1988

CROPSTATUS--A Computer Program to Assess the Effects of Seasonal Weather Changes on Nebraska's Agriculture

R. E. Neild
University of Nebraska-Lincoln

Donald A. Wilhite
University of Nebraska-Lincoln, dwilhite2@unl.edu

K. G. Hubbard
University of Nebraska-Lincoln, khubbard1@unl.edu

Published in Identifying and Coping with Extreme Meteorological Events, edited by E. Antal and M. H. Glantz, pp. 351-366
(Budapest: Hungarian Meteorological Service, 1988).

CROPSTATUS – A COMPUTER PROGRAM TO ASSESS THE AFFECTS OF SEASONAL WEATHER CHANGES ON NEBRASKA'S AGRICULTURE

R. E. Neild, D. A. Wilhite and K. G. Hubbard
Center for Agricultural Meteorology and Climatology, University of Nebraska, Lincoln, Nebraska

ABSTRACT

CROPSTATUS is a series of programs residing in Nebraska's AGNET system using daily weather data to assess seasonal changes in crops, livestock and other agricultural conditions. Assessments are based on parameters developed from accumulations of current daily temperature and precipitation data collected from a network of synoptic, climate and automated micrometeorological stations in Nebraska in comparison with daily normals. The daily normals were derived from monthly summaries using multiple regression models to compute daily values as a function of Julian day numbers. Crop phenology models based on growing degree days were used to monitor and forecast the progress of different crop strains and times of planting. Biological time scale statistical yield models are used for production estimates.

Weather probability information is also available from CROPSTATUS. Long term climatic records have been used to determine spring and autumn freeze probabilities, preseason precipitation available for subsoil moisture recharge and the probabilities of weekly averages of daily maximum and minimum temperatures. These and other features are available in a menu of over 20 different agricultural weather information items developed from a network of 60 weather stations. CROPSTATUS is also used to prepare tabular data and computer maps showing changes in conditions throughout the state. These maps are used in meetings by an interdisciplinary

committee of agricultural extension specialists to prepare weekly agweather situation/advisory reports.

INTRODUCTION

Nebraska produces 1,000,000,000 bushel of grain, 7,000,000 tons of hay and 11,000,000 head of livestock annually with a total value of $6,000,000,000. Agriculture is the largest industry in Nebraska. The effect of weather on this $6,000,000,000 production is of interest to farmers and ranchers, agribusinesses, and groups of other affected citizens. It is the most frequently discussed subject throughout the state. Current information is needed in order for these discussions to take place objectively and for decisions to be timely.

A computer program called CROPSTATUS was, therefore, developed to provide information to assess the effects of seasonal weather changes on the agweather situation in Nebraska. Following is a discussion of the type of input data used by CROPSTATUS, the information menus it provides, and some examples of its information output.

INPUT DATA AND INFORMATION

A. *Current daily weather data*: Daily maximum-minimum temperatures and precipitation from weather stations located at airports /as part of the National Weather Service forecast network/, from a network of volunteer observers in small rural communities /that supply climatic data to the National Environmental Data Information Service/, and from special automated stations providing micrometeorological data are collected and stored in the AGNET system. This is the source of current weather data used by CROPSTATUS and by other agweather programs. The details of these weather networks and their linkages into the AGNET system have been described by Hubbard et al. /1983/.

B. *Daily Normals*: Though generally available, monthly weather normals of temperatures and precipitation are too long and out of phase with critical phases of crop development and associated farming operations such that their use in agriculture is limited. When only monthly summaries are available, it is necessary to wait until the end of each month to determine if seasonal conditions are ahead or behind normal. Daily averages and daily accumulated values are not time restrictive, but permit critical stages of plant development and associated agricultural operations to be oriented to seasonal climatic patterns on a phenological time scale. Daily normals provide a basis for making real time assessments of the affects of seasonal changes in weather by enabling comparisons of current and normal conditions on any day.

Daily average temperature normals were derived from monthly temperature normals using the following multiple regression model.

$$Y = b_0 + b_1 \cos[(2\pi/365)X] + b_2 \sin[(2\pi/365)X] + b_3 \cos[(4\pi/365)X] + b_4 \sin[(4\pi/365\ X]$$

Where:

Y = monthly average temperature

X = day number of the year at the mid-point of each month

Daily average accumulated precipitation was calculated from monthly averages as:

$$\frac{[(Xi/2) + (Xi + 1)/2]}{Ni + ni + 1}$$

Where:

Xi/2 = half the monthly average precipitation
/Xi + 1/2 = half the monthly average precipitation from the adjacent month.
ni and ni + 1 are the number of days in adjacent half month periods.

The procedure is discussed in greater detail in a publication concerning agriculturally oriented weather normals by Neild et al. /1978/ which compares daily normals calculated from long term monthly averages with actual daily data.

These daily temperature and precipitation normals were used as a basis of comparison with current temperature and precipitation accumulations from certain dates to see if seasonal conditions are ahead or behind normal and by how many days, millimeters, or by what percent.

C. *Crop Phenology Models:* A growing plant progresses through a series of phenological stages before it matures. After germinating and emerging from the soil, a young plant develops a number of leaves, flowers, and produces small fruit or grains which also pass through phases before maturing and becoming ready for harvest. These various phases have different environmental requirements which must be met before the developing crop can pass from one stage to the next. The various phenological phases of crops such as emergence, 2-leaves, 16-leaves, flowering, soft kernels, hard kernels and maturity have been assigned a numerical scale for convenient reference, Hanway /1971/ and Vanderlip /1972/.

Growing degree days /GDD/, a concept relating plant growth and development to temperature accumulations have been used to obtain phenology models for different crop strains, Neild and Seeley /1977/. An example of a phenology model for an early maturing maize hybrid, A619 x A632, is graphically illustrated in Figure 1. The vertical or dependent /Y/ axis of the graph shows the phenology stages and stage numbers. The horizonal or independent /X/ axis of the graph shows the accumulated degree days above $10^{o}C$. These data were obtained from an analysis of weekly observations of phenology stage number and accumulated GDD from different plantings made on a seasonal temperature gradient in 1975-

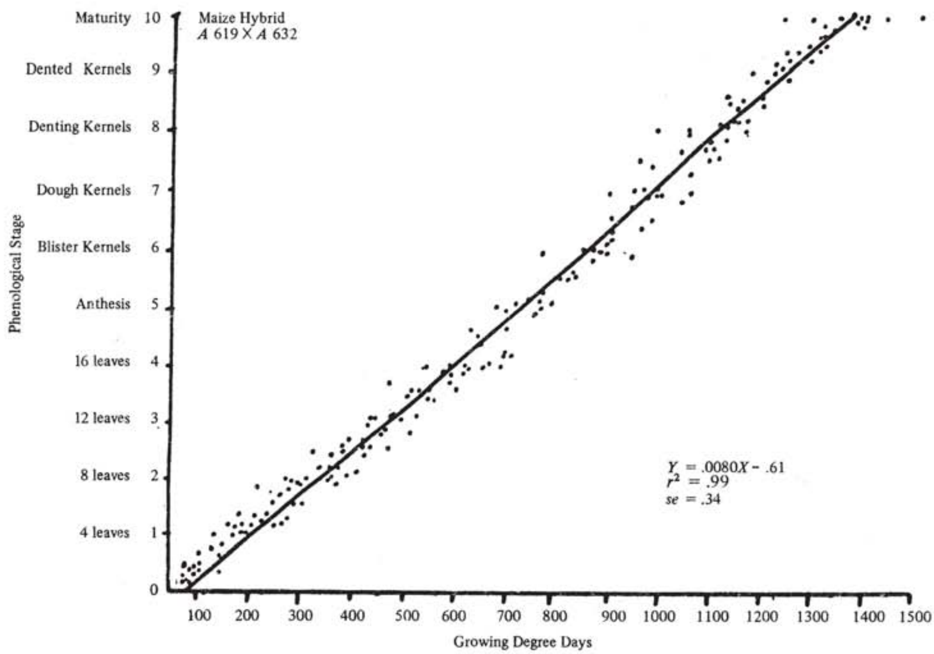


Fig. 1. Phenology/growing degree day model for maize hybrid A619 X A632

1976. The equation $Y = .0080X - .61$ is the phenology model for hybrid A619 x A632. Similar models have been developed for other strains of maize and for grain sorghum, winter wheat and millet. These models were used to estimate current stages of crop development throughout the state and to predict stages of crop development at future dates.

D. *Yield Models:* Data sets consisting of historic yield data from 1950-1974 from Nebraska's principal grain producing regions and corresponding weather data were used to develop statistical models that enable predictions of yields of maize, grain sorghum and wheat on a real time basis, Seeley /1978/ and Neild, /1982/. Phenology models were used to orient the following weather variables' biological time scale.

1. Precipitation available for subsoil moisture recharge between growing seasons.
2. Precipitation during different phenology phases.
3. The number of days during different phenology phases with minimum temperatures stress limits below 7, 10, 13, 15 and 18°C.
4. The number of days during different phenology stages with maximum temperatures stress limits above 27, 30, 32, 35, 37°C.
5. Year number as a "dummy" variable to measure the affect of technological improvements on yield over time.

Multiple regression was used to determine what phenology stages and which weather variables were most critical to grain yields.

The following is an example of a yield model in CROPSTATUS developed for dryland maize:

$$Y = 13.3\ X_1 + 4.5\ X_2 - 10.3\ X_3 + 6.1\ X_4 - 466.8$$

Where:

Y = Kilogram of grain per hectare

X_1 = year number to account for technological improvements.

X_2 = Centimeters of precipitation available for subsoil moisture recharge during an 8 1/2-month period September 1 to May 15.

X_3 = The number of days with stressful daily maximum temperature over 35°C during the ear formation, reproduction and grainfill stages. This period begins when 480 GDD-10 /the requirement for ear formation/ have been accumulated and ends when 1215 GDD-10 /the requirement for denting kernels/ have been accumulated.

X_4 = Centimeters of precipitation during grainfill. It begins with anthesis /775 GDD-10/ and ends with denting kernels /1215 GDD-10/.

Weather input to the model is in the form /Xa + Xn/

Where:

Xa = actual daily weather variable accumulated from the beginning of the critical period to current time a.

Xn = normal daily weather variable accumulated from current time a to time n, the future end of the critical period.

E. *Probabilities:* Spring and autumn freeze probabilities, and precipitation probabilities during the preseason subsoil moisture recharge period /September 1 - May 15/ are also used in CROPSTATUS. These probabilities were determined from analyses of long term /over 70 years/ of daily climatic records. Studies have shown that there is a high probability that yields of maize, grain sorghum, soybeans and alfalfa will be above average when preseason precipitation is above average. As an aid to farming decisions, analyses were made of long term precipitation records to determine the probabilities that future precipitation, Ni, between different decision times and planting time /May 15/ will be sufficiently high enough when added to current precipitation between September 1 and decision times, so that the preseason precipitation /September 1 - May 15/ will be average or higher. The model for this analysis is:

$$A - Ci = Ni$$

Where:

A = the average precipitation for the recharge period September 1 - May 15.

Ci = the current precipitation between September 1 and decision times March 1, March 15, April 1, April 15 and May 1.

Ni = the future precipitation for periods beginning at decision times March 1, March 15, April 1, April 15 and May 1 and planting time May 15.

A series of graphs showing the probabilities that preseason precipitation will be average or above by planting time May 15 depending on the amount accumula-

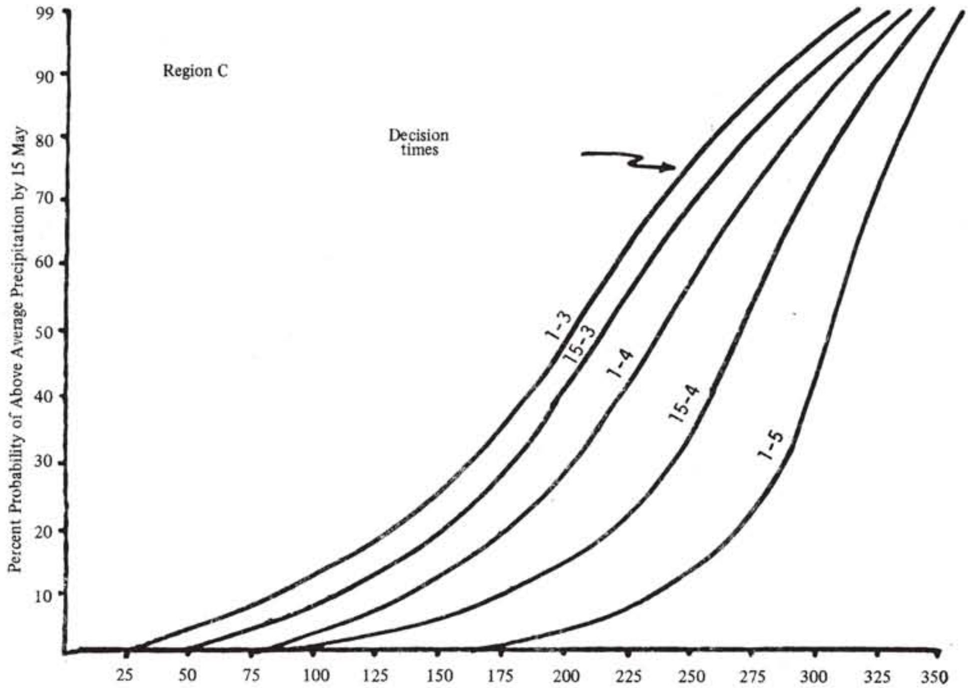


Fig. 2. Probabilities that preseason precipitation will be above average by planting times /15 May/ in region C depending on the amount accumulated from 1 September to different decision times during a 75-day period prior to planting

ted from September 1 to different decision times during a 75-day period prior to planting are shown in Figure 2.

INFORMATION MENU:

There is a menu of 20 different crop/weather information items in CROPSTATUS. A brief description of these items is as follows:

A. PRECIPITATION TO DATE

Moisture conditions for a crop are reflected in a general way by the accumulation of precipitation. Accumulations of precipitation received since the most recent July 1, September 1 and January 1 compared with normal amounts for the same time periods are shown for each station.

B. PRECIPITATION BETWEEN ANY 2 DATES

You don't need an adding machine and a weather data listing for each station to find the precipitation accumulations. Just use Report B. Accumulated rainfall in inches is given for the specified dates. The dates are selected by entering the beginning month and day and the ending month and day: /M D M D/. For example an entry of 7 1 7 31 will result in an accumulation starting on the 1st day of July and ending on the last day of that month. Only the most recent year of data is available to this report.

C. HEATING DEGREE DAYS

If you are interested in assessing recent heating requirements due to the weather conditions then you will want to look at report C. Accumulated heating degree days are highly correlated to the total energy needed to heat buildings during the same period. This report gives the actual accumulation of heating degree days for the period September 1 through the /present or chosen/ date. The report also shows the normal accumulation of heating degree days and the departure from normal /%/ for the same period. A projection for the remainder of the heating season includes an estimate of the heating degree day accumulation, normal, and departure from normal.

D. COOLING DEGREE DAYS

If you are interested in assessing recent air-conditioning needs due to the weather conditions, then you will want to look at Report D. Accumulated cooling degree days are highly correlated to the total energy needed to cool buildings during the same period. This report gives the actual accumulation of cooling degree days for the period May 1 through the /present or chosen/ date. The report also shows the normal accumulation of cooling degree days and the departure from normal /%/ for the same period. A projection for the remainder of the cooling season includes an estimate of the cooling degree day accumulation, normal, and departure from normal.

E. PROBABILITY OF PRECIPITATION FOR SPRING PLANTING

NOTE: REPORT AVAILABLE FROM MARCH 16 TO JUNE 13

The probability of receiving precipitation during the spring planting season is shown in this report. Crop planting schedules may need to be adjusted depending on the current soil moisture conditions and the probability of receiving moisture as shown in this assessment.

F. PROBABILITY OF FREEZE

Spring and fall dates are given for the following probabilities of freeze occurrence: 95, 75, 50, 25, and 5 percent. In this report freezing refers to the occurrence of air temperatures at or below 0° C. /32°F/. For example, you can interpret an entry in the spring table as: 'There remains a 95 percent chance of freeze occurring at the station on or after April 10.'

G. WEATHER DATA LISTING

Listings of weather data for the selected stations are generated in Report G. When G has been selected you are prompted to enter the starting month, day and year of the listing to be generated and the number of days to be listed. The maximum and minimum daily temperatures and precipitation are listed for each day.

H. REGIONAL SOIL TEMPERATURES

Soil temperatures are an important consideration in assessing when to plant a specific crop. The seeds of crops will not germinate and grow if the soil temperature is too cold. Threshold temperature levels for a few crops are:

CROP	TEMPERATURE $^{\circ}$F	TEMPERATURE $^{\circ}$C
Oats, Sugar Beets	41 to 42	5 to 5.6
Potatoes	45 to 46	7.2 to 7.8
Corn	55	12.8
Beans, Soybeans or Grain Sorghum	60 to 61	15.6 to 16.1

The soil temperature at the 4 - inch depth is given for selected stations in the automated weather data network. Weekly averages are shown for the most recent 4 weeks and the most recent observation is given as the last entry in the soil temperature table.

I. REGIONAL CLIMATIC NARRATIVE

A general narrative of the weather and climate is given for any of none sections or regions of the state. Choose one of the following regions:

Following regions:

SE=South East	SC=South Central	SW=South West
EC=East Central	C = Central	SP=Southern Panhandle
NE=North East	NC=North Central	NP=Northern Panhandle

J. REGIONAL CLIMATE STATISTICS

Various climate statistics are given for any of nine sections of regions of the state. Included are the means and extremes in climate for the region and the average dates of certain weather events. Choose one of the following regions:

SE=South East	SC=South Central	SW=South West
EC=East Central	C =Central	SP=Southern Panhandle
NE=North East	NC=North Central	NP=Northern Panhandle

K. REGIONAL CLIMATE OUTLOOK

If you're interested in an outlook based upon historical climate, then you will want to use report K. The range of weather conditions to be expected is given. Certain normals are presented and probability statements are issued for selected weather parameters. Choose one region:

SE=South East	SC=South Central	SW=South West
EC=East Central	C =Central	SP=Southern Panhandle
NE=North East	NC=North Central	NP=Northern Panhandle

L. LIVESTOCK STRESS

Hot, humid weather conditions can cause physical stress of livestock. The time /total number of hours/ in each of 3 stress categories is given. The categories and expected problems in handling and transit of livestock are taken from a NWS study and should be interpreted for local conditions. For specific information on livestock stress contact an extension agent or an extension livestock specialist.

M. WIND CHILL

The wind chill equivalent temperature expresses the combined effect of actual air temperature and wind speed. The wind chill equivalent temperature attempts to answer the question: How cold would it need to be in relatively still air to feel as cold as it now does with the current winds? Clothing and shelter are essential in extremely cold wind chill situations.

R. GROWING DEGREE DAYS

If you're interested in the rate of development of crops you will want to look at Report R. Growing degree days are the accumulation of temperatures above some threshold temperature. The threshold temperature and total growing degree days from planting to maturity are shown for several crops below:

CROP	BASE TEMPERATURE		GDD TOTAL	
	^{o}F	^{o}C	^{o}F	^{o}C
Barley	40	4.4	2000-2400	1111 - 1333
Spring wheat	40	4.4	2000-2400	1111 - 1333
Oats	40	4.4	2100-2400	1117 - 1333
Soybeans	50	10.0	2000-2400	1111 - 1333
Corn	50	10.0	2200-2800	1222 - 1555
Grain sorghum	50	10.0	2200-2600	1222 - 1444

The growing degree day requirement varies with the variety or hybrid within a crop category so consult your seed dealer for information on specific seed lots.

S. ESTIMATED EMERGENCE DATES

Seed germination and growth is accelerated by warmer temperatures. For a given planting date this report gives an estimated emergence date based on actual temperatures. If the estimation process calls for a projection into the future, the normal temperatures for the area in question are brought into play.

T. DEVELOPMENTAL STAGE

This report shows the estimated stage of development /based upon the present accumulation of growing degree days and a known relationship between stage of development and growing degree day accumulation/ for three maturity groups: early, main and late. A numeric value between 0 and 10 is given to indicate the point in development to which the crop has progressed. Below are identifiable stages on this developmental scale:

PLANT PART VISIBLE

Number	Corn	Sorghum	Winter Wheat
0.0	Tip above soil	Tip above soil	
0.5	2 full leaves		
1.0	5 full leaves	Collar of 3rd leaf	Crown, tillers
1.5	6 full leaves		
2.0	8 full leaves	Collar of 5th leaf	Sheath elongation
2.5	10 full leaves		
3.0	12 full leaves	8th leaf-differentiation	Culm elongation
3.5	14 full leaves		
4.0	16 full leaves	Final leaf in whorl	Flag leaf
5.0	Silks, Pollen	Head in flag leaf sheath	Heading
6.0	Kernels blistered	Half bloom	Flowering
7.0	Kernels at dough	Kernels at soft dough	Anthesis complete
8.0	Kernels denting	Kernels at hard dough	Kernels-soft dough
9.0	Kernels full dent	Fully mature	Kernels-hard dough
10.0	Fully mature		Fully mature

U. MINIMUM STAGE NOW FOR MATURITY BY AVERAGE FREEZE DATE

Crops must reach a minimum stage of development by the date of this report to insure that maturity will be reached by the average freeze date at the location in question. This minimum stage is estimated from the degree day requirements for the crop and the number of degree days remaining in the average season.

V. ESTIMATED DATES OF MATURITY

An estimate of the date of maturity is made using all the relevant data. The planting date, the maturity class of the crop selected, the degree day accumulation to date and a projection of degree days based on climatic normals are used to arrive at the estimated date of maturity.

The maturity date can vary greatly from year to year. A table has been included in this report that shows the freeze probability associated with the estimated date of maturity. If you want to estimate the potential for field drying a crop to a certain moisture level, you will want to use this report. The number of growing degree days remaining from the time that maturity is reached to the average freeze date is estimated from the relevant data.

W. YIELD ASSESSMENT

The potential for yield varies considerably with the weather conditions. A prediction equation is used in this report to estimate the yield based on weather conditions. Input into these equations may include: the number of stress days, the preseason precipitation and the precipitation during certain crop growth stages.

COMPUTER OUTPUT

Presented in Table 1 is an example of computer output from CROPSTATUS menu items R and T concerning GDD-40, the progress of the 1987 season and the phenology of winter wheat at 10 weather stations as of June 12, 1987. Shown in the columns from let to right are the current GDD-40 since March 1, 1987, the normal GDD-40 since March 1, XX, the days that the season is ahead as of June 12, 1987, the estimated phenological stage for winter wheat based on current GDD-40 since March 3, 1987 and the expected phenology stage for winter wheat on June 22, 1987 assuming normal temperatures for the 10-day period between June 12, 1987 and June 22, 1987.

For example, there are 1641 GDD-40 between March 1, 1987 and June 12, 1987 for Atkinson. The normal GDD-40 for this time period for Atkinson is 1231. The progress of the season in terms of days is measured as:

$$\frac{Ci - Ni}{Ri} = D$$

Where: Ci = current GDD accumulation at time i
Ni = Normal GDD accumulation at time i
Ri = Daily normal GDD at time i

Then: $$\frac{1641 - 1231}{18} = 14$$

The estimated phenological stage for winter wheat as of June 12, 1987 is 7.4; about half way between the beginning of grain-filling /stage 6/ and stiff dough /stage 8/. This was computed from the GDD/phenology model for wheat:

$$Y = 1.51 + .0036X$$

Where: Y = phenological stage number

X = GDD-40

Thus the phenological stage number for winter wheat at Atkinson on June 12, 1987 is 1.51 + /.0036/ /1641/ = 7.4

Estimates of phenology stage 10 days into the future are determined as:

$$Y = 1.51 + .0036 /X + X10/$$

Where:

X = Current GDD-40

X10 = Normal GDD-40 during next 10 days

Thus the expected phenological stage for winter wheat at Atkinson June 22, 1987 is 1.51 + /.0030/ /1641 + 328/ = 8.6; about half way between stiff dough and ripening.

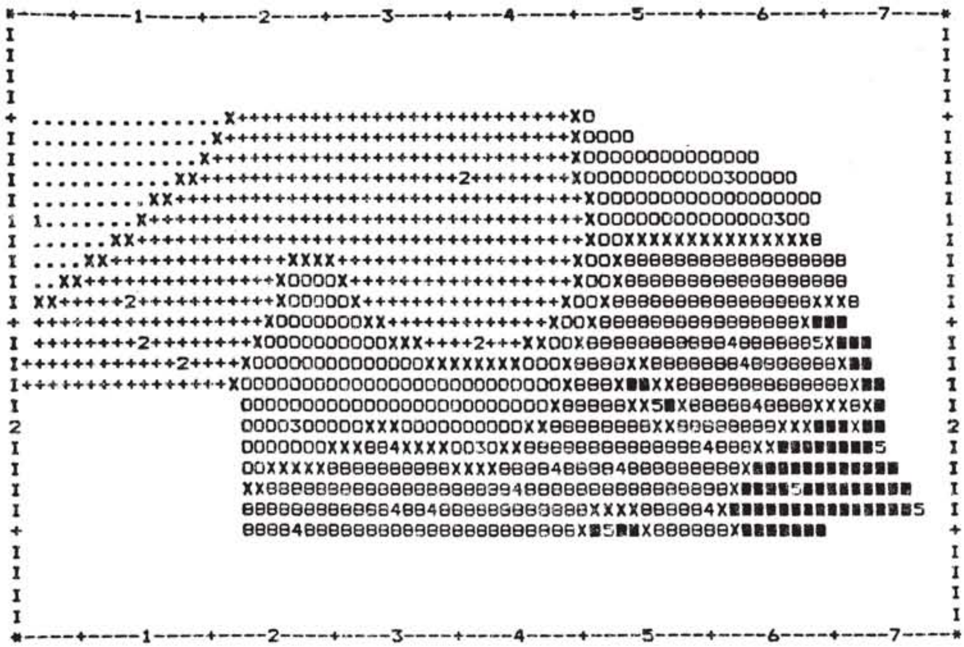
Tabular data such as is presented in Table 1 can also be mapped

TABLE 1

Growing degree day - 40^{O}F accumulations /current, normal and days ahead/ and estimates of winter wheat phenology for different locations in Nebraska as of June 12, 1987.

	GDD-40			Phenological Stage on Certain Dates	
	Current	Normal	Days Ahead	June 12	June 22
ATKINSON	1641	1231	14	7.4	8.6
CURTIS	1554	1428	4	7.1	8.4
FALLS CITY	1981	1719	8	8.6	10.0
HARRISBURG	1204	957	10	5.8	6.9
LINCOLN	1861	1531	10	8.2	9.5
MCCOOK	1551	1554	0	7.1	8.4
MINDEN	1778	1451	10	7.8	9.1
NORTH PLATTE	1473	1215	9	6.8	8.0
RED CLOUD	1643	1578	2	7.4	8.8
SCOTTSBLUFF	1324	1082	9	6.3	7.4

to show changes in the agweather situation throughout Nebraska. Figure 3 shows the phenological stage of winter wheat in Nebraska as of June 12, 1987. Because of temperature difference since March 1,



	BOOT	HEADING	HEADING & FLOWERING	FLOWERING	GRAINFILL

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	....	+++++++++	000000000	888888888	■■■■■■■■■
	....	+++++++++	000000000	888888888	■■■■■■■■■
	....1....	++++2++++	000030000	888848888	■■■■5■■■■
	....	+++++++++	000000000	888888888	■■■■■■■■■
	....	+++++++++	000000000	888888888	■■■■■■■■■
FREQ.	1	5	4	12	6

Fig. 3. Winter wheat development in Nebraska as of 6/12/87 based on GDD-40°F accumulations since 3/1/87

1987, there is considerable difference in GDD-40 and the development of winter wheat across Nebraska. The dark shaded area shows sufficient GDD-40 for wheat development to have advanced to the grainfill stage in the southeast with development progressively delayed westward to only the boot stage as shown by the dotted area in the northwest.

LITERATURE CITED

Hubbard, K.A., Rosenberg, N.J. and Nielsen, D. Automated weather data network for agriculture. Journal of Water Resources Planning and Management 109, 3, July, 1983.

Neild, R.E., M.W. Seeley and N.H. Richman. The computation of agriculturally oriented normals from monthly climatic summaries. Agricultural Meteorology. 19, 181-187. 1978.

Hanway, J.J. How a corn plant develops. Iowa State University of Science and Technology. Special Report 40, 1971.

Vanderlip, R.L. How a sorghum plant develops. Kansas State University Bulletin C 147, 1972.

Neild, R.E. and Seeley, M.W. Growing degree day predictions for corn and sorghum development and some applications to agriculture in Nebraska. Nebraska Agricultural Experiment Station Research Bulletin. 280, 1977.

Seeley, M.W. The development and application of biological time scale models for field corn hybrids in Nebraska. Unpublished Ph. D. Thesis, University of Nebraska, 1978.

Neild, R.E. Temperature and rainfall influences on the phenology and yield of grain sorghum and maize: A comparison. Agricultural Meteorology. 21, 79-88. 1982.