# Challenges in Dryland Agriculture — A Global Perspective

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# Program for Daily Weather Simulation

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## Introduction

Climate and day-to-day variations in weather have major influences on dryland agriculture and rangeland processes such as production, livestock water, insect dynamics, runoff, and erosion, as well as other agricultural and engineering management decisions. Weather data are needed to assess the effects of climate on agricultural and rangeland processes and as inputs to management models. For many dryland agricultural sites, climatic records of sufficient length are not available for making the desired analyses. Therefore, it is often desirable to have the capability to generate climatic data series which have the appropriate statistical characteristics for the location.

In this paper, we give a summary of the microcomputer program, CLIMATE.BAS (Woolhiser et al., 1985; 1988), and describe recent additions to the program. CLIMATE.BAS is a system which provides historical daily climatic information or simulated daily weather data for a location within a state or region. The daily climatic record includes precipitation, maximum air temperature, minimum air temperature, and solar radiation.

## Model Description

### Precipitation

The Markov chain-mixed exponential model (MCME) (Woolhiser and Roldan, 1986) is used to describe daily precipitation. Precipitation occurrence is described by a first-order Markov chain specified by parameters—$P_{00}(n)$, the probability of a dry day on day n given that day n-1 was dry, and $P_{10}(n)$, the probability of a dry day on day n given that day n-1 was wet. On wet days, the amount of precipitation greater than 0.254 mm is described by the mixed exponential distribution:

$$f_x(x) = q/\beta(n) \exp[-x/\beta(n)] + (1-\alpha)/\delta(n) \exp[-x/\delta(n)] \quad [1]$$

where $\alpha$ is a weighting parameter with values between 0 and 1, $\beta(n)$ and $\delta(n)$ are the means of the smaller and larger exponential distributions, respectively. The mean precipitation per "wet" day, $\mu(n)$, equals $\alpha\beta(n) + [1-\alpha]\delta(n)$. The parameter $\alpha$ is a constant and the seasonal variations in the parameters $P_{00}$, $P_{10}$, $\beta$, and $\mu$ are described by the Polar form of a finite Fourier series (Woolhiser and Pegram, 1979).

The Fourier coefficients for each parameter were originally estimated from 40 years of data for 20 South Dakota stations using numerical maximum likelihood procedures. Coefficients for each parameter are now available for other stations in the Northern Great Plains which include northeast Colorado, eastern Montana, Nebraska, North Dakota, and eastern Wyoming.

### Temperature and Solar Radiation

The procedure used in CLIMATE.BAS to describe the multivariate process of maximum temperature, minimum temperature, and solar radiation has been described by Richardson (1981) and Richardson and Wright (1984). In this model, the daily means of maximum temperature, minimum temperature, and solar radiation, conditioned on whether the day is wet or dry, are described by a Fourier series, as are the conditional standard deviations. Deviations from the means are modeled by the weakly stationary generating process used by Matalas (1967) for generating streamflow at multiple sites. The 12 parameter values required for each station can be interpolated from maps provided by Richardson and Wright (1984). The parameter values for several stations in each of the western states of the United States are stored in the computer program. [See Richardson and Wright (1984) and Woolhiser et al. (1988) for more complete discussion of this generation process.]

Since the work by Woolhiser et al. (1988) was completed, a subprogram has been added to CLIMATE.BAS to adjust daily solar radiation for sloping terrain (Richardson et al., 1987). This subprogram adjusts the solar radiation for a horizontal surface to the actual slope and aspect conditions existing at a site.

## The Program CLIMATE.BAS

The program CLIMATE.BAS is written in BASIC language and has been run on several different microcomputers. The program is available on diskettes.

The program is "user friendly" in that the user is guided through the program by a series of screen displayed questions. After the program is initiated, the user has the option of either using file data for the location in question or developing a data file for new stations. In the western United States, the next operation is to enter the latitude and longitude in degrees and minutes of the center of the geographic area under study. A map will then be drawn on the screen that includes an area 2 degrees north and south and 3 degrees east and west of the central grid location (Fig. 1). The next operation is to use the arrow keys to move the cursor to the desired location and have the 48 and 161 km radius circles drawn on the screen as illustrated in Figure 1. If there are one or more stations with the 48 km radius, the nearest neighbor estimate of the daily parameters can be used. The other option is to use the average values from the stations within the 161 km radius. Also, any of the stations can be omitted if they do not represent the study location, e.g., Lead, South Dakota, in Figure 1, which is a mountain station and may not represent the Great Plains conditions that surround the Black Hills.

The western United States map drawing subroutine is an addition to the earlier version of CLIMATE.BAS by Woolhiser et al. (1988). The earlier version had a routine to display the state of South Dakota on the screen. Also, a discussion in the paper by Woolhiser et al. (1988) outlines the procedures required to modify CLIMATE.BAS so that the program can be used for other states or regions. The version of CLIMATE.BAS discussed in this paper has the climatic parameter files, located in storage, for only a few locations in each of the western United States. Therefore, in order to perform daily weather simulations in some areas, it may be advisable to add parameter files for more locations within the area of study.

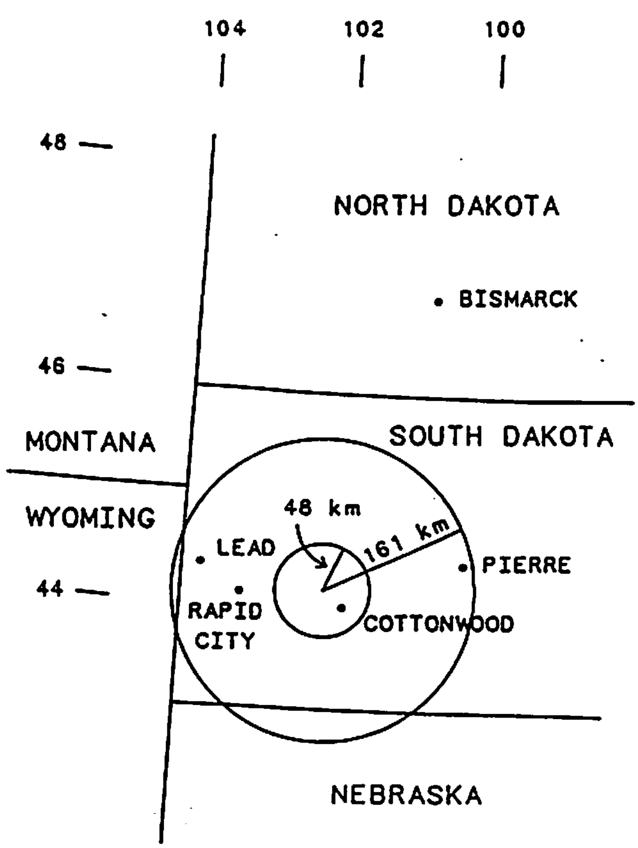


**Figure 1. An example of the area that is displayed on the screen with concentric circles around the location where weather data are desired.**

Next, the screen will provide options to select the calculation of the probabilities of various amounts of total precipitation or number of wet days for an n-day (n<30) period, beginning on any day of the year, or the simulation of n-years of climatic data. If the first option is selected, calculation of precipitation probabilities, the program will calculate the cumulative distribution functions and they can be displayed graphically on the screen, output to a line printer, or both.

If the second option is chosen, simulation of n-years of climate data, the sequence of instructions appears on the screen. By providing the proper input at the prompts, the user will obtain a sequential file of n years of simulated precipitation data or precipitation, maximum temperature, minimum temperature, and radiation data. These simulated data would then be readily accessible for use as input for daily simulation models such as SPUR (Wight and Skiles, 1987), which is a comprehensive rangeland resource model, and other hydrologic or plant growth models.

## Application of the Model

CLIMATE.BAS was used to generate a 30-year sample of weather data for Boise, Idaho, as an example of the application of the weather generation procedure (Table 1). The precipitation parameters were obtained from a 40-year record and the temperature and solar radiation parameters were obtained from the maps published by Richardson and Wright (1984).

Generated mean precipitation amount and average number of wet days per month and year were very close to that of the historic record. Generated mean daily maximum and minimum temperature compared favorably with the observed data for most months. The greatest difference between the monthly maximum temperature was 4°C for February and the greatest minimum temperature difference was 3°C for February and August. Historic and generated mean annual maximum and minimum temperatures were within 1°C.

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Table 1. Summary of historical and generated mean monthly climatic data for Boise, Idaho.

| | Precipitation | | Number of wet days | | Temperature | | | | Solar Radiation | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Maximum | | Minimum | | | |
| | H[a] | G[b] | H | G | H | G | H | G | H | G |
| | mm | | | | °C | | | | MJ m⁻² day⁻¹ | |
| Jan | 42 | 39 | 13 | 14 | 3 | 2 | -5 | -6 | 5.9 | 5.2 |
| Feb | 27 | 33 | 10 | 11 | 7 | 3 | -2 | -5 | 9.7 | 8.9 |
| Mar | 26 | 34 | 9 | 11 | 11 | 9 | -1 | -2 | 14.7 | 14.7 |
| Apr | 30 | 29 | 8 | 9 | 16 | 16 | 2 | 3 | 20.3 | 20.6 |
| May | 31 | 29 | 8 | 8 | 21 | 23 | 7 | 7 | 24.6 | 25.2 |
| Jun | 24 | 17 | 7 | 5 | 27 | 29 | 11 | 11 | 26.5 | 28.0 |
| Jul | 7 | 9 | 2 | 3 | 33 | 32 | 15 | 13 | 28.1 | 27.5 |
| Aug | 10 | 7 | 3 | 2 | 31 | 30 | 14 | 11 | 24.3 | 23.7 |
| Sep | 15 | 15 | 4 | 4 | 25 | 25 | 9 | 8 | 19.1 | 17.6 |
| Oct | 19 | 19 | 6 | 6 | 18 | 18 | 4 | 4 | 12.9 | 11.8 |
| Nov | 33 | 32 | 9 | 10 | 9 | 10 | -1 | -1 | 7.2 | 6.4 |
| Dec | 34 | 34 | 12 | 11 | 4 | 4 | -4 | -5 | 5.2 | 4.6 |
| An. Total | 298 | 297 | 91 | 94 | | | | | | |
| Month Ave. | | | | | 17 | 17 | 4 | 3 | 16.5 | 16.2 |

[a]H = historical (1951-1980).
[b]G = generated (30-yr simulation).


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