THE EVALUATION OF POSSIBLE HAIL SUPPRESSION IN KANSAS

Donald Christy

Scott City, Kansas

The goal of Weather Modification was bushels of wheat--wheat being the major crop of Western Kansas. The intent was to produce more rain, since rainfall is the major limiting factor of wheat production in Western Kansas.

The method of rain enhancement was based on the observation that when an extremely small amount of AgI was released between 10:00 A.M. and 12:00 noon into a gentle up-slope wind (SE) when there was a rain haze showing around the sun or a few small feathery cumulus had started to develop, at about 4:00 PM, a rainstorm often developed approximately 75 miles northwest of the initial seeding location. The storm appeared to move in a general easterly direction. These results seemed to require the seeding to be done about 15-20 miles south of the desired rainfall location.

It was further noted that as long as AgI seeding was being used, these clouds would reappear for days after the seeding stopped. This indicated that the AgI persisted and remained in the area.

During 1956, the author developed the concept that continuous seeding of small amounts of AgI was a means of starting an early convergence close enough to the Kansas-Colorado border for the rains to continue into Kansas. Those that started just west of the Kansas border were the ones that supplied much of the Kansas summer rainfall. It had been noted that the extremely short vectors of the windroses of Western Kansas were of about equal length in each direction, indicating little net air movement into or out of the area during the summer. If these assumptions are true, then AgI releases in the area should permeate the area between rainstorms so that upslope winds would carry them to a desirable location where energy releases would start the convergence process.

The map (Fig. 1) showing the morning upslope wind direction and the storm's easterly movement illustrates the concept. Since the rainstorms form in the area every few days, and each storm results in a convergence, the convergence would concentrate the AgI and it would be washed out of the air on a regular basis. This would indicate the need for continuous reseeding.

The nine year Weather Modification attempt was initiated in 1957. The idea was to use an eleven year trial, one sunspot phase. The experiment was terminated after nine years due to the Federal requirements of record keeping. It was noted that hail loss north and east of Scott City seemed to be low during the seeding period. Crop Hail Actuarial Association Insurance of Chicago was contacted as to available data. They supplied a crop-hail computer print out of the hail low-risk ratio for the years 1924-1972 inclusive. This included not only a township by township, but county by county, and finally a state, year by year summary.

The search for the area of influence, if any, was initiated. The procedure for determining changes in yields and changes in rainfall had already been worked out. The same general procedure of analysis was used to determine the effect of such seeding on hail losses. The procedure was to determine the normal hail loss risk for each county for the period of record. This was plotted on a Kansas map. Then a similar map was made by subtracting the period of record from the period of study. Hence, if the results were positive, there was an increase in hail loss compared to risks taken. Since the anticipated effects were widely variable and small, compared to other factors, the 4-county average, moved progressively, tended to clarify the locations of change in losses. When the hail loss results are plotted on a map, the lines of equal loss drawn, the resulting map (Fig. 2) indicates a reduction of hail loss about 80% in the affected areas. The data was plotted on the map (Fig. 2) then lines A-A, B-B, etc. were analyzed. The cross sections representing A-A, B-B, etc. (Fig. 3) indicates a broadening comparable to the original estimated divergence of the storm paths. The divergence results in a broadening of the area affected until it is almost as wide as the state is broad with indicated hail loss reductions equal to about 30%.

There are two other comparisons that might be possible. The counties just north and south of the affected area can be compared to the area affected as indicated by Fig. 3. The hail loss of the area itself can be compared to the years in which seeding was not being done.

In the first instance the normal hail loss for all the years are compared to see whether there is substantial difference of hail loss period during which seeding was practiced would give some bias o servative side. Compare column 4, Table I, the seeded area with of the unseeded area. Note the 7.39 loss of the unseeded years of the seeded area compared to 7.47 of the unseeded area. To be conservative the $\frac{6.13}{9.43}$ ratio of 65.01 would be corrected by multiplying it by $\frac{7.47}{7.15} \times \frac{6.13}{9.43}$ by 100 = 67.91% of normal loss, a 32% reduction in hail loss.

The other, compares the nine seeded years with the unseeded years for the same counties divides the hail loss during the seeded years by the hail loss during the unseeded years, Table I, Col. 3 divided by Col. 4 - $\frac{6.13}{7.39} \times 100 = 82.95$ or a 17.05% reduction.

One of the problems of this analysis is that a seeding comparison between the hail losses during one phase of the sunspot magnetic polarization could seriously bias the result if it were compared to an unseeded period of the opposite polarity. Using Kansas as an example, if the years of seeding had been in the south sunspot phase of 1951-1960 and the comparison was the straddling years of 1941-1950 inc. plus 1961-1970 the results would have been

$\frac{3.74 + 1.98}{4.73 + 1.54} \times 100 = 79.07$ or an apparent 21% reduction. For the total period of 1924-1972 the reduction would have apparently been $\frac{2.69}{4.73} \times 100 = 46.33$ or 54% reduction.

In this particular instance the number of years selected accidentally straddled the change from south to north phases with 4 years in the south mode of the sun spot cycle and 4 years in the north mode of the cycle (Fig. 5). In other words the seeding period covered the last part of the 1950 drought and the first part of the ensuing wet phase of the sun's polarity.

It should be noted that the sun spot phase does not affect precipitation on the same time table in all parts of the world.

There does not seem to be correlation between the sunspots and the precipitation in the Columbia River Basin. Further, there are places like the northeastern United States where the effect of the sunspots are the reverse of that of the mid-continent U.S. Hence, there is a need to analyze the sunspot effect for the area in question.

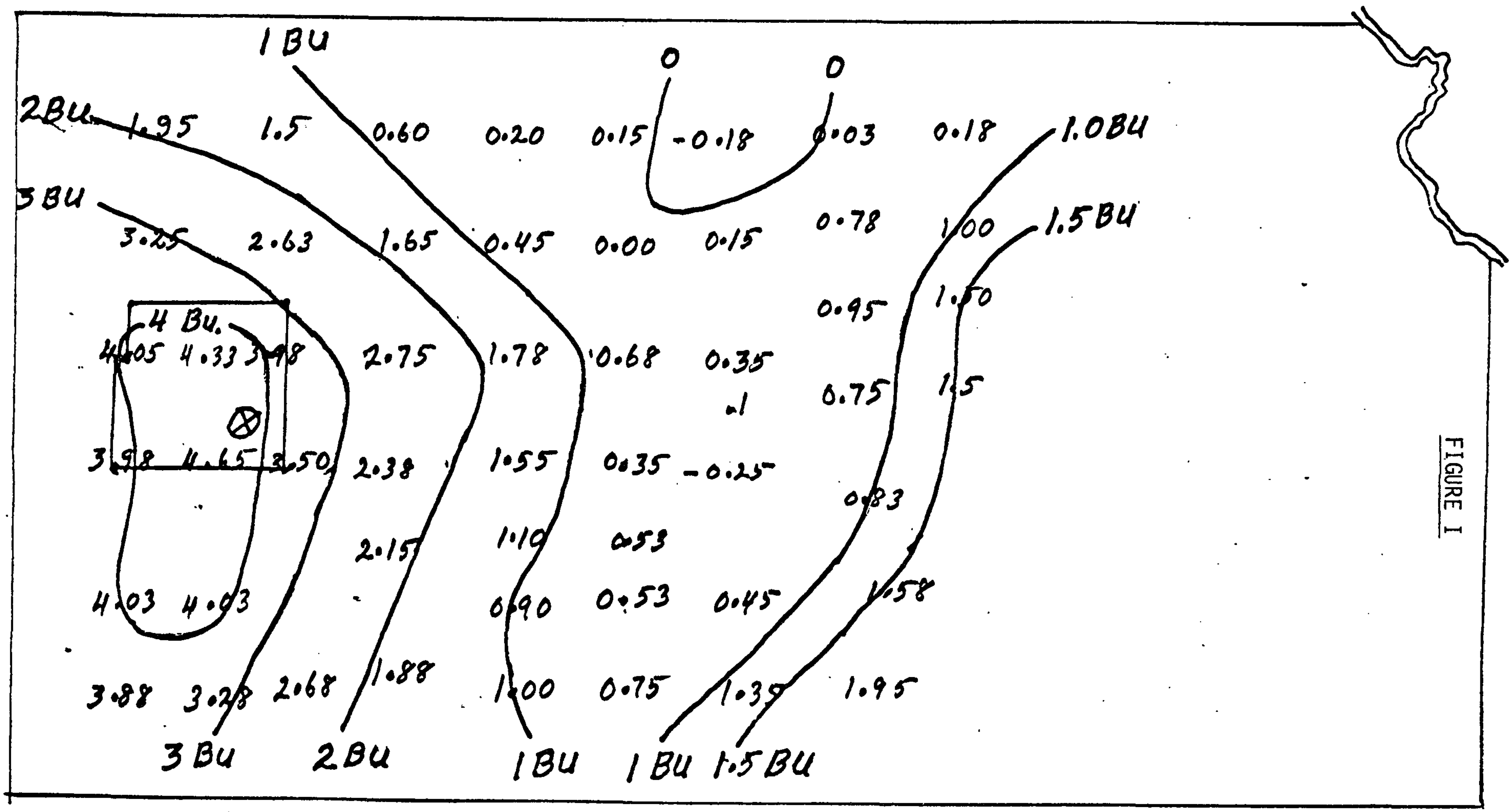
Eleven counties of southwestern Kansas engaged in an all-out attempt at weather modification in 1975. It started April 15 for both rain enhancement and hail suppression. The rain enhancement stopped during most of June to the first week of July, the wheat harvest period. The program is to terminate in mid-September. The initial attempt to evaluate is shown in Fig. 6 and Fig. 7, which shows the rainfall and the evaluation available at the time of preparation of this presentation.

Table I

Seeded Counties	Yrs.	1924 to 1972	1957 to 1965	1924 to 1956	Unseeded Counties	Yrs.	1924 to 1972	1957 to 1965
Wallace	47	8.10	7.76	8.18	Cheyenne	49	11.22	14.89
Thomas	49	6.08	3.59	6.64	Rawlins	49	6.98	6.99
Logan	45	9.28	8.03	9.58	Decatur	49	4.96	6.27
Scott	48	7.86	5.67	8.37	Norton	49	4.56	7.23
Sheridan	49	6.54	4.98	6.89	Greeley	46	9.45	16.40
Gove	48	7.69	7.48	7.74	Wichita	46	9.96	8.43
Lane	48	6.48	7.53	6.24	Kearny	47	9.84	15.36
Graham	49	5.74	3.67	6.21	Finney	48	8.04	8.07
Trego	48	7.21	6.67	7.33	Gray	47	5.08	5.21
Ness	48	6.53	5.87	6.68	Ford	48	4.62	5.48
No.		10.00	10.00	10.00			10.00	10.00
+		1.08	1.65	1.08			2.56	4.35
Āv.		7.15	6.13	7.39			7.47	9.43
Variance		15.16	26.91	14.65			34.26	46.15

$\frac{7.47}{7.15}$ X $\frac{6.13}{9.43}$ X 100 = 67.91 = 32% reduction or $\frac{6.13}{7.39}$ X 100 = 82.95 = 17% Reduction

FIGURE I



WHEAT YIELD BU./AC. DIFFERENCE

SUMMERFALLOW

$$\frac{\sum\left(\frac{1}{2}1957 \text{ ---- } \frac{1}{2}1966\right)}{9} - \frac{\sum\left(1950 \text{ ---- } 1972\right)}{23} =$$

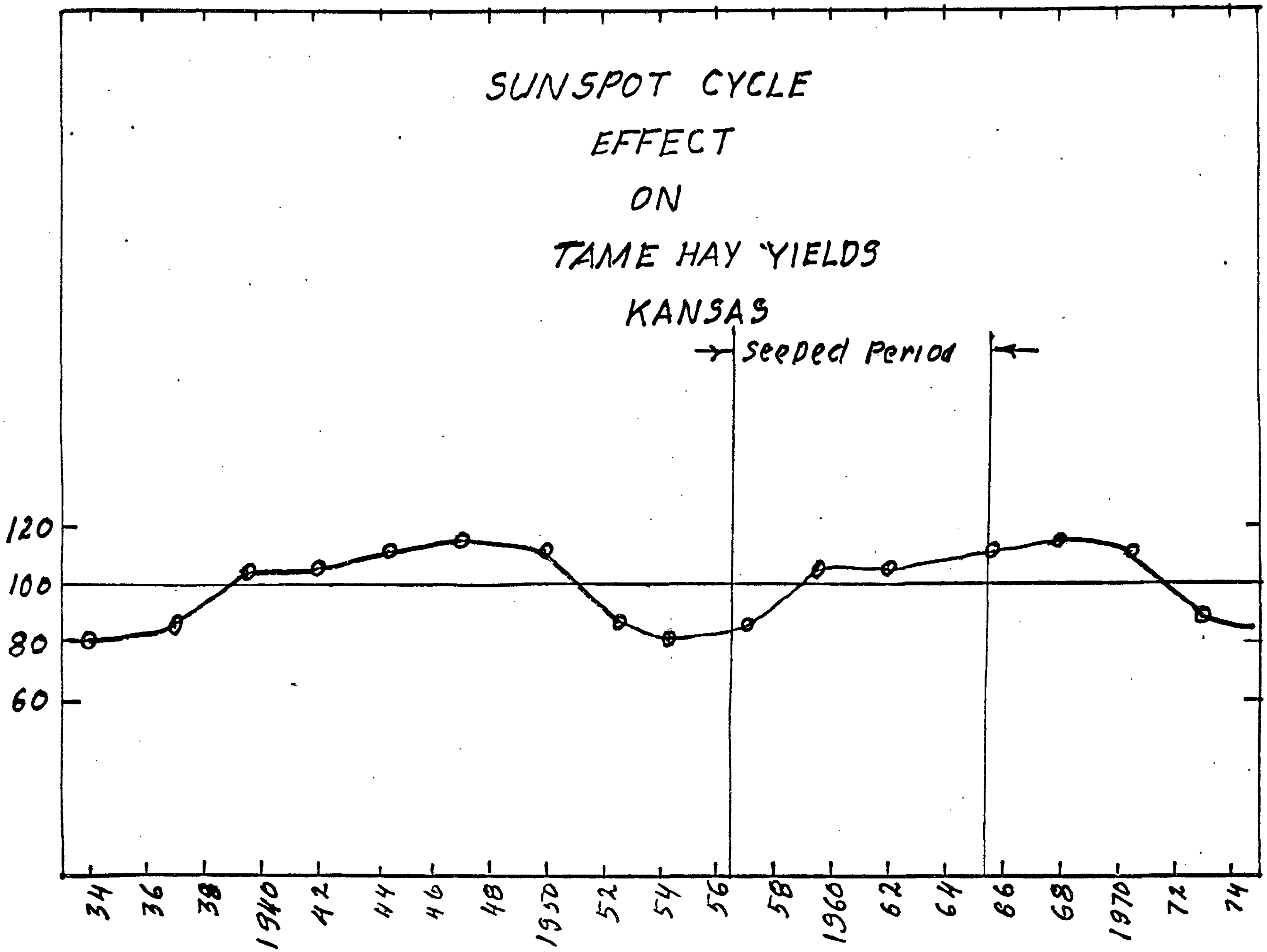

SUNSPOT CYCLE
EFFECT
ON
TAME HAY YIELDS
KANSAS
Seeded Period
120
100
80
60
34
36
38
1940
42
44
46
48
1950
52
54
56
58
1960
62
64
66
68
1970
72
74

FIGURE II

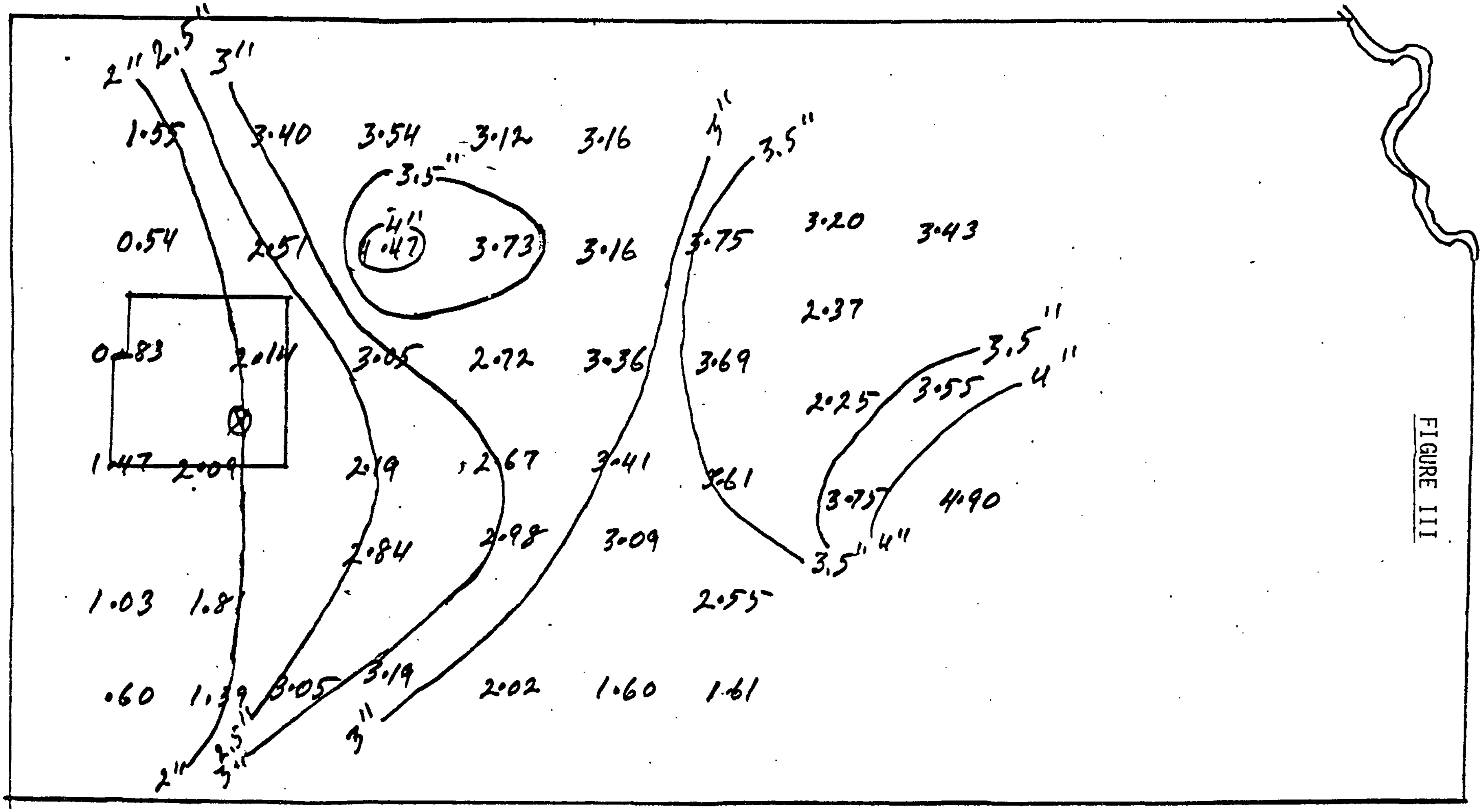


FIGURE III

RAINFALL INCREASE

(1957-1965 INC)-(1950 & PRIOR RAINFALL)=

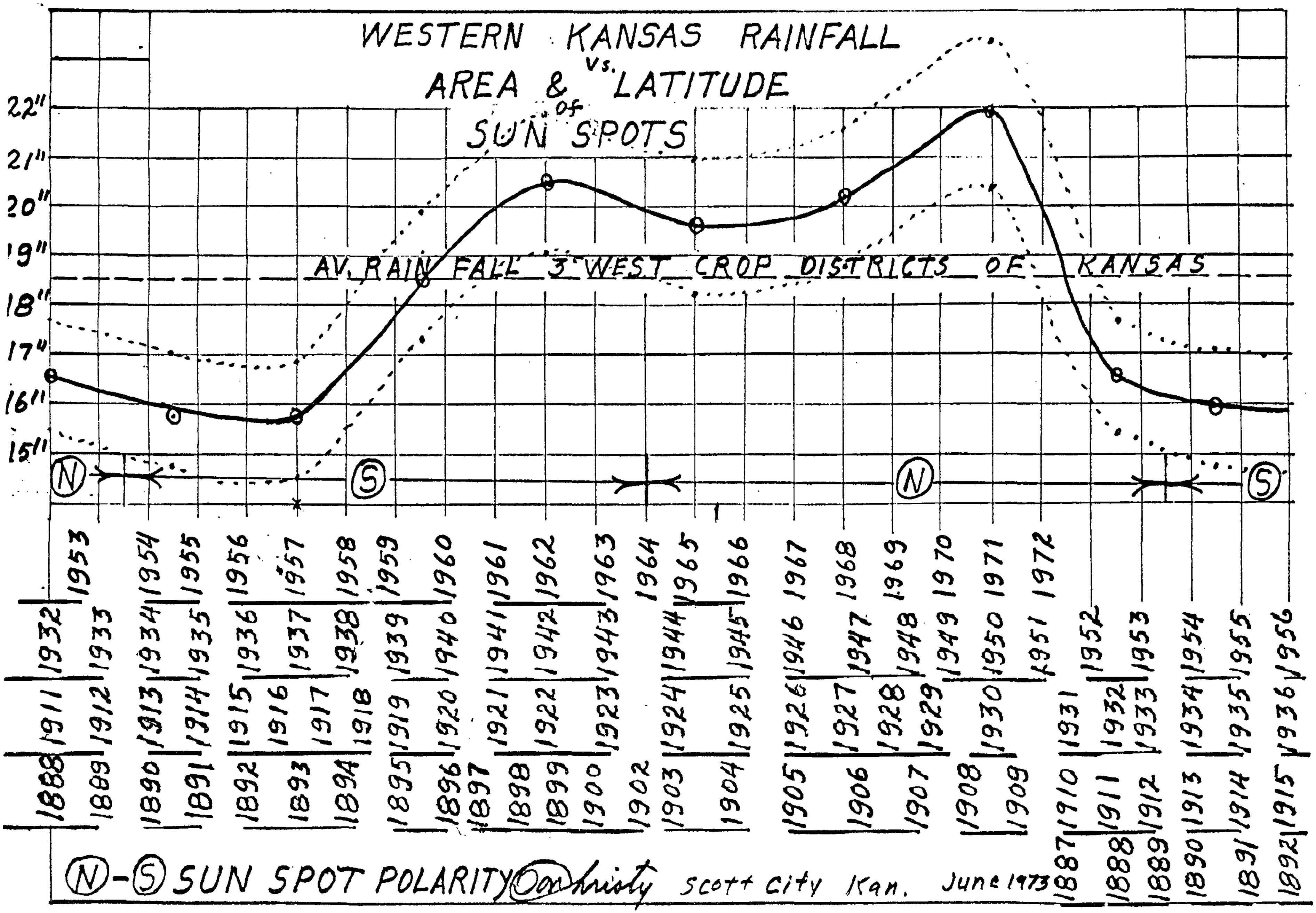

WESTERN KANSAS RAINFALL
vs.
AREA & LATITUDE
of
SUN SPOTS
22"
21"
20"
19"
18"
17"
16"
15"
AV. RAIN FALL 3 WEST CROP DISTRICTS OF KANSAS
N
S
N
S
N - S SUN SPOT POLARITY
Scott City Kan. June 1973

Fig. IV

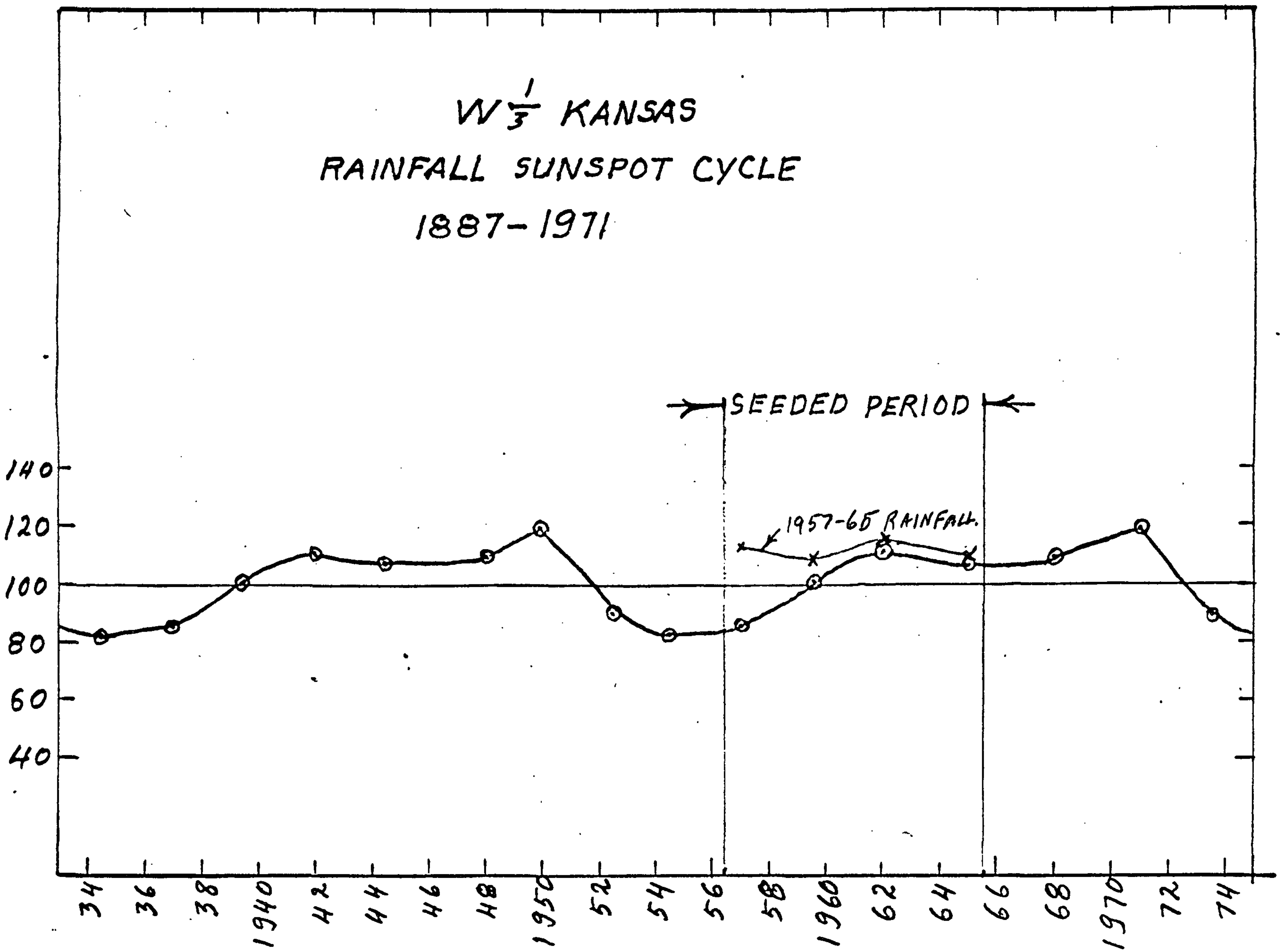
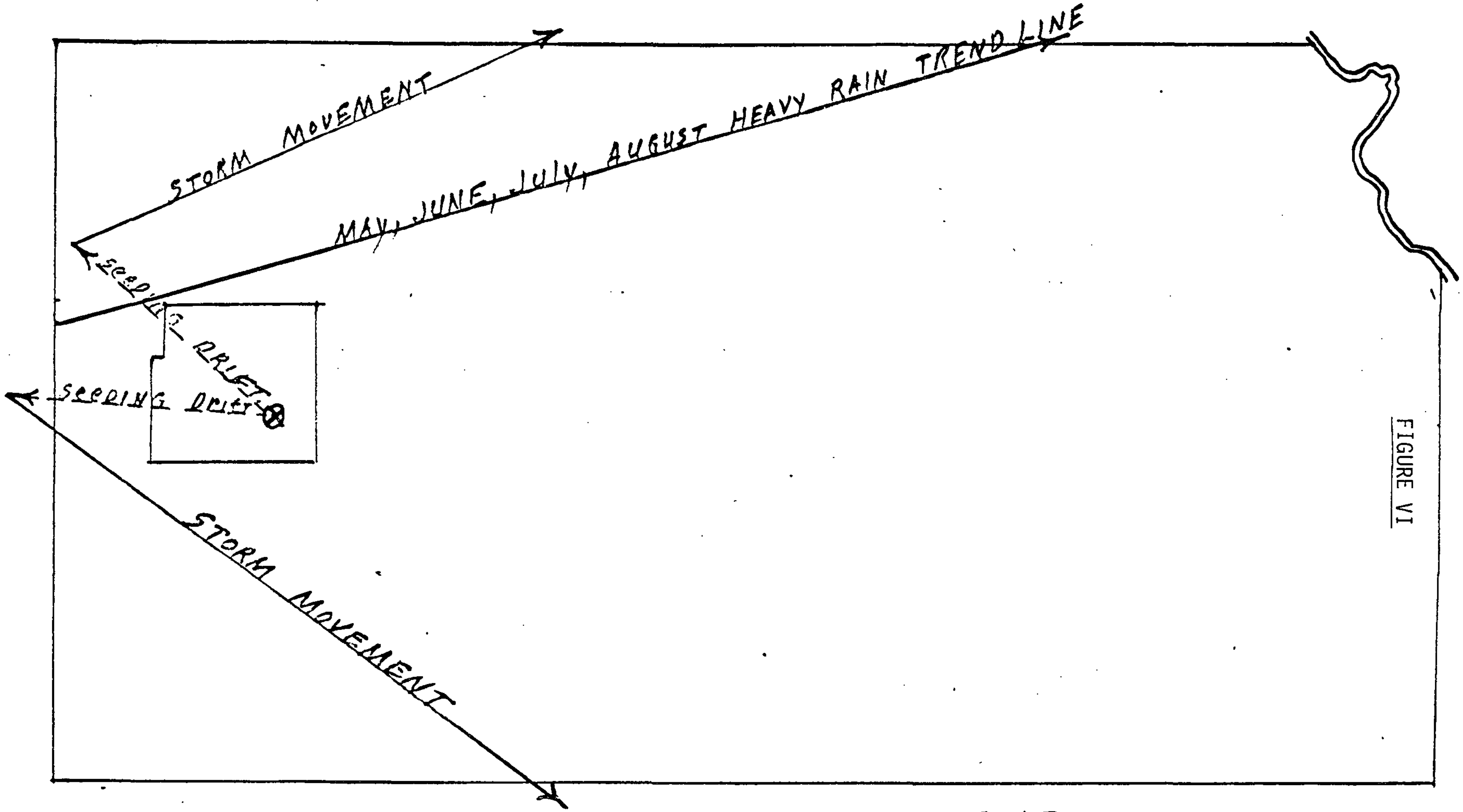

W 1/3 KANSAS
RAINFALL SUNSPOT CYCLE
1887-1971
SEEDED PERIOD
1957-65 RAINFALL
140
120
100
80
60
40
34
36
38
1940
42
44
46
48
1950
52
54
56
58
1960
62
64
66
68
1970
72
74

FIGURE V

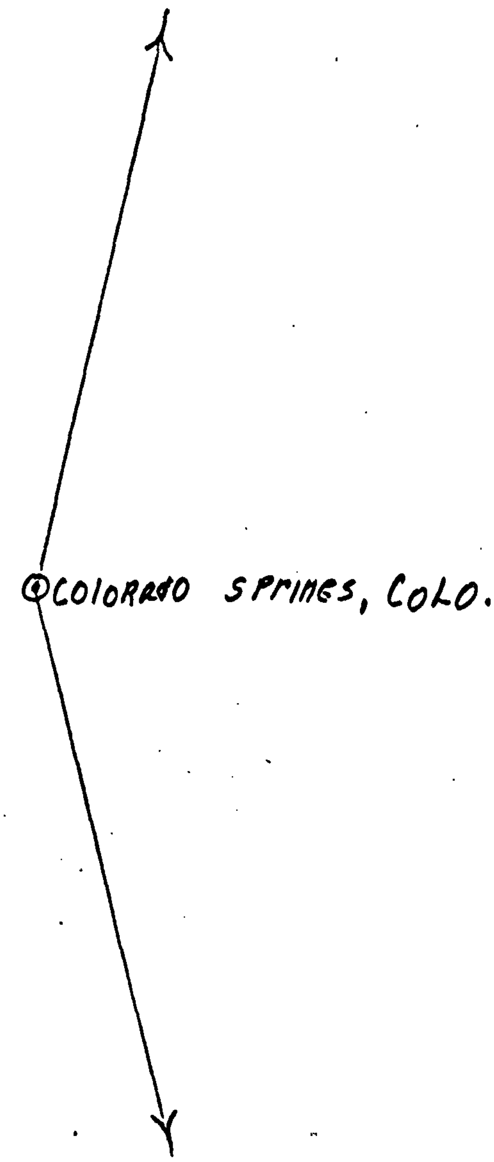
FIGURE VI



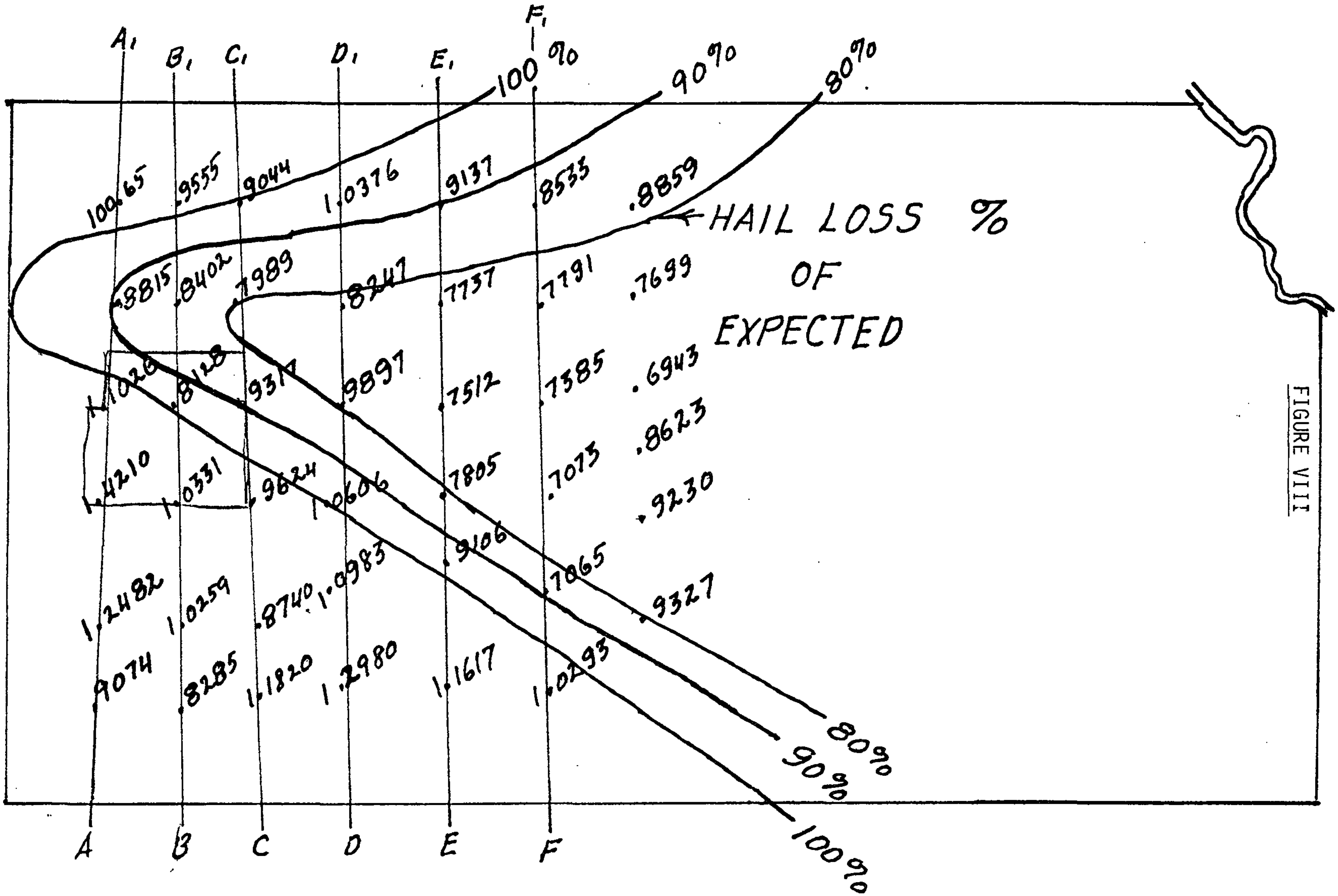
DIRECTION OF ANTICIPATED MOVEMENT.

Seed (AgI)
LIMITS of STORM MOVENENT.
May, June July, Aug. Normal Movement.

FIGURE VII



ATOMIC ENERGY Fallout Pattern.
As Sketched By One Of Staff.



HAIL LOSS % OF EXPECTED
A₁
B₁
C₁
D₁
E₁
F₁
A
B
C
D
E
F
100 %
90%
80%
100.65
.9555
.9044
1.0376
.9137
.8533
.8859
.8815
.8402
.7989
.8247
.7737
.7791
.7699
1.1020
.8128
.9317
.9897
.7512
.7385
.6943
.8623
1.4210
1.0331
.9624
1.0606
.7805
.7075
.9230
.9106
.7065
1.2482
1.0259
.8740
1.0983
.9327
.9074
.8285
1.1820
1.2980
1.1617
1.0293

FIGURE VIII

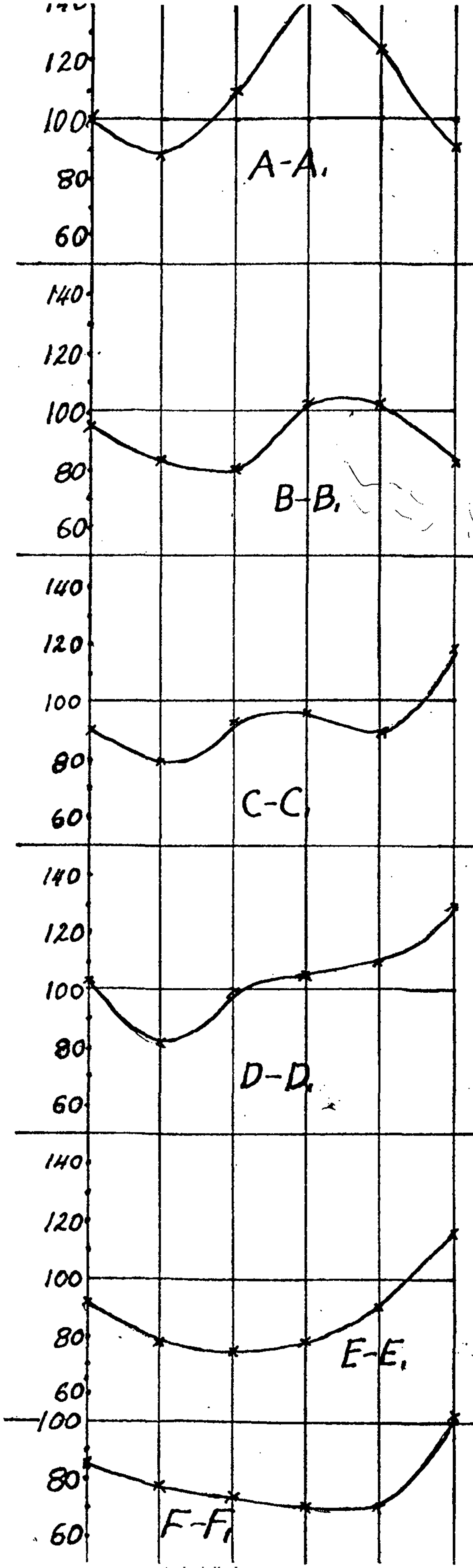


FIGURE IX

CO'S	NO YRS DATA.	1924 to 1972	1957 TO 1965	UN-SEEDED YRS.
WALLACE	47	8.10	7.76	8.18
THOMAS	49	6.08	3.59	6.64
LOGAN	45	9.28	8.08	9.58
SCOTT	48	7.86	5.67	8.37
SHERIDAN	49	6.54	4.98	6.89
GOVE	48	7.69	7.48	7.74
LANE	4.8	6.48	7.53	6.24
GRAHAM	49	5.74	3.67	6.21
TREGO	48	7.21	6.67	7.33
NESS	48	6.53	5.87	6.68
	AV.	7.15	6.13	7.49
	±	1.08	1.65	1.22
VARIANCE	%	15.16	26.99	16.30
CHEYENNE	49	11.22	14.89	
RAWLINS	49	6.98	6.99	
DECATUR.	49	4.96	6.27	
NORTON	49	4.56	7.23	
GREELEY	46	9.45	16.40	
WICHITA	46	9.96	8.43	
KEARNY	47	9.84	15.36	
FINNEY	48	8.04	8.07	
GRAY	47	5.08	5.21	
FORD	48	4.62	5.48	
	AV	7.47	9.43	
	±	2.56	4.35	
VARIANCE	%	34.26	46.15	

$$\frac{7.47}{7.15} \times \frac{6.13}{9.43} \times 100 = 67.91$$

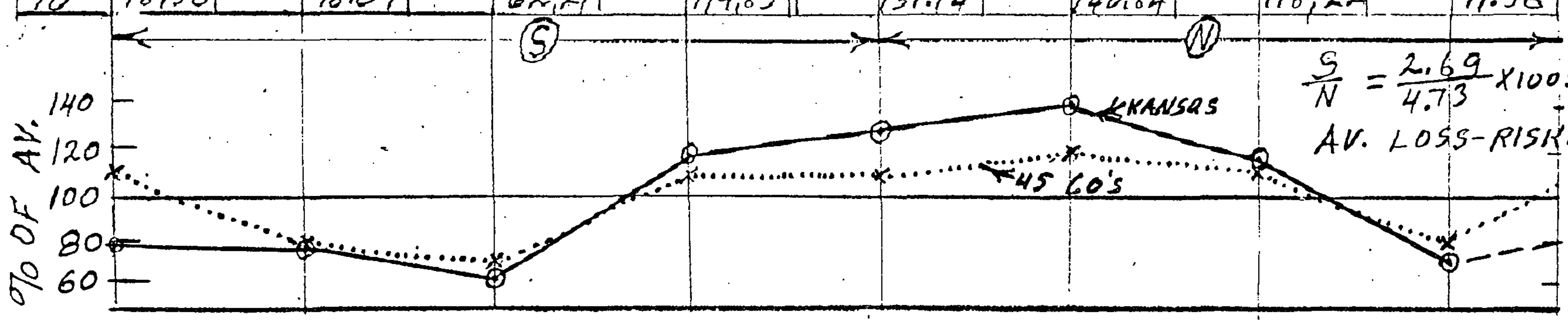
32 % REDUCTION

OR

$$\frac{6.13}{7.49} \times 100 = 81.84 \text{ OR } 18.16\%$$

HAIL LOSS÷RISK IN KANSAS V.S. SUNSPOTS

HIGH LAT LOW AREA		MID LAT MAX AREA		TRANS		LOW LAT. LOW AREA		HIGH LAT LOW AREA		MID LAT. MAX AREA		TRANS.		LOW LAT. LOW AREA	
1934	1.51	1936	.65					1924	5.35	1926	4.63				
35	1.26	37	1.84	1939	4.87			25	5.44	27	6.12	1929	2.81		
		38	4.20	40	.28	1941	3.62			28	7.81	30	2.38	1931	1.57
1954	3.47					42	6.33							32	1.74
55	5.40	1956	1.63			43	5.09	1944	2.84	1946	3.51			33	.52
		57	4.04	1959	1.56			45	7.29	47	5.70	1949	5.76		
		58	5.51	60	2.53	1961	4.40			48	5.44	50	2.51	1951	7.78
						62	5.59							52	2.36
						63	3.02	1965	3.76	1967	6.53			53	3.12
						64	3.13	66	4.55	68	3.74	1970	4.76		
										69	3.60	71	8.10	1972	1.45
AV	2.91		2.90		2.31		4.45		4.87		5.23		4.39		2.65
±	1.93		1.87		1.94		1.27		1.54		1.48		2.27		2.40
%	78.36		78.09		62.21		119.83		131.14		140.84		118.22		71.36



$\frac{S}{N} = \frac{2.69}{4.73} \times 100 = 46.33$

AV. LOSS-RISK = 3.285

FIGURE X

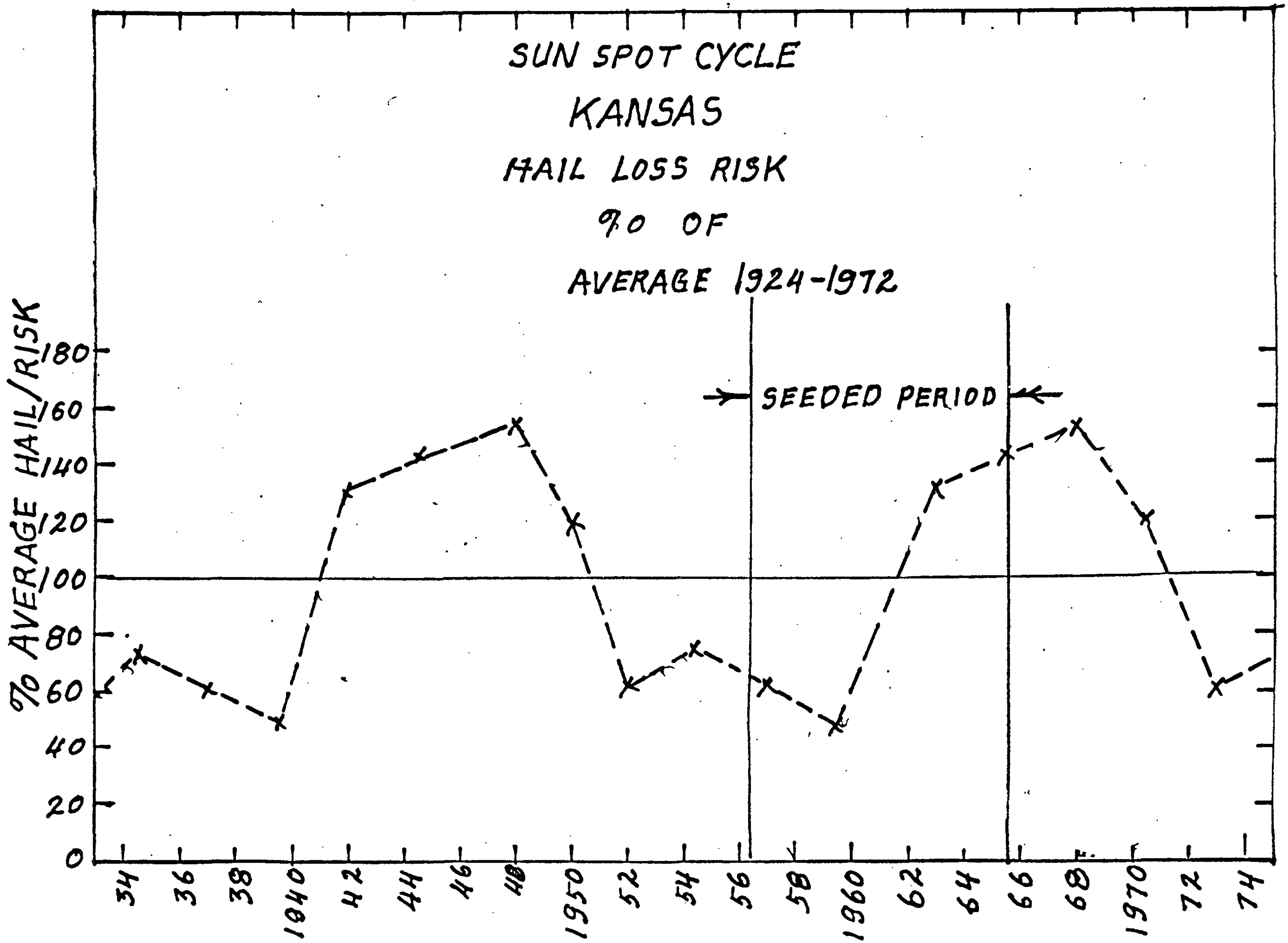

SUN SPOT CYCLE
KANSAS
HAIL LOSS RISK
% OF
AVERAGE 1924-1972
% AVERAGE HAIL/RISK
0
20
40
60
80
100
120
140
160
180
SEEDED PERIOD
34
36
38
1940
42
44
46
48
1950
52
54
56
58
1960
62
64
66
68
1970
72
74

FIGURE XI

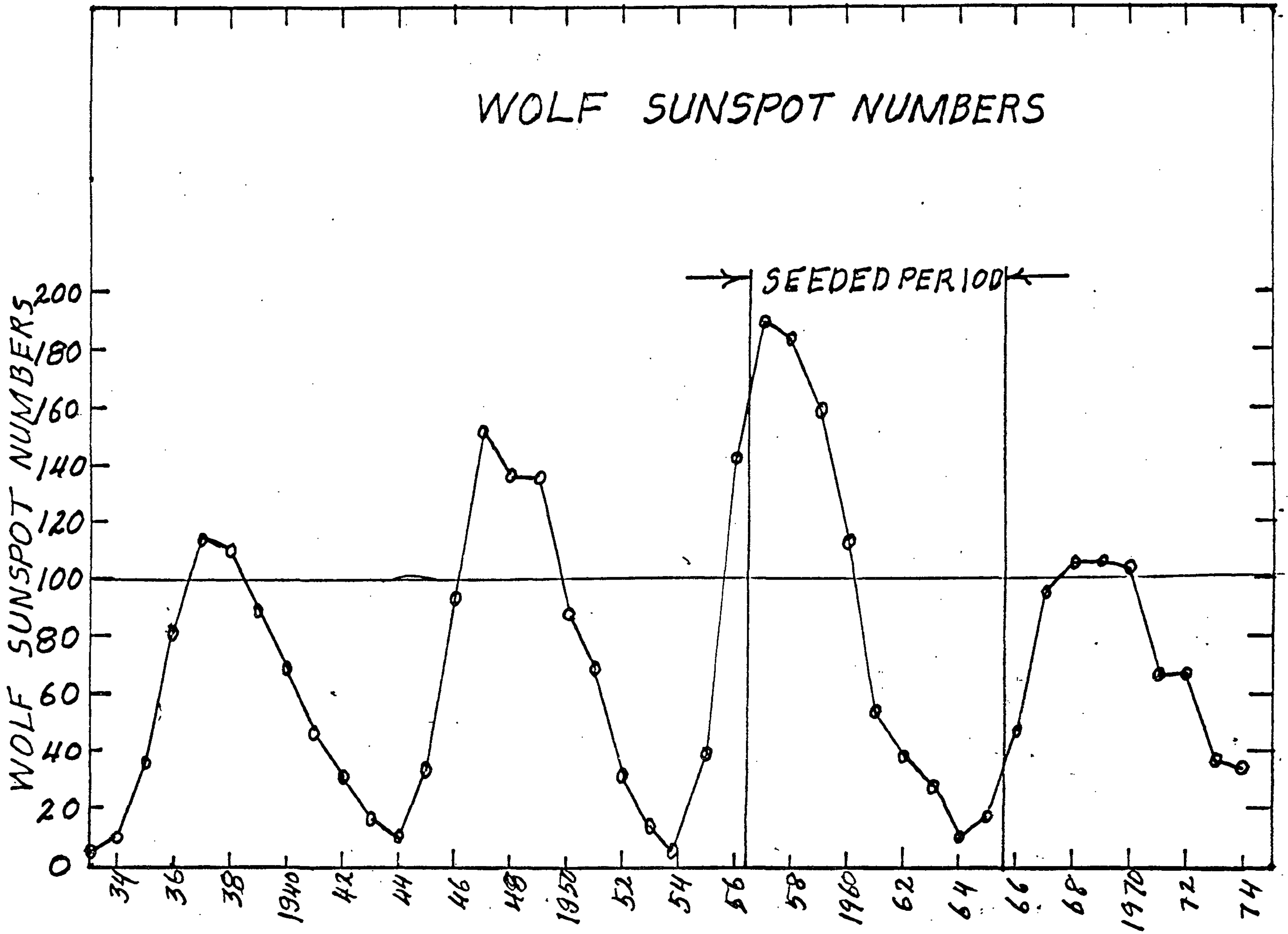

WOLF SUNSPOT NUMBERS
SEEDED PERIOD
WOLF SUNSPOT NUMBERS
0
20
40
60
80
100
120
140
160
180
200
34
36
38
1940
42
44
46
48
1950
52
54
56
58
1960
62
64
66
68
1970
72
74

FIGURE XII

FIGURE XIII

RESULTS OF
MUDDY ROAD I
15 APRIL TO 1 SEPTEMBER

HAIL REDUCED BY 32% IN TARGET AREA

463,473.00 ACRE FEET OF ADDITIONAL WATER (EST.)

COST PER ACRE FOOT - 17¢

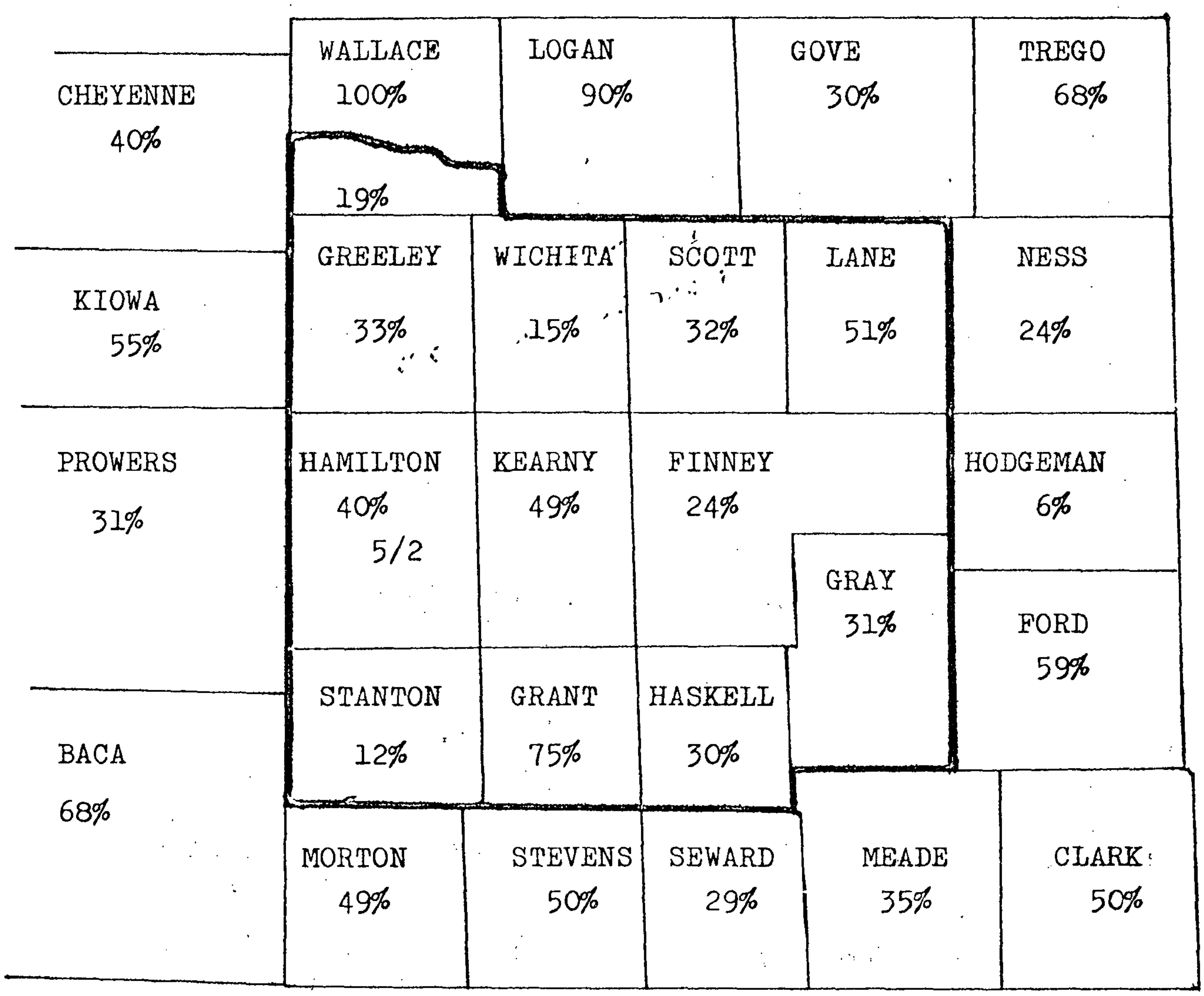
COST OF PROGRAM - $80,000.00

NORTH DAKOTA	50% COST SHARING
SOUTH DAKOTA	$75,000.00 FROM STATE AND 75% COST SHARING

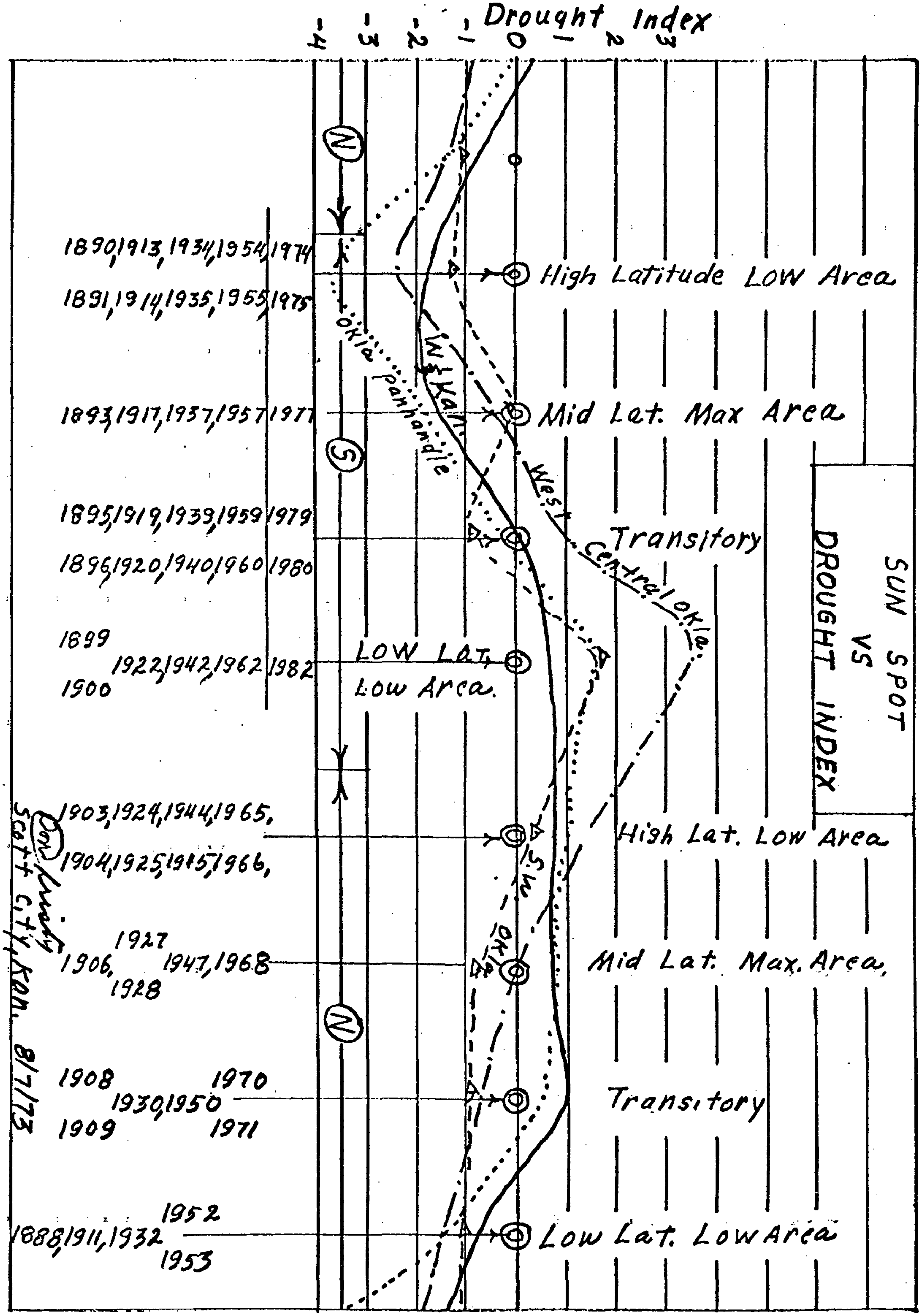
FIGURE XIV

INSURED TO LOSS PERCENTAGE

15 APRIL - 7 JULY



32% REDUCTION IN CLAIMS FILED IN TARGET AREA



Drought Index
-4 -3 -2 -1 0 1 2 3
1890,1913,1934,1954,1974
1891,1914,1935,1955,1975
High Latitude Low Area
Okla panhandle
W. Kan.
1893,1917,1937,1957,1977
Mid Lat. Max Area
West Central Okla.
1895,1919,1939,1959,1979
1896,1920,1940,1960,1980
Transitory
1899
1900
1922,1942,1962,1982
LOW LAT. Low Area
1903,1924,1944,1965,
1904,1925,1945,1966,
High Lat. Low Area
S.W. Okla.
1906, 1927 1928 1947,1968
Mid Lat. Max. Area,
1908 1909 1930,1950 1970 1971
Transitory
1888,1911,1932 1952 1953
Low Lat. Low Area
SUN SPOT VS DROUGHT INDEX
Scott City, Kan. 8/7/73

FIGURE XV

TABLE 2

HAIL LOSS - RISK RATIO

	WEST KAN.	N.W KAN	W C KAN	S.W KAN	45 CO.'S	KAN.	
1924	6.43	8.90	3.50	7.0300	3.45	5.35	Σ+
1925	6.53	5.04	4.91	8.5400	4.02	5.44	Σ+
26	9.27	4.96	16.38	6.8300	5.11	4.63	Σ+
27	9.05	9.98	7.48	9.5200	5.46	6.12	Σ+
28	17.16	9.37	15.55	22.6700	5.25	7.81	Σ+
29	8.87	4.33	11.03	10.0400	2.57	2.81	Σ+
1930	4.97	1.97	3.72	7.5500	1.83	2.38	Σ+
31	1.85	0.93	2.30	2.0600	1.32	1.57	Σ+
32	6.22	1.23	6.39	8.8000	2.45	1.74	Σ+
33	0.12	0.33	0.00	0.0000	0.30	0.52	Σ+
34	5.55	10.26	6.53	4.1000	4.56	1.51	Σ+
1935	0.97	0.87		1.0500	0.82	1.26	Σ+
36	0.34	0.30	0.97	1.0900	0.58	0.65	Σ+
37	1.36	1.54	0.53	3.0800	1.24	1.84	Σ+
38	6.65	7.33	8.72	4.8200	5.85	4.20	Σ+
39	8.52	5.41	12.19	10.8000	6.35	4.87	Σ+
1940	2.20	1.38	1.77	2.9400	0.62	0.28	Σ+
41	4.94	7.37	6.30	6.3100	3.94	3.62	Σ+
42	9.18	8.73	14.92	5.7500	6.65	6.33	Σ+
43	7.64	4.24	11.42	7.1500	5.21	5.09	Σ+
44	3.53	7.44	2.23	2.1400	2.55	2.84	Σ+
1945	8.65	15.92	8.04	4.8900	7.95	7.23	Σ+
46	3.57	6.51	3.12	2.7900	2.91	3.51	Σ+
47	5.14	8.29	4.74	3.6000	5.71	5.70	Σ+
48	9.82	19.33	10.91	1.4800	5.01	5.44	Σ+
49	13.01	23.26	9.40	9.4700	4.65	5.76	Σ+
1950	6.99	5.57	9.17	6.4100	3.33	2.51	Σ+
51	11.77	8.45	10.99	14.1700	10.95	7.78	Σ+
52	3.58	6.07	2.75	2.6900	4.10	2.35	Σ+
53	2.53	5.50	1.37	1.5700	3.82	3.12	Σ+
54	7.73	8.83	9.14	6.3200	5.95	3.47	Σ+
55	9.60	8.98	16.44	5.5600	7.21	5.40	Σ+
56	6.28	9.37	2.59	6.5400	1.93	1.63	Σ+
57	12.35	6.63	15.29	15.0600	6.43	4.04	Σ+
58	10.23	8.61	6.50	13.5600	4.53	5.51	Σ+
59	2.33	6.50	1.51	1.5100	1.69	1.56	Σ+
1960	3.90	3.37	6.39	1.9300	2.07	2.55	Σ+
61	10.78	14.45	16.53	4.9800	4.70	4.40	Σ+
62	7.83	9.39	7.91	7.0100	5.81	5.59	Σ+
63	6.34	3.92	4.59	8.8400	2.48	3.02	Σ+
64	5.05	7.13	8.71	1.4300	4.14	3.13	Σ+
1965	7.51	6.12	5.76	9.4400	4.35	3.76	Σ+
66	5.60	7.06	9.16	2.4600	6.97	4.55	Σ+
67	13.05	11.97	13.06	13.6100	8.10	6.53	Σ+
68	6.30	4.78	10.33	4.2500	4.60	3.74	Σ+
69	4.13	3.81	3.37	4.4900	4.40	3.60	Σ+
1970	3.92	5.26	5.09	4.8300	5.25	4.76	Σ+
71	6.66	10.17	8.76	3.3000	11.28	8.10	Σ+
72	3.34	4.54	3.91	3.5200	1.31	1.45	Σ+
NO YRS	49.00	49.00	48.00	49.0000	49.00	49.00	◇
	3.57	4.53	4.63	4.4334	2.43	2.02	Δ◇
AV.	6.53	7.00	7.39	6.0843	4.34	3.90	x̄ ◇
VARI-ANCE	54.25	55.4157	63.3057	72.8671	56.08	51.57	÷ × ◇