MOISTURE BALANCE AS A LOCATIONAL FACTOR FOR THE WESTERN HARVESTER ANT IN NORTH DAKOTA

Michael N. DeMers
Department of Geography-Meteorology
University of Kansas
Lawrence, Kansas 66045

ABSTRACT. North Dakota's most important group of harvesting ants is the genus Pogonomyrmex. These ants consume significant amounts of seeds from natural and cultivated vegetation. Clearings around their mounds cause problems to farmers and ranchers through reducing cropping and pasturage areas. The western harvester ant, P. occidentalis, has the largest range of the genus. Its spatial distribution ends just east of the Missouri River in North Dakota. P. occidentalis is not reported to be in moist areas of North America, so moisture balance was selected as a factor to study for determining the extent to which climatic conditions affect P. occidentalis's range. Based upon interpretation of data for a case study of southwestern North Dakota using SYMAP and SYMVU mapping packages as tools of locational analysis, it appears that there is no ecological gradient to the range of the species in North Dakota. P. occidentalis seems to be prohibited from establishing colonies in areas of low annual moisture deficit. However, further research in this aspect of North Dakota's zoogeography is necessary to establish if there are other factors which help also explain this specie's spatial distribution.

INTRODUCTION

Ants of the genus Pogonomyrmex constitute the most important group of harvesting ants in North Dakota. This genus inhabits dry regions of Mexico and the United States and collects food by tearing seeds from plants with powerful mandibles (Cole 1968). This seed harvesting has been cause for much concern among farmers in the American southwest. They consume great amounts of seed from both natural and cultivated vegetation. Large clearings created peripherally to the mounds reduce crop yields and limit grazing (King 1961).

The western harvester ant, P. occidentalis, occupies the largest geographic range of any species in the genus. Found from eastern California to central Oklahoma and from southern Arizona to southwestern North Dakota, its location corresponds roughly with the Upper Sonoran transitional life zone (Cole 1934) (Fig. 1). With the ant's range ending just east of the Missouri River in North Dakota, the state becomes an excellent laboratory for investigating the possible range controls on this species (Fig. 2).

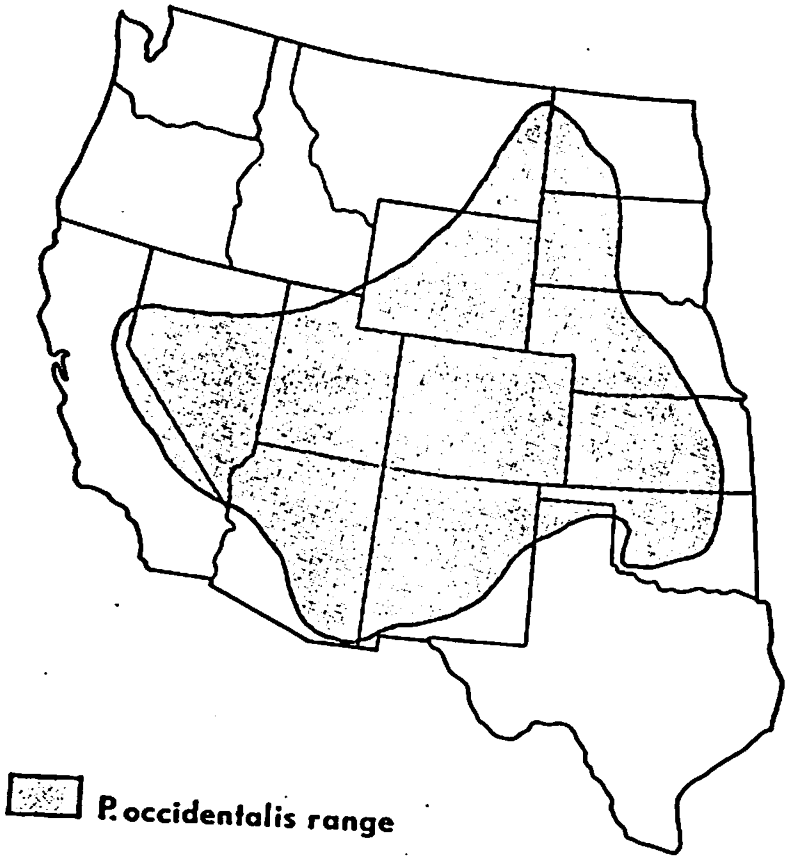

FIGURE 1. Location of P. occidentalis Range in the Western United States.

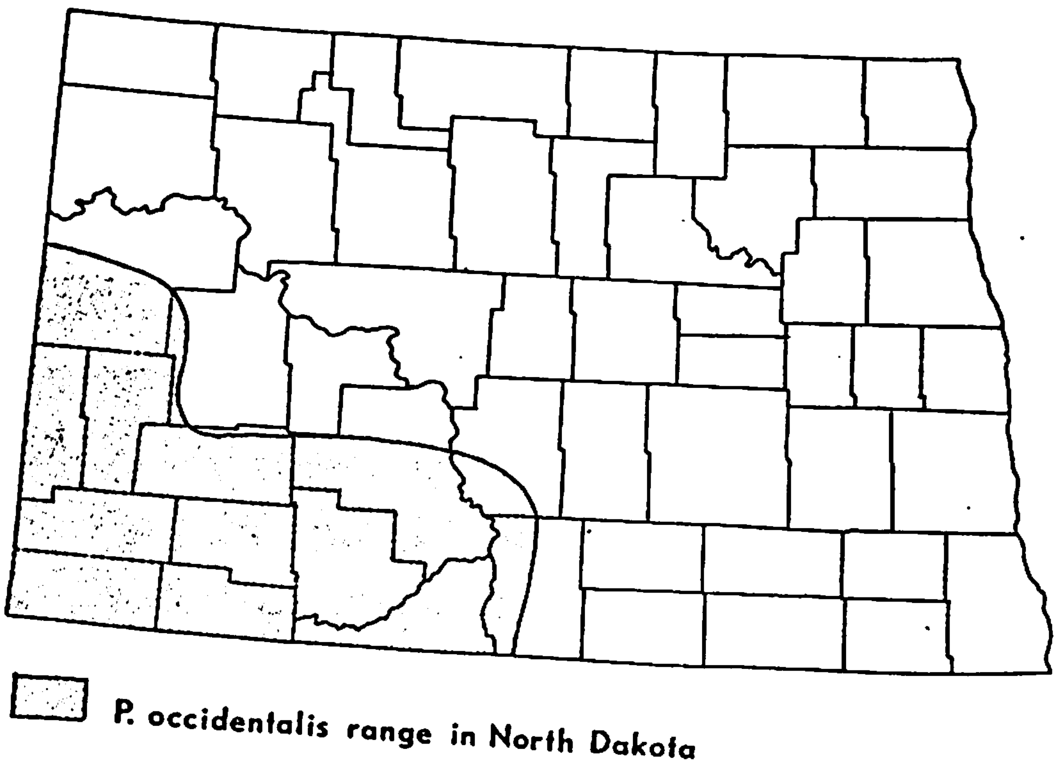

FIGURE 2. Range of P. occidentalis in North Dakota.

Researchers often refer to both ecological and behavioral adaptations to xeric conditions which occur in this species. Because P. occidentalis does not locate in moist areas of North America and since the highest concentrations of the species occur in semi-desert regions, it can be assumed that these adaptations play a large role in locational selectivity. Thus, moisture balance was selected for study to determine the extent to which it affests P. occidentalis distribution patterns.

BIOLOGICAL BACKGROUND

Often referred to as the "mound-building prairie ant," this large red ant builds conspicuous mounds which are located at or near the center of an area it clears of vegetation (Wheeler and Wheeler 1944). Its cone-shaped mounds indicate an environmental adaptation to temperature and moisture conditions. Mounds are constructed of excavated soil material and fine gravel, probably collected from the surface (Wheeler and Wheeler 1963). Wheeler and Wheeler (1963) speculated that the pebbles prevent mound destruction during heavy rains and high winds. Internal galleries in the mound allow excess moisture to drain, prevent drowning of the young and reduce waterlogging and sprouting of the ant's primary food source: seeds.

Mound shape also is thought to be an adaptation to temperature conditions. During the day, the rays of the sun strike at least one surface of the mound almost perpendicularly; thus, the mound would be warmer than the surrounding soil which receives more dispersed solar radiation (Cole 1933). This would permit the ants a longer foraging day by signaling an early exit from the mound before the foraging area reached similar temperatures.

There is some disagreement concerning the purpose of the clearing around the mound. Cole (1932a, 1932b) believed that such clearings protected mounds from grass fires. He also speculated that bare areas might provide better sunlight penetration by reducing the shadow of vegetation. Other suggestions include the removal of moisture held by plant roots that would damage seeds, reduction of concealment for ant enemies, and removal of obstacles that restrict the ant's foraging activities (Headlee and Dean 1968).

One behavioral characteristic of this ant also indicates its adaptation to xeric conditions. When the temperature becomes excessively warm, the foraging ants return to the nest for aestivation. Although activity continues below the mound and nest entrances remain open, foraging activity ceases. Conversely, with the advent of cooler night-time temperatures, the ants go below ground, but the nest entrances are closed.

LITERATURE SURVEY

A study of casual factors which determine both range and spatial patterns of P. occidentalis interrelates the sciences of zoology and geography. It calls for insight into the phylogeny, systematics, paleontology, physiology and behavior of the ant as well as a knowledge of the environment in which it lives. This type of study presupposes a knowledge of the location of the ant's range as acquired over many years by numerous scientists.

Early investigations were carried out by Cresson (1865), Leidy (1877), and McCook (1879). It was McCook (1882) who was responsible for the first major description of the ant's known distribution. Verifying the first sighting of the species in North Dakota, he delimited the northeastern extent of the ant's range (McCook 1883).

Taxonomic keys to the identification of species within the genus Pogonomyrmex first were produced by Cressor (1887). Pogonomyrmex owyheei was later described as a separate sub-species by A. C. Cole (1938). After World War II (1950), Creightong elevated the ant P. owyheei to species status. With this status change, a benchmark geographic range of P. occidentalis was established. This permits research in potential range extension and further locational analysis of this species.

With the range of P. occidentalis determined, factors which might indicate the causes for the range or for spatial arrangements of the ants within the range could be studied. Cole (1940) first examined relationships between P. occidentalis and its habitat. His work provided the framework for other studies of Pogonomyrmex ecology. In his paper concerning the ants in the Great Smokey Mountains (Cole 1940), he pointed out that:

> A complex group of factors - climate, edaphic and biotic - governs the distribution of the ants as well as other organisms. So intimately bound together are these factors that one cannot assign a single one of them as being instrumental above all others as the determinant.

However, Cole indicated that one factor can be considered a controlling variable in the determination of ant locations: climate.

Although the effects of climatic factors on the biology of P. occidentalis have been studied, little research has been carried out on the effects of such variables on locational analysis. Cole (1934), in his research on aestivation and overwintering of P. occidentalis, examined temperature as it affects only a small portion of the ant's activities but did not relate this to location or range extension of the species. Nagel (1971) conducted specific research on survivorship of P. occidentalis in regions of differing relative humidities, but again no effort was made to relate this to location. Whitford (1975) was concerned with climate, especially temperatures as it affected water loss in desert-dwelling species, but went no further in studying how this might influence ant distributions.

However, relationships of climatic variables to locations of ant species had been considered to some degree in related research by Cole (1934). In the sagebrush semi-desert region studied he found moisture and temperature to be " . . . apparent dominants . . . " in the determination of seasonal succession of some species (Cole 1934). Climatic effect on the brood development had been investigated more completely by Cole (1934): he stated that " . . . temperature within an ant mound is of vital importance for the incubation and survival of the young . . ." In subsequent research Cole (1940) pointed out that an

"Occidentalis brood will not mature in soils of high moisture content. It can be inferred from Cole's statement that P. Occidentalis will not survive in regions that have soils that retain water, nor will they survive in regions with an abundance of moisture.

A two part research report of the Wyoming Game and Fish Commission (King 1961, 1962) has been the most thorough report on locational analysis of the ant P. occidentalis. That study in the Big Horn Basin of Wyoming began with a predominantly climatic survey of the ant's locations within this region. Survey results indicated that far more of the ant population was to be found in low precipitation regions than in higher precipitation locations.

In North Dakota, locational analysis of ants has not been examined in detail, although Weber (1941, 1942) did examine the effects of drought on ant nesting habits in the state. Neither of his two reports was concerned specifically with P. occidentalis nor with its zoogeography. In her doctoral dissertation concerning the biogeography of North Dakota ants, J. Wheeler (1962) raised an interesting question concerning the effects of climate on P. occidentalis range, "Does the limit of the range of Pogonomyrmex occidentalis fluctuate with the wet and dry cycles?" It is this relationship between moisture balance and the range of this species which is presently under consideration.

METHODOLOGY

Locational data for P. occidentalis range and spatial patterns first were collected from several sources (Wheeler and Wheeler 1963; Wheeler 1962; Moreland 1966; Kannowski and Benner 1978) and tabulated (Table 1). These sites were then plotted on a map of the state (scale 1:1,000,000) to illustrate spatial patterns. Since this revealed that only the southwest corner of North Dakota was occupied by this species, that region of the state was selected as a study region for later correlation with weather and climatic data (Fig. 3).

TABLE 1. NORTH DAKOTA LOCATIONS OF P. OCCIDENTALIS

The following locations are listed by section, township north and range west:

Adams County:	17-129-91; 11-129-95; 32-130-91; 4-130-92; 4-130-93; 4-130-94.
Billings County:	8-137-100; nr-139-102; 12-140-101; 1-140-102; 10-140-102; 11-140-102; 12-140-102; 13-140-102; 16-140-102; 23-140-102; 25-140-102; 27-140-102; 11-141-99; 35-141-101; 22-142-99; 4-143-102; 22-144-102; 33-144-102; Mikkelson.
Bowman County:	31-129-106; 24-131-106; 35-132-106; 10-135-105.

TABLE 1. CONTINUED

Burleigh County: 10-137-78; 12-137-78; 15-137-78; 18-137-78; 27-137-78; 27-137-78; 26-139-78; 28-139-78; 30-139-78; 7-137-79; 8-137-79; 9-137-79; 12-137-79; 18-137-79; 27-138-79; 34-138-79; 25-139-79; 33-139-79; 34-139-79; 35-139-79; 1-137-80; 2-137-80; 11-137-80; 12-137-80; 23-137-80; 24-137-80; 4-138-80; 15-138-80; 22-138-80; 23-138-80; 26-138-80; 35-138-80; 34-139-80; 36-139-80; 2-140-81; 3-140-8; 22-140-81; 35-140-81; Bismarck.

Emmons County: 2-129-79; 27-130-78; 36-130-78; 20-130-79; 32-131-79; nr-132-78; 17-135-78; 7-136-78; 20-136-78; 28-137-78.

Golden Valley County: 24-140-104; 19-140-105.

Grant County: 9-131-85; 32-131-85; 26-132-84; 27-132-85; 5-132-88; 5-134-85; 12-134-87; 20-134-87; 23-134-89; 8-135-85; 24-135-86; 14-135-89; 16-136-87; 21-136-87; nr-136-89.

Hettinger County: 19-135-96.

McKenzie County: 13-146-99; 1-147-98; 13-147-99; 33-148-99; 35-148-99; 32-148-100; 5-148-104; 32-149-104; 21-150-104.

Morton County: 20-134-80; 19-134-81; 24-134-82; 3-136-84; 23-137-85; 13-138-81; 35-138-85; 34-138 86; 27-139-81; 15-139-83; 23-139-85; Breien.

Sioux County: 7-129-79; 9-129-79; 10-129-79; 22-129-81; 8-129-85; 1-130-80; 35-130-81; 36-130-81; 4-130-82; 29-130-85; 7-131-79; 25-131-80; 1-131-83; 32-132-79; 9-132-82; 32-132-83; 19-133-81; 33-134-81; 36-134-82; Solen; 15-134-79.

Slope County: 36-133-106; 26-134-106; 13-135-100; 32-135-105; 33-135-106; 10-136-102; 11-136-102; 25-136-102; 17-136-102; 9-136-104.

Stark County: 35-140-99.

Additional Records: Billings County - Medora. Emmons County "opposite the mouth of the Cannon Ball River" (McCook 1883, p. 294).

TABLE 2. YEARLY MOISTURE DEFICIT IN SOUTHWEST NORTH DAKOTA

Station	Moisture Deficit (cm.)	Sites
Almont	19.4	2
Amidon	19	4
Beach	20.6	1
Belfield	11.8	3
Bismarck AP	20	12
Bowman CH	21.7	0
Carson #2	19.2	13
Center	13.4	0
Dickinson Exp. St.	18.1	0
Dickinson AP	20.3	0
Dunn Center 2SW	17	0
Fort Yates	22.4	21
Hettinger	22.6	4
Linton	21	3
Marmarth	22.7	9
Medora	22.3	9
Mott	19.6	2
New England	20.3	1
New Salem	20	5
Richardton Abbey	18.9	1
Watford City	21.7	8
Wilton	16	0

TABLE 3. MOISTURE DEFICIT MATING SEASON SOUTHWEST NORTH DAKOTA

Station	Moisture Deficit (cm.)	Sites
Almont	11.6	2
Amidon	11.5	4
Beach	11.5	1
Belfield	10.3	3
Bismarck AP	11.6	12
Bowman CH	11.6	0
Carson #2	12.0	13
Center	10.7	0
Dickinson Exp. St.	10.9	0
Dickinson AP	11.0	0
Dunn Center 2SW	10.9	0
Fort Yates	11.8	21
Hettinger	11.6	4
Linton	12.0	3
Marmarth	11.7	9
Medora	11.8	9
Mott	11.5	2
New England	11.4	1
New Salem	11.4	5
Richardton Abbey	11.5	1
Watford City	11.9	8
Wilton	11.0	0

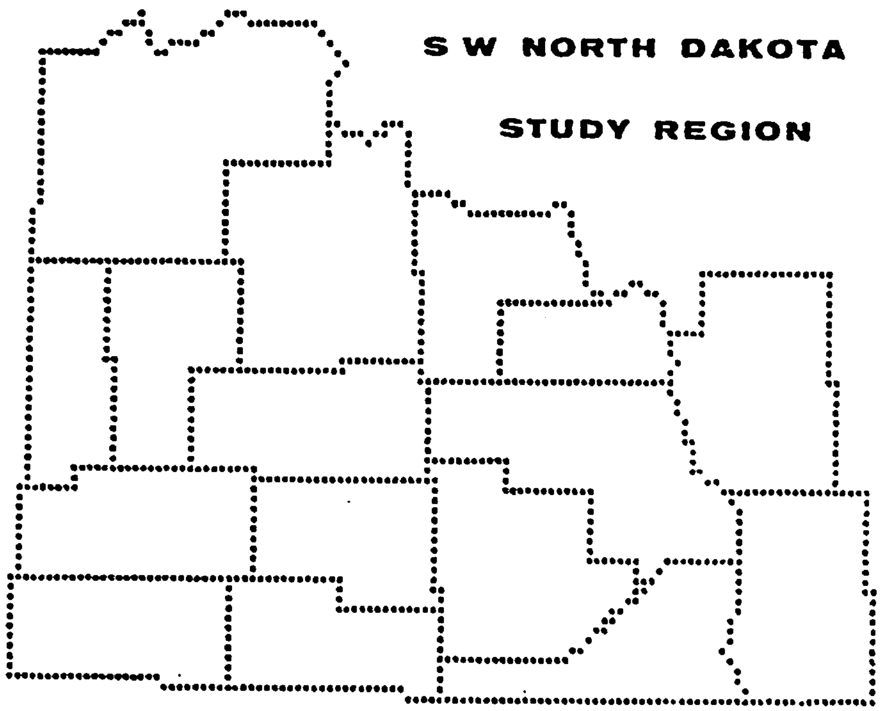

FIGURE 3. SYMAP Outline of Preliminary Study Area.

Selection of appropriate weather stations could not be facilitated by any statistical method because of the sparsity of these stations in that area. Twenty-two stations were selected on the basis of availability of appropriate data and reflect an appropriate sample (Fig. 4).

Surrogates for individual mound numbers was necessary due to the large numbers of mounds within the study region. Collected locations and mapped sites provided by Wheeler (1962) and others were then used as surrogates for colony density; each identified site suggested the probability of locating individual mounds in a smaller area. The ant's particular attraction to arid and semiarid locations having high evaporative indices made use of moisture deficit values to be a most effective variable to compare to surrogates of colony density.

Climatic averages for the selected weather stations for the period of 1951-1960 (U.S. Dept. of Commerce 1965) were selected as most representative of the period in which P. occidentalis data were mapped. Thornthwaites's annual potential evaporation index, corrected for day length, was calculated for each station using a computer program designed for use with the IBM 370 (appendix) (Faflak 1979) which is derived directly from formulae found in Muller et al. (1974). Moisture balance, an indicator of available soil moisture, was then determined by subtraction of annual precipitation from the annual potential evaportranspiration. The numbers of P. occidentalis sites closest to each of the twenty-two weather stations were found by simple map measurement (Table 2.). Isoline SYMAP and SYMVU (Dougenik 1975; Harvard University 1975) maps were constructed from the moisture balance values; recorded sitings of ant colonies were placed on the same maps (Figs. 5, 6). Visual correlation then was made between isolines of high and low moisture deficit and locations with high or low concentrations of P. occidentalis. Moisture balance values then were correlated to the number of sites nearest each weather station by Kendall's correlation coefficient (Tau) corrected for paired ranks.

Moisture balance for the months of July and August also were calculated using the previous method (Table 3). These months were selected because of the presence of winged females and males within the P. occidentalis nests in North Dakota (Wheeler and Wheeler 1963). It is assumed that mating flights occur during July and August; such correlations can be made during this period in the ant's life cycle.

Isoline SYMAP and SYMVU maps of the moisture balance during these two months were constructed (Figs. 7, 8). Ant density was again plotted on these maps. Correlation was made between isolines of high and low moisture deficit between July and August and locations with high or low concentrations of P. occidentalis. Moisture deficit values for the two month period were correlated to the number of sites nearest each weather station again using Kendall's Tau.

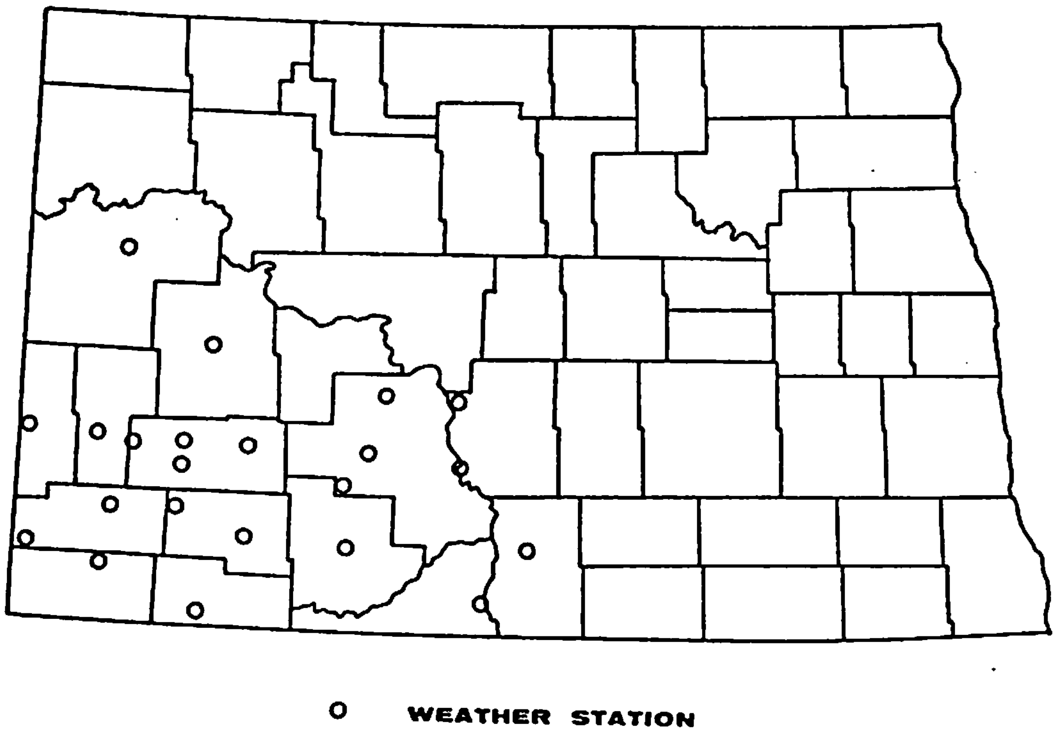

FIGURE 4. Weather Station Distribution Within Preliminary Study Area.

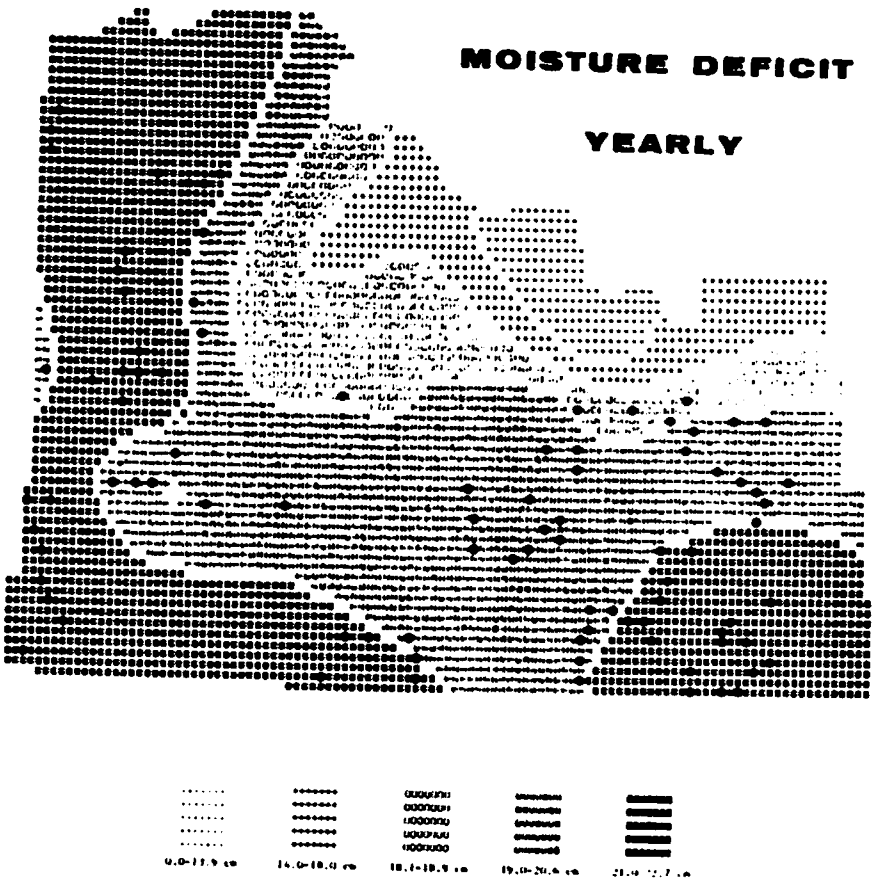

FIGURE 5. SYMAP of Yearly Moisture Deficit with Distribution of P. occidentalis.

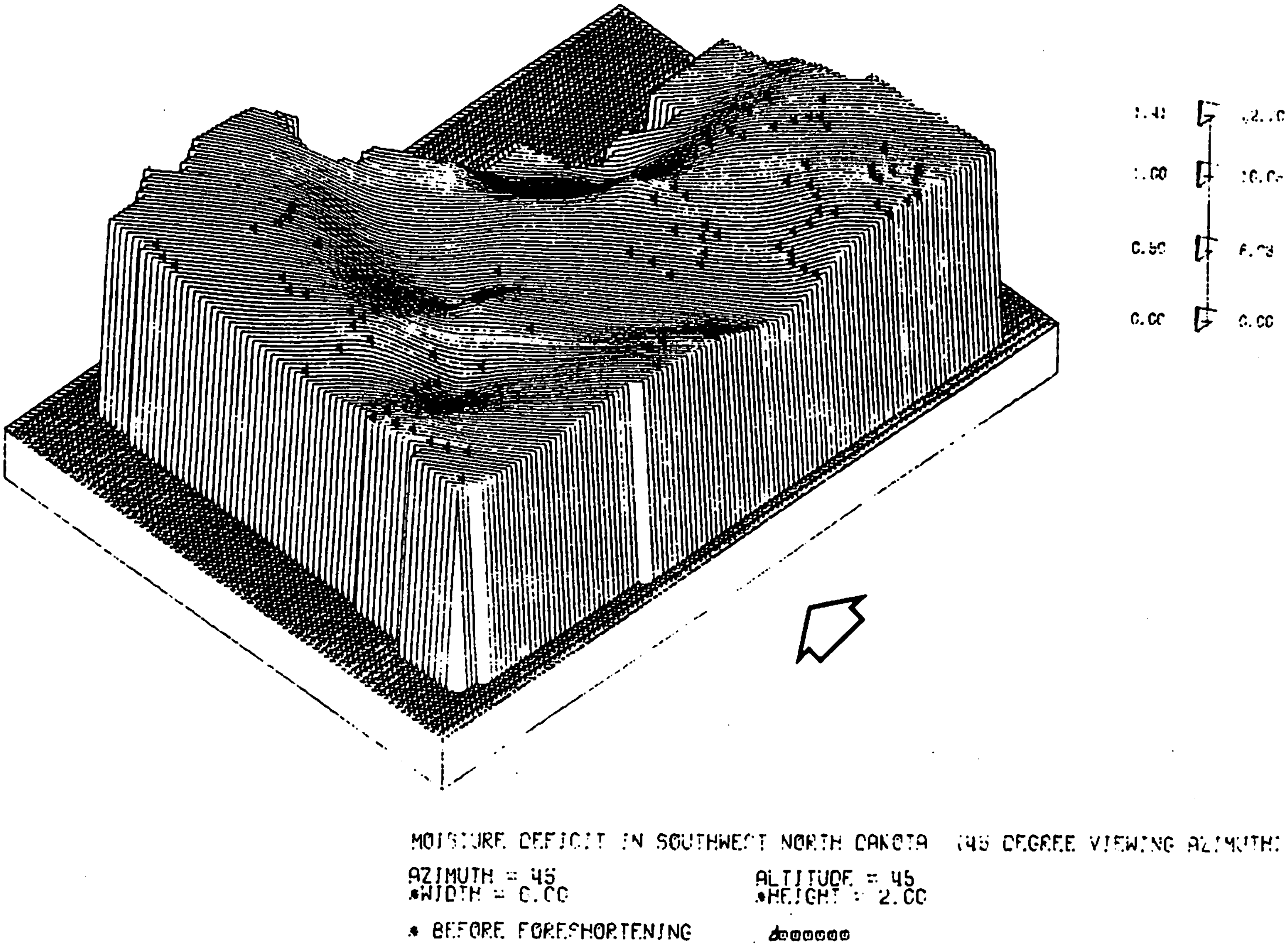

FIGURE 6. SYMVU Map of Yearly Moisture Deficit with P. occidentalis Distribution.

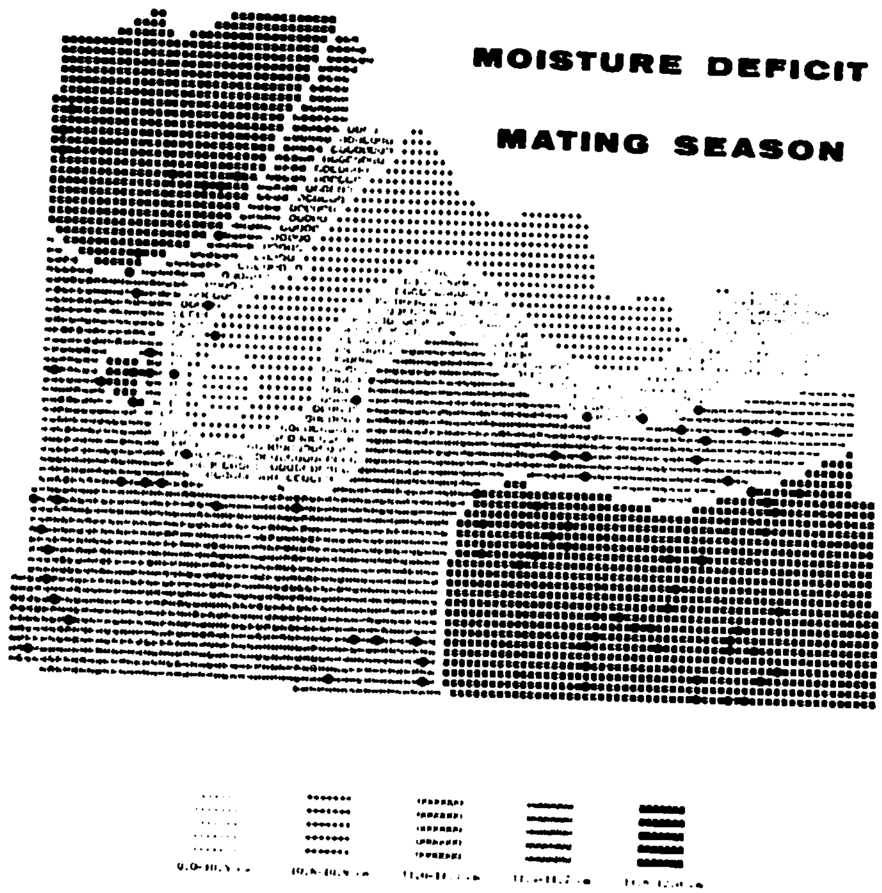

FIGURE 7. SYMAP of Moisture Deficit During Mating Season With Distribution of <u>P. occidentalis</u>.

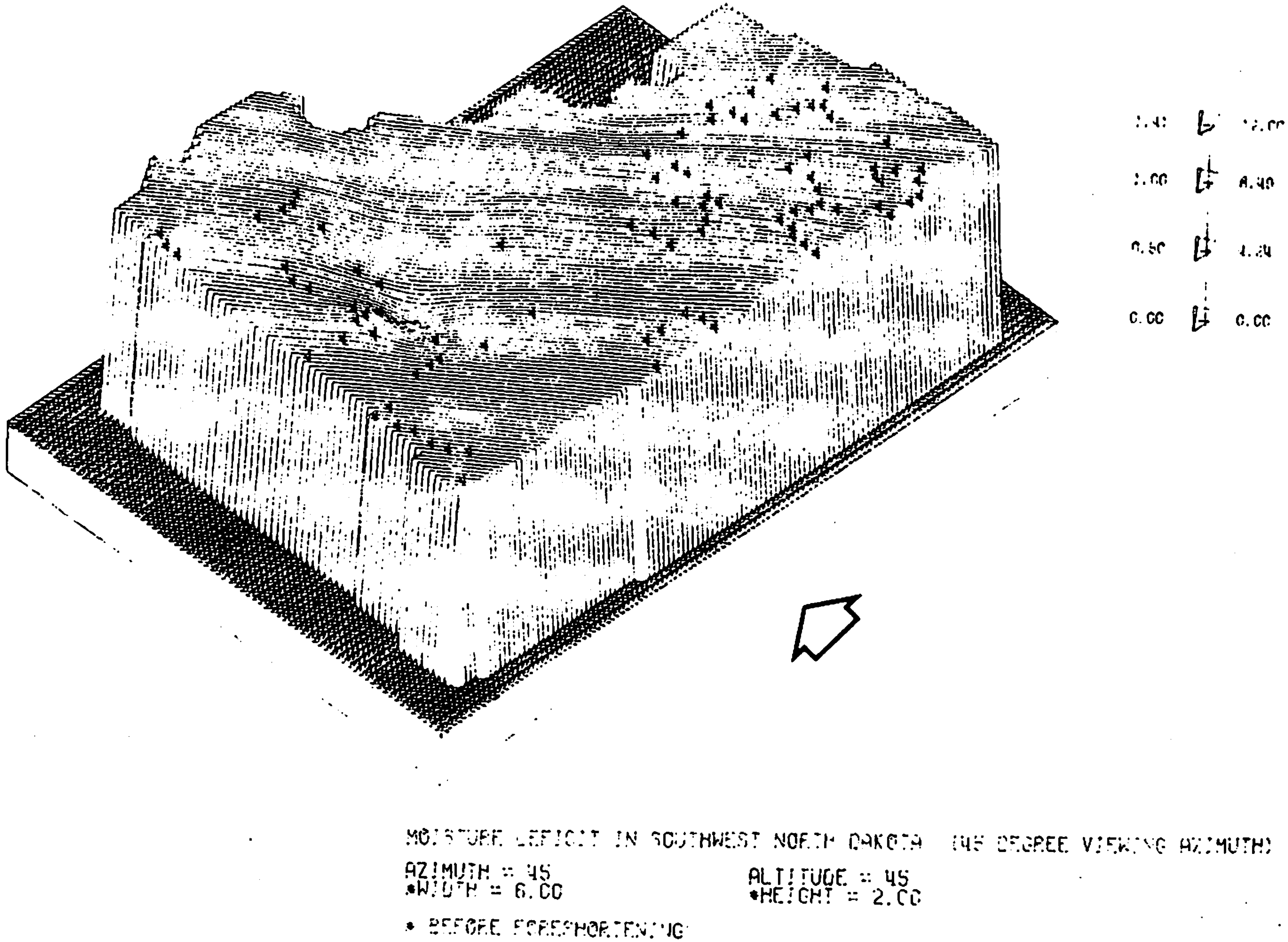

FIGURE 8. SYMVU Map of Moisture Deficit During Mating Season with <u>P. occidentalis</u> Distribution.

RESULTS AND CONCLUSION

Map comparison indicates that regions on the maps of yearly moisture deficit which have the highest mositure deficit are also the most heavily populated with P. occidentalis sites (Figs. 5, 6). An increase in mound sightings corresponds with areas of highest moisture deficit in the west, northwest and southeast portions of this study area. P. occidentalis is less numerous or totally nonexistent in the large central and northeast portions of the case study, an area characterized by a lower annual moisture deficit. Kendall's Tau shows a positive correlation between site density and moisture deficit of .40. A "Z" value of 2.6 demonstrates that the probability that this correlation occurred by chance is .5 percent.

When later map comparison was made between spatial patterns of P. occidentalis and moisture balance values for the months of July and August over the same ten-year period, the visual correlation was much weaker. Although the western and southeastern portions of the map do indicate higher moisture deficit and correspondingly high site density, the south-central portion of the study area shows lower moisture deficit. This is inconsistent with location of a relatively large number of mound sightings in that region. Furthermore, correlation by Kendall's Tau of site density to moisture deficit yielded no significant result. This gives some indication that the correlation of moisture balance to mound density is much stronger during the remainder of the year. It is important to note, however, that moisture deficit values are highest during July and August, when the brood and winged sexual forms are present. It is also important to observe that there seems to be no ecological gradient to the range of this species in North Dakota. Thus, P. occidentalis apparently is prohibited from establishing viable colonies in conditions not suited for survivorship. Still, there is need for further investigation into this aspect of North Dakota's zoogeography to determine if there are factors other than moisture balance which help explain P. occidentalis' range. Such research is being undertaken so that further contributions can be made to this aspect of North Dakota's biogeography.

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