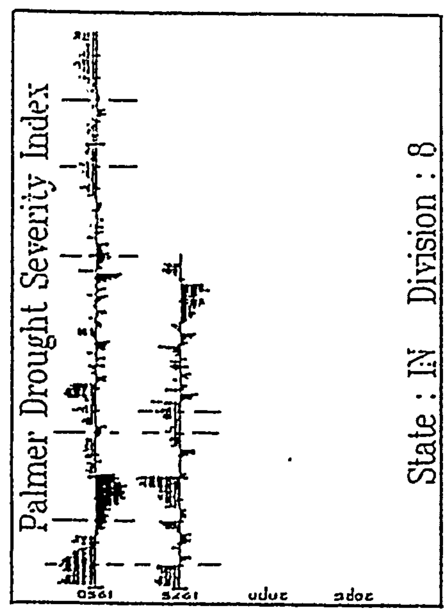
Palmer Drought Severity Index
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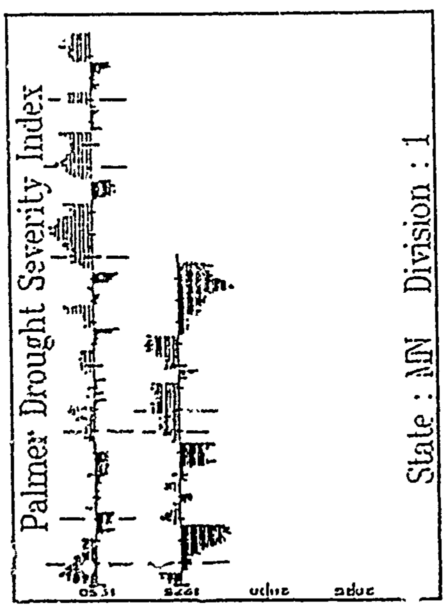
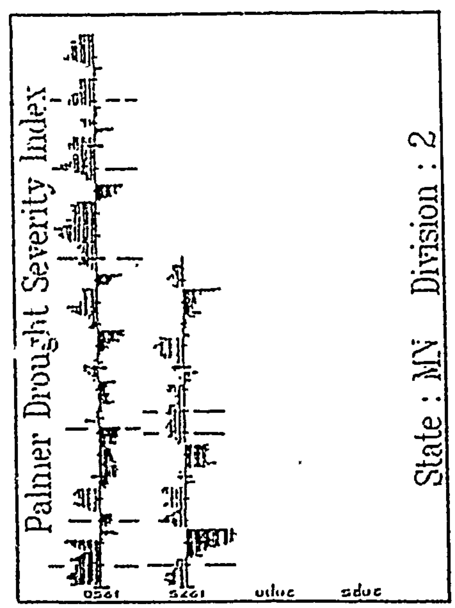
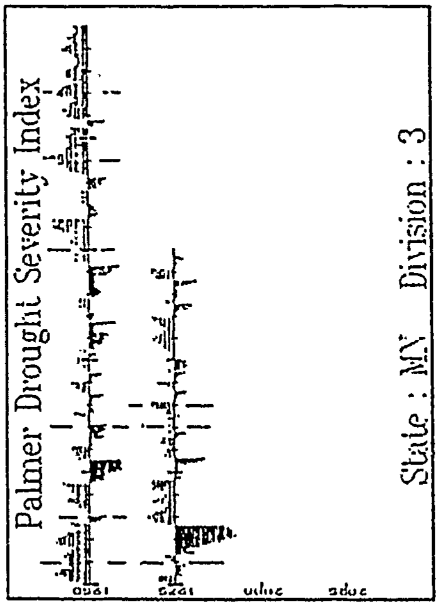

Palmer Drought Severity Index
State : MN Division : 1


Palmer Drought Severity Index
State : MN Division : 2


Palmer Drought Severity Index
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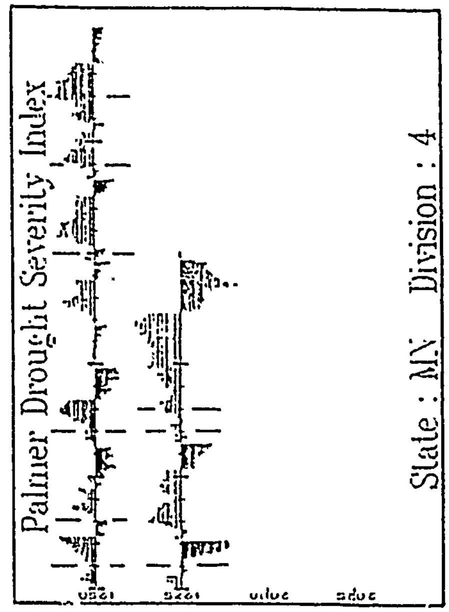
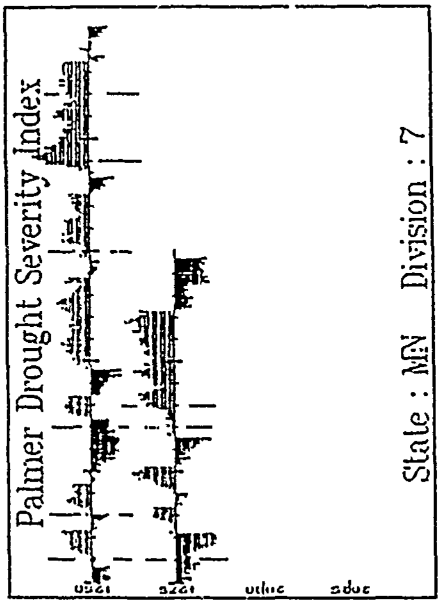
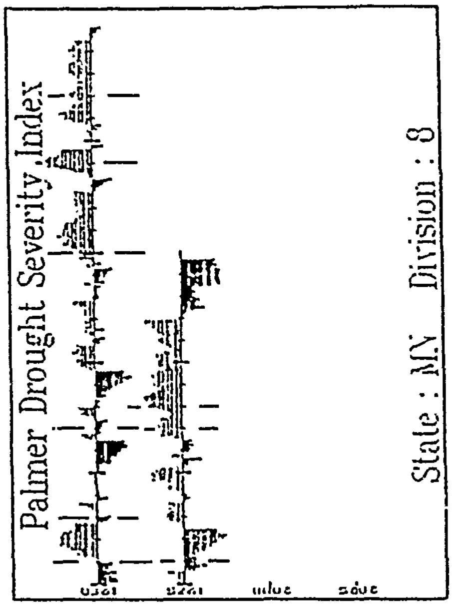
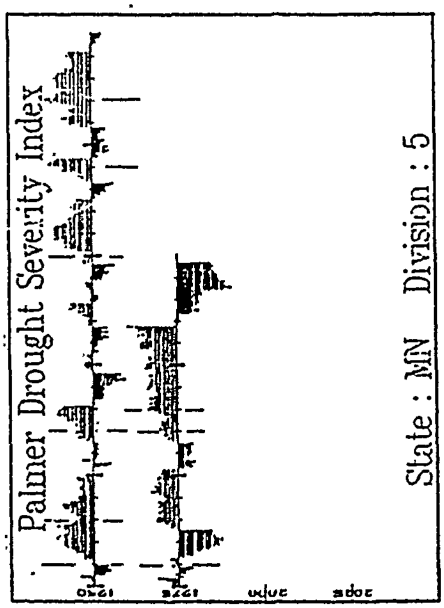
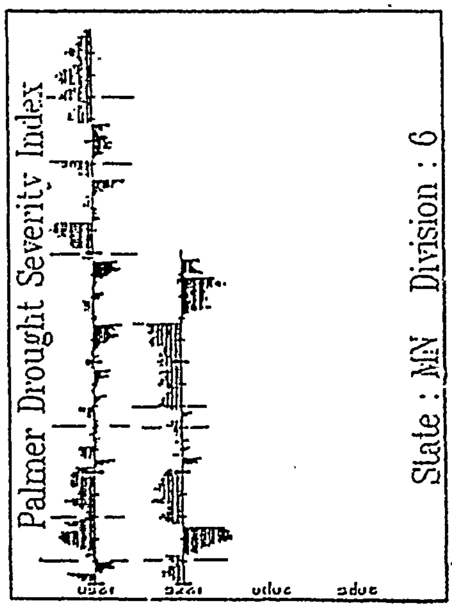
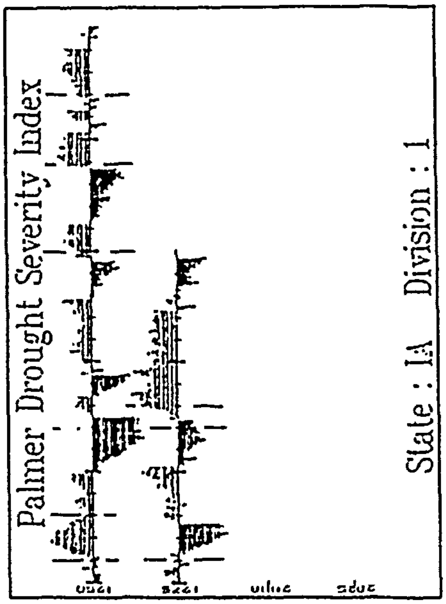

Palmer Drought Severity Index
State : MN Division : 4

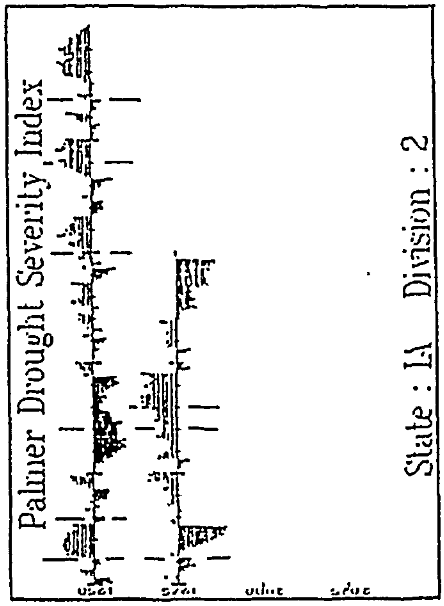

Palmer Drought Severity Index
State : MN Division : 7

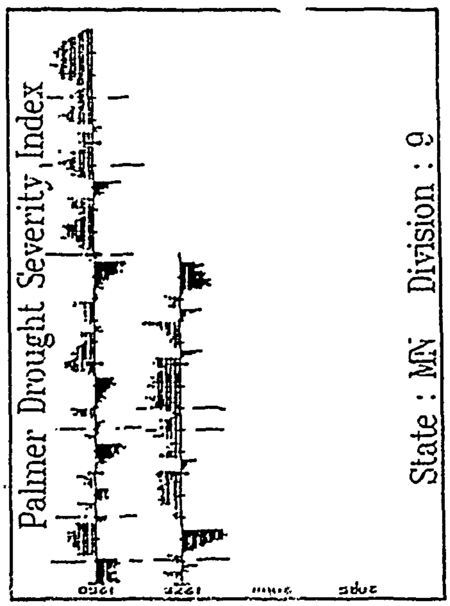

Palmer Drought Severity Index
State : MN Division : 8

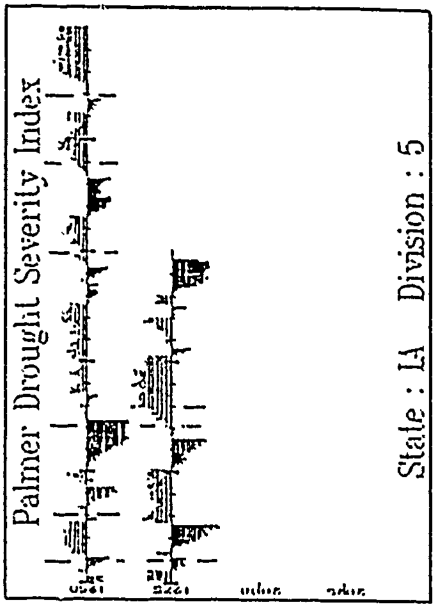

Palmer Drought Severity Index
State : MN Division : 5

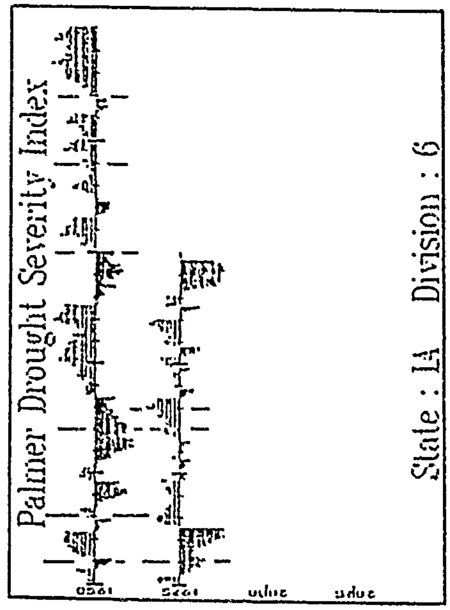

Palmer Drought Severity Index
State : MN Division : 6

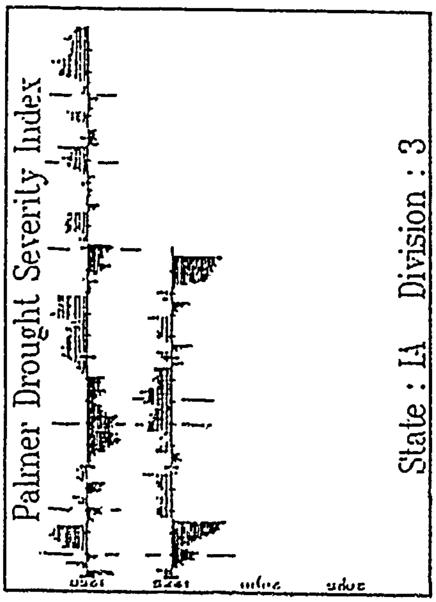

Palmer Drought Severity Index
State : IA Division : 1

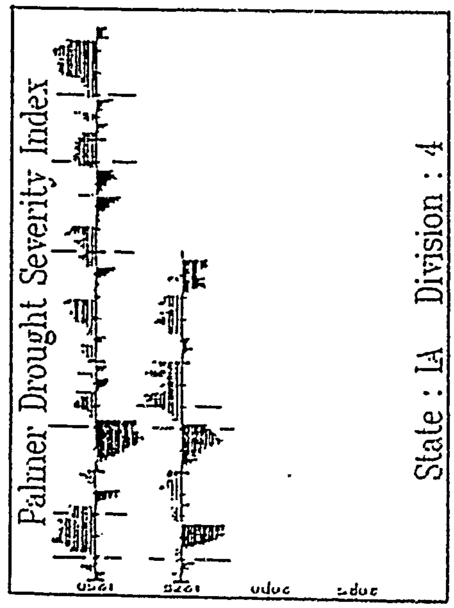

Palmer Drought Severity Index
State : IA Division : 2

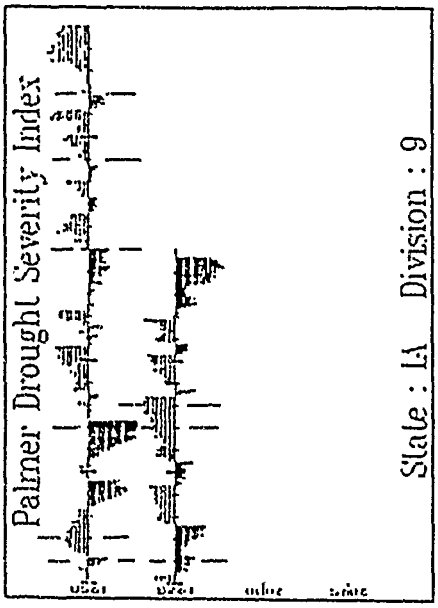

Palmer Drought Severity Index
State : MN Division : 9

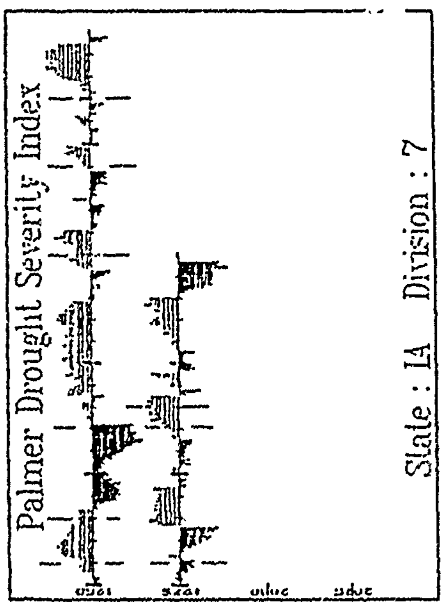

Palmer Drought Severity Index
State : LA Division : 5

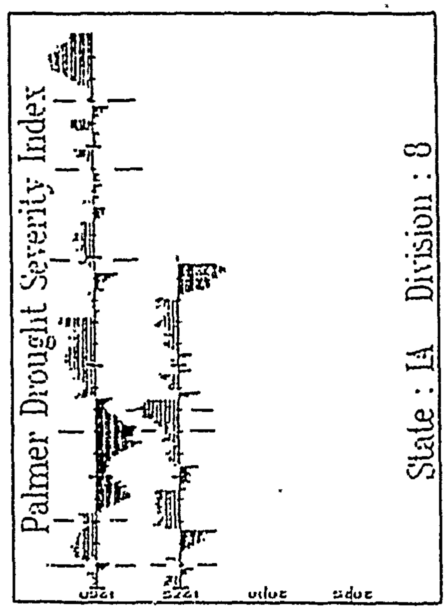

Palmer Drought Severity Index
State : LA Division : 6

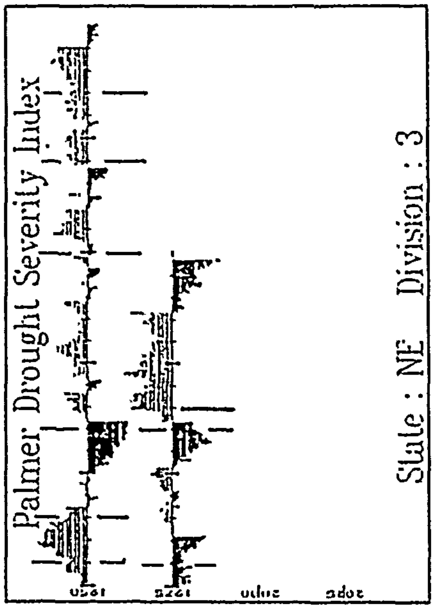

Palmer Drought Severity Index
State : LA Division : 3

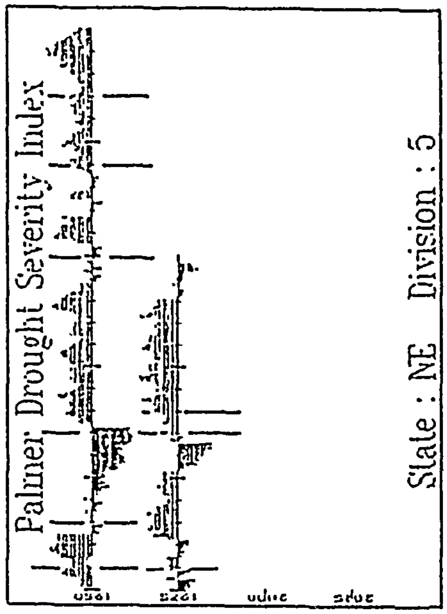

Palmer Drought Severity Index
State : LA Division : 4


Palmer Drought Severity Index
State : IA Division : 9


Palmer Drought Severity Index
State : IA Division : 7


Palmer Drought Severity Index
State : IA Division : 8


Palmer Drought Severity Index
State : NE Division : 3


Palmer Drought Severity Index
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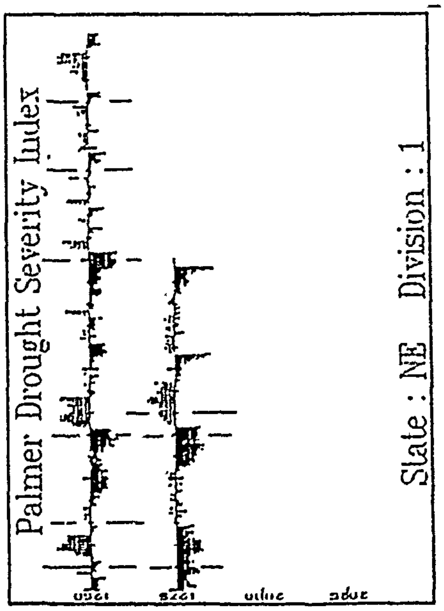
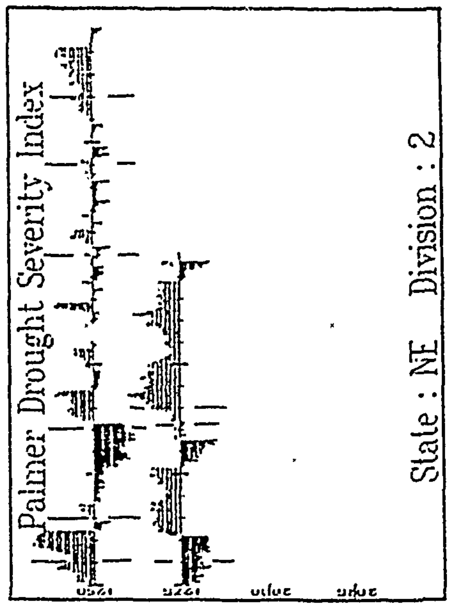
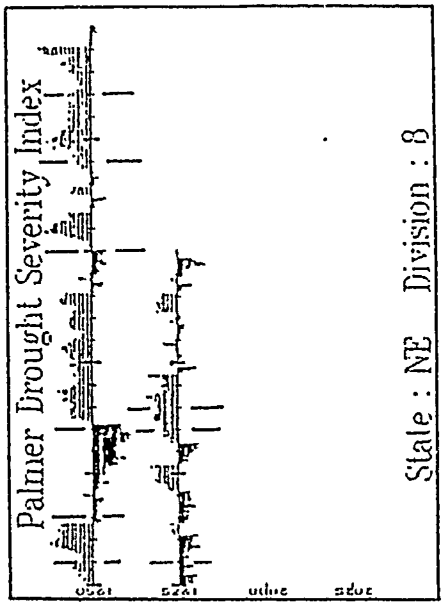
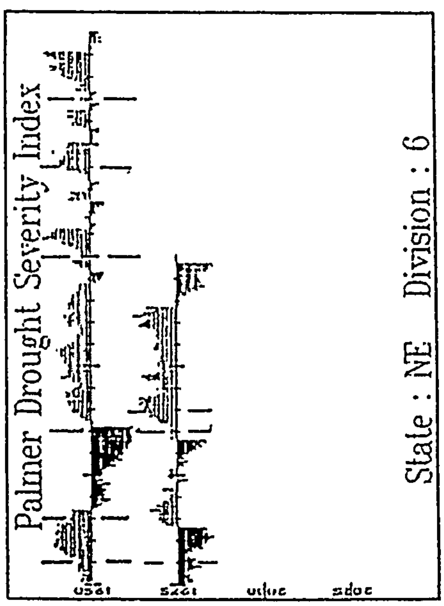
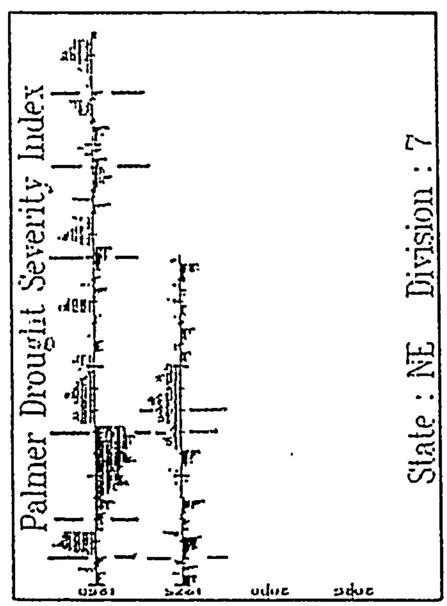

Palmer Drought Severity Index
State : NE Division : 1


Palmer Drought Severity Index
State : NE Division : 2


Palmer Drought Severity Index
State : NE Division : 8


Palmer Drought Severity Index
State : NE Division : 6


Palmer Drought Severity Index
State : NE Division : 7

Appendix G. Yearly Corn-Yield Averages for the U. S. and the Five Midwestern States.
(bushels/acre) (USDA-SRS, ANNUAL CROP AND LIVESTOCK SUMMARIES)

YEAR	US AVE	IOWA	INDIANA	NEBRASKA	MINNESOTA	ILLINOIS
1950	37.4	47.0	49.5	37.0	38.0	51.0
1951	35.9	43.5	53.0	26.5	39.5	55.0
1952	40.4	64.0	50.0	37.0	50.5	58.0
1953	39.6	53.0	51.5	28.0	48.0	54.0
1954	38.1	52.5	53.5	28.0	50.5	49.5
1955	40.6	48.5	56.0	18.0	49.0	56.0
1956	45.7	51.0	62.0	22.0	57.5	68.0
1957	47.1	62.0	59.0	46.0	56.5	64.0
1958	51.8	65.5	63.0	51.5	54.5	69.0
1959	53.1	65.0	118.4	48.5	49.0	67.0
1960	54.7	62.0	65.7	50.5	52.5	68.0
1961	62.4	75.5	74.0	52.0	64.5	77.0
1962	64.7	76.0	82.0	61.0	59.5	83.0
1963	67.9	81.5	87.0	56.0	67.2	85.0
1964	62.9	77.0	72.0	52.0	53.1	78.0
1965	74.1	82.0	94.0	70.0	61.0	94.0
1966	73.1	89.0	78.0	79.0	76.0	80.0
1967	80.1	88.5	82.0	74.0	72.0	100.0
1968	79.5	93.0	85.0	74.0	81.0	89.0
1969	85.9	98.0	96.0	93.0	85.0	98.0
1970	72.4	86.0	76.0	76.0	85.0	74.0
1971	88.1	102.0	101.0	85.0	83.0	106.0
1972	96.9	116.0	104.0	104.0	93.0	110.0
1973	91.3	107.0	102.0	94.0	93.0	103.0
1974	71.9	80.0	71.0	68.0	61.0	83.0
1975	86.4	90.0	98.0	85.0	70.0	116.0
1976	88.0	91.0	110.0	85.0	59.0	107.0
1977	90.8	86.0	102.0	99.0	100.0	105.0
1978	101.0	115.0	108.0	113.0	104.0	111.0
1979	109.7	127.0	112.0	115.0	100.0	128.0
1980	91.0	110.0	96.0	85.0	97.0	93.0
1981	109.8	127.0	109.0	115.0	110.0	128.0
1982	114.8	121.0	129.0	111.0	113.0	134.0
1983	81.0	87.0	73.0	96.0	84.0	79.0
1984	106.6	112.0	117.0	116.0	107.0	114.0
1985	118.0	126.0	123.0	128.0	115.0	135.0
1986	119.3	135.0	122.0	128.0	122.0	135.0
1987	119.4	130.0	135.0	131.0	127.0	132.0

Appendix H. Yearly Corn-Yield Averages for the U. S. and the Five Midwestern States After a 9-Year Smoothing Technique
(bushels/acre)

YEAR	US AVG	IOWA	INDIANA	NEBRASKA	MINNESOTA	ILLINOIS
1950	37.6	51.7	51.8	31.5	45.3	53.0
1951	38.0	50.4	52.3	30.2	45.7	52.9
1952	39.9	52.6	54.5	30.4	47.9	56.1
1953	40.4	52.7	54.3	31.6	48.2	56.9
1954	41.8	54.1	55.6	33.7	49.3	58.2
1955	45.6	56.1	56.9	34.9	50.6	60.1
1956	45.7	58.2	58.3	37.6	52.0	61.5
1957	48.1	59.4	61.0	39.3	53.6	63.6
1958	50.9	62.0	64.4	41.9	54.8	66.8
1959	54.2	65.2	68.1	45.1	56.7	70.8
1960	56.7	68.4	69.9	48.8	57.1	73.2
1961	59.9	71.8	73.4	54.2	57.5	76.1
1962	62.7	74.8	75.6	57.8	59.7	77.9
1963	65.9	77.4	77.7	60.3	61.6	81.3
1964	68.8	80.5	80.0	63.2	65.2	83.8
1965	72.3	84.5	83.3	67.9	68.8	87.1
1966	73.4	85.6	83.6	70.6	71.1	86.8
1967	76.0	88.5	85.7	73.2	73.7	89.3
1968	79.2	92.4	87.6	78.6	76.6	92.1
1969	82.4	95.7	90.9	83.2	81.0	94.9
1970	82.1	96.6	88.3	83.0	81.0	93.7
1971	83.6	95.6	90.6	83.7	80.3	97.7
1972	84.5	95.8	93.7	84.9	78.9	98.4
1973	85.7	95.0	95.6	87.7	81.0	100.2
1974	87.4	97.0	96.9	89.9	83.1	101.7
1975	91.6	101.5	100.8	94.2	84.8	107.7
1976	91.9	102.4	100.3	94.2	86.3	106.2
1977	93.3	103.6	100.8	95.4	88.2	108.2
1978	95.9	105.2	103.8	97.3	90.4	111.7
1979	96.9	106.0	104.1	100.4	93.0	111.2
1980	100.6	108.4	106.2	103.9	97.1	111.0
1981	102.7	112.3	107.6	108.7	103.3	114.1
1982	105.7	117.7	109.9	111.9	105.8	117.4
1983	107.7	119.4	112.9	113.9	108.5	119.8
1984	112.0	122.6	118.3	120.4	114.1	124.9
1985	113.4	123.4	120.6	124.1	116.2	125.4
1986	119.1	130.8	128.0	129.3	122.7	133.7
1987	119.4	132.2	129.2	129.7	124.8	132.9

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